One of our major responsibilities as scientists and technologists is to lead the world to the state of richness in health and technology. We, therefore, dedicate our lives and souls for deep researches in such areas of our own interest. Publishing our research knowledge in the journal is one way to convey our knowledge to the world, so preparing this issue of journal of Science and Technology Mahasarakham University is one of our main tasks. The applications of applied statistics—vit. environmental, hydrology, economics and other related areas, are also emphasized with the technique of data mining, copulas, quality control, optimal designs, optimization and sampling design. In addition, the application for health science and education such as the satisfactions level of outpatients by Jonckheere-Terpstra, the development of hot-deck corrected item mean (HDD-CIM) for estimating missing data and student retirement analysis, are also selected for journal in this issue. We do believe that this issue of our Journal of Science and Technology Mahasarakham University will serve as media of knowledge and to enhance the communication in this modern world of technology.

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Editor in chief
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A Study on Search Algorithms for Constructing Optimal Designs

Jaratsri Rungrattanaubol¹, Anamai Na-udom¹*
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Abstract
Computer simulated experiments (CSE) are often used in science and engineering applications. The nature of CSE is that they are time consuming and computationally expensive to run. Normally, the output response from computer simulated experiments is deterministic. Consequently the space filling designs, which focus on spreading design points over a design space, are necessary. Latin hypercube designs (LHD) are normally practiced in the context of CSE. The optimal LHD for a given dimension of problem is constructed by using a search algorithm under a pre-specified optimality criterion. Usually this searching process takes a long time to terminate, especially when the dimension of the problem is large. This paper proposes methods to enhance the performance of search algorithms which are widely used in the context of CSE. The comparative studies are employed based on a range of problems and optimality criteria. The results indicate that the proposed method can improve the capability of the search algorithms for constructing the optimal LHD.

Keywords: Computer simulated experiments, Latin hypercube designs, simulated annealing algorithms, enhanced stochastic evolutionary algorithm, optimality criteria

Introduction
Recently computer simulated experiments (CSE) have replaced classical experiments to investigate a physical complex phenomena, especially when classical (physical) experiments are not feasible. For example, the use of reservoir simulator to predict ultimate recovery of oil, the use of finite element codes to predict behavior of metal structure under stress, and so on¹. The nature of computer simulated experiments is deterministic²³ hence identical settings of input variables always produce an identical set of output response. Therefore, space filling designs that aim to spread the design points over a region of interest are necessary. The most popular class of space filling design in the context of computer simulated experiments is Latin hypercube design (LHD). LHD design was originally proposed by McKay and co-workers⁴ in 1979. The ultimate goal of selecting the settings of input variables is to attain the coverage of all design regions of interest.

As mentioned before the space filling designs are preferred in the context of computer simulated experiments. Space filling designs or the optimal LHD can be constructed through combinatorial methods (non-search algorithm)⁵⁶ or searching for a design through search algorithms⁷⁸. The former method generates design with good design properties but it is restricted in terms of a design size. For example methods proposed by Butler⁵ are limited to a design size of a prime number. The latter method is based largely on improving design by exchanging between the pairs of design points. Exchange algorithms can be time consuming to implement, however, the generated design are flexible and straightforward. The CSEs are usually complex and consist of many input variables to investigate⁹. In this case a large number of runs are required to estimate the parameters corresponding to the factors of interest in the model. For example, if the problem of interest consists of \( d \) input variable and \( n \) number of runs, the total number of LHD is \( (n!)^d \). Obviously

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this number explodes exponentially as the values of \( n \) and \( d \) increase; hence the full space of LHD cannot be explored. In this case we need the search algorithms to lead us to a good design with respect to an optimality criterion. The key idea of all existing search algorithms is to use some kinds of exchange procedures to move towards the better designs.

The search based approach for selecting a design is implemented by combining search algorithms and the optimality criterion. For example, Morris and Mitchell adopted a version of Simulated Annealing algorithms (SA) to search for optimal LHDs with respect to \( \phi_p \) criterion. Li and Wu proposed a columnwise-pairwise algorithm (CP) with respect to the D efficiency criterion. It was reported that CP is very simple and easy to implement. The only parameter required to set as a priori is the tolerance level (tl). Further, CP is able to generate a good supersaturated design and it can be used along with various optimality criteria. In order to avoid the problem of convergence and the search being stuck at a local optimum value, usually multiple search with different starting points are performed. The best result, among different trials, is selected as optimal design. It should be noted that for large dimensional problems, CP algorithm can be time consuming to implement. Ye and his co-workers adapted CP algorithm to search for symmetric LHD under various optimality criteria such as entropy and \( \phi_p \) criteria. Park proposed a row-wise element exchange algorithm along with IMSE and entropy criteria. Leary et al. adapted CP and SA algorithms to construct the optimal designs within the orthogonal-array based Latin hypercube class by using the \( \phi_p \) criteria. Jin et al. developed an enhanced stochastic evolutionary algorithm (ESE) to search for the best design considering various optimality criteria such as a maximin distance criterion, \( \phi_p \) criterion and entropy criterion. ESE has received wide attention from researchers due to its performance in constructing the optimal LHD. Liefvendahl and Stocki applied a version of Genetic algorithm (GA) to search for the optimal LHD considering \( \phi_p \) and a maximin distance criterion. A similar work can be found in as the authors applied GA for constructing maximin designs. Grosso et al. used the iterated local search algorithm and SA in constructing the optimal LHD under maximin distance and \( \phi_p \) criterion. Vianna et al. proposed the algorithm for fast optimal LHD by using the idea of seed design under maximin distance and \( \phi_p \) criterion. Due to the popularity of SA and ESE along with \( \phi_p \) criteria, this paper presents the efficient method to improve the capability of SA and ESE under \( \phi_p \) criterion. In the following sections we present details of these search algorithms, followed by the details of the optimality criteria. The enhancement methods on SA and ESE are also presented in section III. The results of the enhancement methods will be presented in the result section and conclusion will be given in section V respectively.

**Experimental Design and Optimality Criterion**

This section presents the details of LHD and the steps of search algorithms including the enhancement methods to improve their performance in constructing the optimal LHD.

**Latin hypercube design (LHD)**

LHD can be constructed based on the idea of stratified sampling to ensure that all subregions in the divided input variable space will be sampled with equally probability. A Latin hypercube sampling has

\[
X_{ij} = \frac{\pi_{ij} - U_{ij}}{n}
\]

where \( \pi_{ij} \) are the elements of an \( n \times d \) matrix comprising of columns \( \pi_j(j = 1, 2, \ldots, d) \). Each column \( \pi_j(j = 1, 2, \ldots, d) \) is independent random permutation of number 1 through \( n \) and \( U_{ij} \) are \( n \times d \) values of independent \( U[0,1] \) random variables independent of the \( \pi_{ij} \). The example of LHD is shown in Figure 1.
The element exchange operation to construct a new LHD design is developed by using the concept of column-wise operation proposed by Li and Wu\textsuperscript{10}. The process is randomly interchange two distinct elements in a randomly selected column as shown in Figure 2. After an element exchange has been performed, the LHD properties still remains.

Let a Euclidean distance list \((d_1, d_2, \ldots, d_m)\) be the distinct elements list from the smallest to largest. Also define index list \((J_1, J_2, \ldots, J_m)\), which \(J_j\) is the number of pairs of sites in the design separated by distance \(d_j\). Thus \(X\) is a maximin design if among available designs, it maximizes \(d_j\) while \(J_j\) is minimized. The scalar criterion can be expressed as \(\phi_p = \left[ \sum_{j=1}^{m} J_j d_j^p \right]^{-1/p} \) (3), where \(P\) is a positive integer, \(J_j\) and \(d_j\) specified from \(X\). The design that minimizes \(\phi_p\) is a maximin LHD in the class. In this study, the adaptive form of \(\phi_p\), which is simpler than (3) to implement is considered

\[
\phi_p = \left[ \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \frac{1}{d_{ij}^p} \right]^{-1/p}
\] (4)

After \(\phi_p\) value has been calculated, a design that minimizes \(\phi_p\) is considered as an optimal design in the class.

Search algorithms

This section presents the details of search algorithms used in this study including the enhancement methods to improve the performance of the search algorithms.

Modification of simulated annealing algorithm (MSA)

Morris and Mitchell\textsuperscript{7} developed a simulated annealing algorithm to search for an optimal LHD using \(\phi_p\) optimality criterion. The design that minimizes \(\phi_p\) value is considered as the best design in the class. The steps of SA are presented as follows.
SA requires parameter settings, \( t_0 \), \( t_{\text{max}} \), \( FAC_t \) and \( p \). In this study, we use the heuristic methods to find the best set of parameters for use in SA. The choice of initial parameters for SA can be found in (7). It was also reported in the paper that SA performed very well in terms of moving away from the local optimum value of criterion.

The emphasis of this paper is on the modification of SA by applying the calculation of criterion by using the method that avoids re-calculating of \( \text{value} \) value.

As mentioned before, SA uses the exchange procedure between two pairs of points within the randomly selected column. Hence, after an exchange between rows \( i_1 \) and \( i_2 \) within column \( k \) (\( x_{i1,k} \leftrightarrow x_{i2,k} \)), only elements in rows \( i_1 \) and \( i_2 \), and columns \( i_1 \) and \( i_2 \) are changed in the distance matrix \( D_4 \).

For any \( 1 \leq j \leq n \) and \( j \neq i_1, i_2 \) let:

\[
s(i, i_2, k, j) = \left| x_{i,j} - x_{j,k} \right|^p - \left| x_{i_2,j} - x_{j,k} \right|^p
\]

then

Thus new \( \Phi_p \) is computed by

\[
\Phi'_p = \left[ \Phi_p + \sum_{1 \leq j \leq n, j \neq i_1, i_2} \left( (d_{ij})^p - (d_{i1})^p \right) + \sum_{1 \leq j \leq n, j \neq i_1, i_2} \left( (d_{ij})^p - (d_{i2})^p \right) \right]^{1/p}
\]

As shown in (5) to (8), only some rows and columns are updated to calculate \( \Phi_p \) criterion in MSA. Hence the complexity or BigO of MSA is much smaller than SA as presented in Table 1.

<table>
<thead>
<tr>
<th>ESE and modification of ESE algorithm (MESE)</th>
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<tr>
<td>As presented in the previous section, the complexity of MSA is less than the original SA. Hence MSA is recommended for use in constructing the optimal design for CSE if time constraint is of interest. Jin et al. proposed a new algorithm called enhanced stochastic evolutionary (ESE) algorithm and did a comparison between ESE and the existing algorithms such as CP and SA. The results showed that ESE is superior over the other algorithms in terms of computational time burden and the number of exchanges required for generating the optimal LHD design. According to the goodness of MSA and ESE, we combine them together to improve the search process. In the next section we present the steps of ESE including the methods to improve the performance of ESE.</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Table 1</th>
<th>The complexities to calculate ( \Phi_p ) criterion in SA and MSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>BigO(SA)</td>
<td>( O(\text{dn}^2) + O(n^2 \log_2(p)) )</td>
</tr>
<tr>
<td>BigO(MSA)</td>
<td>( O(n) + O(n \log_2(p)) )</td>
</tr>
</tbody>
</table>

\[
d_{ij}^{p'} = d_{ij}^p = \left[ d_{ij}^p + s(i, i_2, k, j) \right]^{1/p}
\]

and

\[
d_{ij}^{p'} = d_{ij}^{p'} = \left[ d_{ij}^{p'} + s(i, i_2, k, j) \right]^{1/p}
\]
loop performs a local search process by constructing a new design and decides whether to accept new design or not. In the inner loop, both of acceptance ratio and improvement ratio are recorded. The outer loop works as a controller of the inner loop as it performs a global search by adjusting the threshold \( (T_h) \) based on acceptance ratio and improvement ratio from the inner loop. The steps of ESE are presented as follows.

**Step 1:** Set initial parameters and design \( x_0 \) in the outer loop, \( x = x_0, i = 0, n_{act} = 0 \) and \( n_{imp} = 0 \)

**Step 2:** Construct a set of new design \( x_{pry} \)

**Step 3:** Select the best design \( x_{pry} \) from this set

**Step 4:** Decide to accept the best design \( x_{pry} \) and replace the current best design \( x \) from as shown in Figure 3.

**Step 5:** If \( x_{pry} \) is better than the global best design \( x_{best} \), replace it with \( x_{pry} \) and increase \( n_{imp} \) by 1 \((n_{imp} = n_{imp} + 1)\).

**Step 6:** Terminate the inner loop if \( i > M \), else go to step 2.

The flowchart of the inner loop for ESE is visualized in Figure 3.

In this study the parameters \( J \) is set to be \( \frac{n}{2} \) but no larger than 50, and the parameter \( M \) is in a range of \( 2 \times \frac{n}{d} / J \leq M \leq 100 \). The outer loop of ESE is presented in Figure 4.

**Step 1:** Randomly generate an initial design \( x_0 \) and set \( x = x_0, x_{best} = x, T_h = T_{h0} \), initialize \( \theta_h = 0.005 \times \delta_{e}(x_0) \) and \( T_h = 0.005 \).

**Step 2:** Set \( x_{old_{best}} = x_{best} \).

**Step 3:** Go to the inner loop process.

**Step 4:** Select a method to update \( T_h \) by setting \( flag_{imp} \).

**Step 5:** Update \( T_h \) (discussed later for more details).

**Step 6:** Terminate the search by using a stopping rule, else go to step 2.
The tolerance level ($tl$) is set to 0.0001 as it was observed from the empirical study that a smaller value does not improve the search process. The process of updating the value of $Th$ in step 5 is divided into 2 processes called improving process and exploration process, respectively. The search process works as the improving process when $flag$ = 1, if the best design $X_{best}$ is improved in the inner loop. If not, the search process will be in the exploration process ($flag$ = 0).

In improving process ($flag$ = 1), $Th$ is adjusted in order to find the local best LHD based on an acceptance ratio ($n_{act}/P$) and improvement ratio ($n_{imp}/M$). If $n_{act}/M > \beta_1$ and $n_{imp}/M < n_{act}/M$, then $Th$ is decreased by $Th = \alpha_1 \times Th$. If $n_{act}/M > \beta_1$ and $n_{imp}/M = n_{act}/M$, then $Th$ is unchanged. Otherwise, $Th$ is increased by $Th = Th / \alpha_1$, where $0 < \alpha_1 < 1$ and $0 < \beta_1 < 1$, we use $\alpha_1 = 0.8$ and $\beta_1 = 0.1$ as suggested by Jin et al. [4].

Further the results obtained from our empirical studies also indicate that $\beta_1$ should be set to a small value. In the exploration process ($flag$ = 0), $Th$ will be adjusted to drive the algorithm to move far away from a local optimal design based on the range of acceptance ratio. If $n_{act}/M < \beta_2$, then $Th$ is increased until $n_{act}/M > \beta_3$ by equation $Th = Th / \alpha_2$ if $n_{act}/M > \beta_3$, then $Th$ is decreased till $n_{act}/M < \beta_2$ by equation $Th = Th \times \alpha_2$, where $0 < \beta_2 < \beta_3 < 1$, and $0 < \beta_2 < \beta_3 < 1$, we set $\alpha_2 = 0.9$, $\alpha_3 = 0.7$. While $\beta_2$ should be small, we set $\beta_2 = 0.1$ and $\beta_3$ should be large enough so we set $\beta_3 = 0.8$, as recommended in 2.

**Modification of ESE (MESE)**

In this section we present the enhancement method on ESE. The modified version is called MESE. We combine the advantage of SA (i.e. local search process) and the advantage of ESE (i.e. global search process) together to improve the search process. MESE contains 2 nested loops as displayed in Figure 5. The outer loop is similar to the ESE except that there is only one change in a stopping rule as in step 6. The maximum number of cycles used is replaced by the following condition. If a local best design after the inner loop $X_{best}$ is not improved from the global best design ($X_{globalbest}$) for $\delta$ consecutive times, then the search process will be terminated. In this study we set $\delta = 10$.

The major enhancement was made in the inner loop. There are many changes have been made in step 2, step 5 and step 6. In step 2, the process for constructing a new design $X_{try}$ is changed to element-exchange in column $(i \mod d)$ for all $J$ iterations while the original ESE used the random strategy to pick $J$ distinct element-exchange in column $(i \mod d)$. By doing this, the computational complexity decreases from $O(n^2)$ to $O(n)$. As can be seen in ESE process, a random element exchange for all $J$ iteration is required in all $i$ iterations, so all distinct loops must be checked. Hence the complexity is $O(n(n-1)) = O(n^2)$. In MESE, we adapt the process of element-exchange from SA shown in Figure 6.

So in any $J$ iteration, element exchange of a current design $X$ in column $i \mod d$ is independent. Thus there is no need to perform all $J$ iterations. It is obvious that the computation complexity decreases to $O(n)$. In step 5, if a new design $X_{try}$ is improved (better than the best achieved design, $X_{best}$), let $j = 0$ otherwise increase $j$ by 1 ($j = j + 1$). Finally, in step 6 of the inner loop, a stopping rule is modified to if $i > M$ or $j > C_{max}$. In this study, we set $C_{max} = 10$. All simulation studies presented in this paper were performed using R program.
### Results

The values of \( \phi_p \) criteria at the termination step of MSA, ESE and MESE from each dimension of problems are presented in Table 2. Each case study was repeated for 10 times to consider the effect of different starting points. The descriptive statistics on the \( \phi_p \) values obtained from each search technique are displayed in columns 3-6. The results in columns 3-6 indicate that MSA, ESE and EMSE perform similarly for small dimension of problem in terms of minimization of \( \phi_p \) criterion. Further, the standard deviation values appeared in column 6 displays a slightly larger amount of variation over 10 replications in ESE and EMSE than that of MSA. This indicates the consistency in the search process for MSA when different starting points are considered. When medium dimensions are considered, \( \phi_p \) values from ESE and MESE are slightly lower than MSA. In addition, small amount of standard deviation is observed. For large dimensions of problem, both of ESE and MESE perform similar results in terms of minimization of \( \phi_p \) values. Hence if the good property of design is concerned, either ESE or MESE can be used for constructing the optimal LHD.

#### Table 2

<table>
<thead>
<tr>
<th>LHDs</th>
<th>Algorithm</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 × 2</td>
<td>MSA</td>
<td>4.273</td>
<td>4.273</td>
<td>4.273</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>ESE</td>
<td>4.273</td>
<td>4.344</td>
<td>4.287</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>MESE</td>
<td>4.273</td>
<td>4.344</td>
<td>4.280</td>
<td>0.022</td>
</tr>
<tr>
<td>51 × 5</td>
<td>MSA</td>
<td>5.417</td>
<td>5.430</td>
<td>5.422</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>ESE</td>
<td>5.415</td>
<td>5.431</td>
<td>5.422</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>MESE</td>
<td>5.418</td>
<td>5.430</td>
<td>5.423</td>
<td>0.004</td>
</tr>
<tr>
<td>201 × 10</td>
<td>MSA</td>
<td>6.179</td>
<td>6.181</td>
<td>6.180</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>ESE</td>
<td>6.170</td>
<td>6.174</td>
<td>6.172</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>MESE</td>
<td>6.173</td>
<td>6.185</td>
<td>6.184</td>
<td>0.000</td>
</tr>
<tr>
<td>451 × 15</td>
<td>MSA</td>
<td>6.776</td>
<td>6.779</td>
<td>6.777</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>ESE</td>
<td>6.760</td>
<td>6.762</td>
<td>6.761</td>
<td>0</td>
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<tr>
<td></td>
<td>EESE</td>
<td>6.760</td>
<td>6.762</td>
<td>6.761</td>
<td>0</td>
</tr>
<tr>
<td>801 × 20</td>
<td>MSA</td>
<td>7.272</td>
<td>7.273</td>
<td>7.272</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>ESE</td>
<td>7.253</td>
<td>7.254</td>
<td>7.254</td>
<td>0</td>
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<tr>
<td></td>
<td>EESE</td>
<td>7.254</td>
<td>7.254</td>
<td>7.254</td>
<td>0</td>
</tr>
</tbody>
</table>

The results of the performance (efficiency) for MSA, ESE and MESE algorithms are presented in Table 3. This table presents the time elapsed and number of exchange required for each algorithm to reach the same level of \( \phi_p \) values. For each dimension of problem, the search algorithms are repeated for 10 times. Hence all values are presented as the average values. For small
dimension case, it can be clearly seen that ESE and MESE converges much faster than MSA. The number of exchange required in the search process is also less than the MSA, while MESE requires less number of exchanges comparing to ESE. For medium and large dimensions of problem, MESE converges much faster than MSA while it performs slightly better than ESE. Further, the number of exchange obtained from MESE is the smallest value. This indicates that if time constraint is taken into account, MESE could be the better choice to use in the construction of the optimal LHD designs.

The results in columns 5-7 display time ratio for each search algorithm. It can be concluded from these ratio that MESE converges much more quickly than MSA. The maximum improvement over MSA can be observed when the dimension of problem is small. In the case of larger dimension, the improvement ratio turns to a small value. It could be concluded that the performance of these three algorithms are close to each other especially ESE and MESE algorithm.

**Table 3 Performance of MSA, ESE and EMSE**

<table>
<thead>
<tr>
<th>LHDs</th>
<th>Algorithm</th>
<th>Performance (Average)</th>
<th>Time ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Time (sec.)</td>
<td>#Exchange</td>
</tr>
<tr>
<td>2 x 9</td>
<td>MSA</td>
<td>19.993</td>
<td>47140</td>
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<tr>
<td></td>
<td>ESE</td>
<td>3.595</td>
<td>5760</td>
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<td>2.296</td>
<td>5415</td>
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<td>51 x 5</td>
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<td>751.54</td>
<td>284931</td>
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<tr>
<td></td>
<td>ESE</td>
<td>550.762</td>
<td>150000</td>
</tr>
<tr>
<td></td>
<td>MESE</td>
<td>313.067</td>
<td>118950</td>
</tr>
<tr>
<td>201 x 10</td>
<td>MSA</td>
<td>2795.741</td>
<td>209912</td>
</tr>
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<td>17580</td>
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<tr>
<td></td>
<td>MESE</td>
<td>1176.529</td>
<td>94070</td>
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<tr>
<td>451 x 15</td>
<td>MSA</td>
<td>8686.660</td>
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<td></td>
<td>ESE</td>
<td>3648.646</td>
<td>185220</td>
</tr>
<tr>
<td></td>
<td>MESE</td>
<td>3526.691</td>
<td>124550</td>
</tr>
<tr>
<td>801 x 20</td>
<td>MSA</td>
<td>20854.01</td>
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<td></td>
<td>MESE</td>
<td>7672.487</td>
<td>185750</td>
</tr>
</tbody>
</table>

**Conclusions**

This paper presents a method to enhance the SA and ESE algorithms in the construction of the optimal LHD. The major enhancement method appears in the calculation of $\theta_p$ criterion and the tolerance level setting in SA. For ESE, the enhancement is applied by using the combination of SA and ESE especially in the inner loop as shown in Figure 5 and 6. As presented in the result section, MESE perform better than ESE and MSA in terms of the design property achievement and the efficiency. Hence MESE would be recommended for the construction of optimal LHD for CSE. In order to extend
the conclusion, other classes of design can be developed and collaborated with MESE to search for the best design in the class. Further, other types of search algorithm like Particle swarm optimization (PSO) or Ant colony can be further developed in constructing an optimal LHD or other classes of space filling design. The validation of the approximation model accuracy developed from the obtained optimal design could also be further investigated.

References
Modified Ratio Estimators in Stratified Random Sampling

Prayad Sangngam¹*, Sasiprapa Hiriote²
Received: 18 February 2013    Accepted: 15 June 2013

Abstract
This paper considers two modified ratio estimators of population mean in stratified random sampling. The approximated mean squared error and bias of the proposed estimators are derived and theoretically compared with those of the existing estimators. The results show that the modified estimators produce smaller mean squared error and bias than the existing estimators in some conditions. Moreover, the theoretical result is confirmed by using a census data set.

Keywords: Ratio estimator, Mean squared error, Stratified random sampling.

Introduction
The problem of improving an unbiased estimator by using ratio estimators has received considerable attention in sampling theory. When an auxiliary variable (X), available for all units in the population, is highly correlated with a study variable, a ratio estimator can be used to improve the unbiased estimator. The efficiency of a ratio estimator depends on the coefficients of variation of auxiliary variable (C_x) and coefficients of variation of study variable (C_y). Murthy¹ has suggested that if \( \rho > \frac{C_y}{2C_x} \), the ratio estimator performs better than the unbiased estimator under simple random sampling where \( \rho \) is the correlation coefficient between X and Y. When the C_x is known, Sissodia and Dwivedi² has proposed a modified ratio estimator for the population mean (\( \bar{Y} \)) as

\[
\bar{Y}_{sd} = \bar{Y} = \frac{\bar{X} + C_x}{\bar{X} + C_y},
\]

where \( \bar{X} \) is the population mean of auxiliary variable. In addition, there are several authors, such as Upadhya and Singh³, Singh and Tailor⁴, who have developed various ratio estimators under simple random sampling. When the population is heterogeneous and can be divided into homogenous subpopulations, it is advantageous to draw a sample by stratified random sampling. An unbiased estimator under stratified random sampling is given by

\[
\bar{Y}_{st} = \frac{1}{N} \sum_{h=1}^{L} W_h \bar{Y}_h,
\]

where L is the number of stratum, \( W_h = \frac{N_h}{N} \) is stratum weight, N is the population size, \( N_h \) is the number of units in stratum h, and \( \bar{Y}_h \) is the sample mean of the study variable in stratum h. The variance of the unbiased estimator is

\[
V(\bar{Y}_{st}) = \sum_{h=1}^{L} W_h^2 \gamma_h S^2_y,
\]

where \( \gamma_h = \frac{N_h}{n_h} \) is sampling fraction in stratum h, \( n_h \) is sample size in stratum h and \( S^2_y \) is the variance of the study variable in stratum h. According to⁵, there are two types of ratio estimators in stratified random sampling, namely combined and separate ratio estimators. The combined ratio estimator is given by

\[
\bar{Y}_{rc} = \frac{\bar{Y}_a}{\bar{X} + C_y},
\]

where \( \bar{X}_a = \sum_{h=1}^{L} W_h \bar{X}_h \) is an unbiased estimator of \( \bar{X} \) and \( \bar{X}_h \) is the sample mean of auxiliary variable in stratum h. An approximated mean squared error (MSE) of the combined ratio estimator is

\[
MSE(\bar{Y}_{rc}) \approx \sum_{h=1}^{L} W_h^2 \gamma_h \left( \bar{S}^2_{yh} + R^2 S^2_{sh} - 2RS_{sh} \right),
\]

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where \( R = \frac{\bar{Y}}{\bar{X}} \) is the population ratio. \( S_h^2 \) is the variance of auxiliary variable in stratum \( h \) and \( S_{xyh} \) is the covariance variance between auxiliary and study variables in stratum \( h \). An approximated bias of the combined ratio estimator is

\[
B(\bar{Y}_{RC}) \approx \sum_{h=1}^{k} W_h \frac{\bar{Y}_h}{X_h} \left( \frac{R}{X} S_{xyh} - \frac{1}{X} S_{xyh} \right).
\]  

(5)

The separate ratio estimator is given by

\[
\bar{Y}_{RS} = \sum_{h=1}^{k} W_h \frac{\bar{Y}_h}{X_h} \bar{X}_h.
\]

(6)

An approximated MSE of the separate ratio estimator can be given as,

\[
\text{MSE}(\bar{Y}_{RS}) \approx \sum_{h=1}^{k} W_h \left( \frac{\bar{Y}_h}{X_h} \right)^2 \left( S_{xyh}^2 + R^2 S_{sh}^2 + 2R S_{xyh} S_{sh} \right).
\]

(7)

where \( R_h = \frac{\bar{Y}_h}{\bar{X}_h} \) is the population ratio in stratum \( h \). We can derive an approximated bias of the separate ratio estimator as,

\[
E(\bar{Y}_{RS} - \bar{Y}) = E\left[ \sum_{h=1}^{k} W_h \frac{\bar{Y}_h}{X_h} \bar{X}_h \right] - \bar{Y} = \sum_{h=1}^{k} W_h \left( E\left( \frac{\bar{Y}_h}{X_h} \right) - \bar{Y}_h \right).
\]

Applying the bias of \( \bar{Y}_h = \frac{\bar{Y}_h}{\bar{X}_h} \) for estimating \( \bar{Y}_h \) under simple random sampling to draw in stratum \( h \), we get

\[
B(\bar{Y}_{RS}) \approx \sum_{h=1}^{k} W_h \bar{Y}_h \left( \frac{R}{X} S_{xyh} \right).
\]

(8)

For combined ratio estimation in stratified sampling, Kadilar and Cing\(i\) have proposed several modified ratio estimators. The simplest estimator based on\(^2\) is defined as

\[
\bar{Y}_{RC,KC} = \frac{1}{2} \sum_{h=1}^{k} W_h \left( \bar{X}_h + C_{sh} \right),
\]

(9)

where \( C_{sh} \) is coefficient of variation of auxiliary variable in stratum \( h \). The MSE and bias of this estimator are approximated as follow:

\[
\text{MSE}(\bar{Y}_{RC,KC}) \approx \sum_{h=1}^{k} W_h^2 \bar{Y}_h \left( S_{xyh}^2 + R^2 S_{sh}^2 + 2R S_{xyh} S_{sh} \right),
\]

(10)

\[
B(\bar{Y}_{RC,KC}) \approx \sum_{h=1}^{k} W_h \bar{Y}_h \left( \frac{R}{X_{KC}} \bar{X}_h - \frac{1}{X_{KC}} S_{xyh} \right),
\]

(11)

where \( R_{KC} = \frac{\bar{Y}_h}{X_{KC}} = \frac{\bar{Y}_h}{\sum_{h=1}^{k} W_h (\bar{X}_h + C_{sh})} \).

Kadilar and Cing\(i\) have improved the combined ratio estimator in stratified random sampling based on\(^8\) estimator. However, this estimator depends on such several unknown parameters that it is very difficult for application. Therefore, in the next section, a new combined ratio estimator in stratified random sampling based on\(^2\) will be proposed. We also develop a new modified separate ratio estimator for stratified random sampling. The approximated MSE and bias of the two modified estimators will be derived. In Section 3, the comparison of efficiency between the modified estimators and the existing estimators will theoretically be provided. A numerical example will be used to confirm the result in Section 4.

**Modified Ratio Estimators**

In stratified random sampling, when the coefficient of variation \( C \) is known, a combined ratio estimator can be modified based on\(^3\) as follows:

\[
\bar{Y}_{RC,SD} = \frac{\bar{Y}_h}{\bar{X}_h + C_s} \left( \bar{X} + C_s \right),
\]

(12)

To obtain the MSE and bias of this estimator, let

\[
e_1 = \frac{\bar{Y}_h - \bar{Y}}{\bar{Y}} \quad \text{and} \quad e_2 = \frac{\bar{X}_h - \bar{X}}{\bar{X} + C_s}.
\]

It may be noted that

\[
E(e_1) = 0, \quad E(e_2) = 0, \quad E(e_1^2) = \frac{V(\bar{Y}_h)}{\bar{Y}^2}, \quad E(e_2^2) = \frac{V(\bar{X}_h)}{\bar{X}^2} \quad \text{and} \quad E(e_1 e_2) = \frac{\text{Cov}(\bar{Y}_h, \bar{X}_h)}{\bar{Y} \bar{X} (\bar{X} + C_s)^2}.
\]

The estimator \( \bar{Y}_{RC,SD} \) can be written as

\[
\bar{Y}_{RC,SD} = \bar{Y} \left( 1 + e_1 \right) \left( 1 + e_2 \right)^{-1}
\]

Using Taylor series, we obtain
When the terms of degree greater than two are ignored, we get

\[
\bar{Y}_{RC, SD} = \bar{Y}(1 + c_1)(1 - c_2 + c_3 - \ldots) \\
= \bar{Y}(1 + c_1 - c_2 + c_3^2 - c_4 c_2 + \ldots).
\]

By substituting \(Cov(\bar{x}_h, \bar{y}_h) = \sum \frac{1}{N_h} W_h^2 \gamma_h s_{yh} \) and

\[V(\bar{x}_h) = \sum \frac{1}{N_h} W_h^2 \gamma_h s_{yh}^2,\]

an approximated bias of the modified combined ratio estimator is

\[
B(\bar{Y}_{RC, SD}) = E(\bar{Y}_{RC, SD} - \bar{Y}) \\
\approx \bar{Y} E(e_1^2 - c e_2) \\
= \bar{Y}\left[ \frac{V(\bar{x}_h)}{(X + C_s)^2} - \frac{Cov(\bar{x}_h, \bar{y}_h)}{\bar{Y}(X + C_s)} \right].
\]

For sample estimate of the \(R_s\), \(R_{sh}\), \(S_{sh}^2\), and \(S_{syh}\), the estimate of the \(R_s\) is given by

\[
R_{sh} = \frac{\bar{Y}_s}{X + C_s}.
\]

The estimate of the \(S_{sh}^2\) is given by

\[
S_{sh}^2 = \frac{\sum \frac{1}{n_h - 1}(x_{hi} - \bar{x}_h)^2 + \sum \frac{1}{n_h - 1}(y_{hi} - \bar{y}_h)^2}{n_h - 1}
\]

Note that the bias of the modified separate ratio estimator is the cumulative bias of ratio estimates in each stratum. The bias of this estimator may not be negligible when the biases have the same signs in all strata. However, if the sample size in each stratum is large enough, the bias is negligible.

\[
\bar{Y}_{RS, SD} = \sum \frac{1}{N_h} W_h \frac{\bar{Y}_h(\bar{x}_h + C_{sh})}{\bar{X}_h + C_{sh}}.
\]

To obtain the MSE and bias of the modified separated ratio estimator, applying the MSE and bias of

\[
\bar{Y}_{SDh} = \frac{\bar{Y}_h(\bar{x}_h + C_{sh})}{\bar{X}_h + C_{sh}}
\]

draw in stratum \(h\), the results are as follows:

\[
B(\bar{Y}_{RS, SD}) = \sum \frac{1}{N_h} W_h Y_h \left( \frac{R_{sh}}{X_h + C_{sh}} S_{sh}^2 - \frac{1}{X_h + C_{sh}} S_{syh} \right),
\]

where \(R_{sh} = \frac{\bar{Y}_s}{X_h + C_{sh}}\). For estimating MSE(\(Y_{RS, SD}\)), we substitute the sample estimates as

\[
MSE(\bar{Y}_{RS, SD}) = \sum \frac{1}{N_h} W_h^2 Y_h \left( S_{sh}^2 + R_{sh} S_{sh}^2 - 2R_{sh} S_{syh} \right),
\]

where \(R_{sh} = \frac{\bar{Y}_s}{X_h + C_{sh}}\). Note that the bias of the modified separate ratio estimator is the cumulative bias of ratio estimates in each stratum. The bias of this estimator may not be negligible when the biases have the same signs in all strata. However, if the sample size in each stratum is large enough, the bias is negligible.

**Comparison of Efficiency**

We compare the modified combined ratio estimator with the unbiased estimator. The condition is as follows:

\[
MSE(\bar{Y}_{RC, SD}) < MSE(\bar{Y}_s) \\
\sum \frac{1}{N_h} W_h^2 Y_h \left( S_{sh}^2 + R_{sh} S_{sh}^2 - 2R_{sh} S_{syh} \right) < \sum \frac{1}{N_h} W_h^2 Y_h S_{sh}^2 \\
\sum \frac{1}{N_h} W_h^2 Y_h S_{sh}^2 < 2 - \frac{1}{R_s} \sum \frac{1}{N_h} W_h^2 Y_h S_{syh}
\]

where

\[
\sum \frac{1}{N_h} W_h^2 Y_h S_{sh}^2 < \frac{\bar{X}_s + C_s}{\bar{Y}}.
\]
When the condition (19) is satisfied, the modified combined ratio estimator will be more efficient than the unbiased estimator. The condition to compare the modified combined ratio estimator with the combined ratio estimator is as follows:

$$\text{MSE}(\bar{y}_{RC, SD}) < \text{MSE}(\bar{y}_{RC}),$$

$$\sum_{h=1}^{H} w_{h}^2 y_{h} \left( S_{sh}^2 + R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right) < \sum_{h=1}^{H} w_{h}^2 y_{h} \left( S_{sh}^2 + R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right),$$

$$\sum_{h=1}^{H} w_{h}^2 y_{h} \left( R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right) < \sum_{h=1}^{H} w_{h}^2 y_{h} \left( R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right),$$

$$R_{sh} A - 2 R_{sh} B < R_{sh} A - 2 R_{sh} B \quad \text{(20)}$$

When the condition (20) is satisfied, the modified combined ratio estimator will be more efficient than the combined ratio estimator.

Next, we compare the modified separated ratio estimator with the unbiased estimator. The condition is as follows:

$$\text{MSE}(\bar{y}_{RS, SD}) < \text{MSE}(\bar{y}_{s}),$$

$$\sum_{h=1}^{H} w_{h}^2 y_{h} \left( S_{sh}^2 + R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right) < \sum_{h=1}^{H} w_{h}^2 y_{h} S_{sh}^2,$$

$$\sum_{h=1}^{H} w_{h}^2 y_{h} S_{sh}^2 R_{sh} < 1$$

$$2 \sum_{h=1}^{H} w_{h}^2 y_{h} S_{sh}^2 R_{sh} \quad \text{(21)}$$

When the condition (21) is satisfied, the modified separated ratio estimator is more efficient than the unbiased estimator. The condition to compare the modified separated ratio estimator with the separated ratio estimator is given by

$$\text{MSE}(\bar{y}_{RS, SD}) < \text{MSE}(\bar{y}_{RS}),$$

$$\sum_{h=1}^{H} w_{h}^2 y_{h} \left( S_{sh}^2 + R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right) < \sum_{h=1}^{H} w_{h}^2 y_{h} \left( S_{sh}^2 + R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right),$$

$$\sum_{h=1}^{H} w_{h}^2 y_{h} \left( R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right) < \sum_{h=1}^{H} w_{h}^2 y_{h} \left( R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right),$$

$$\quad \text{MSE}(\bar{y}_{RC, SD}) < \text{MSE}(\bar{y}_{RC}),$$

$$\sum_{h=1}^{H} w_{h}^2 y_{h} \left( S_{sh}^2 + R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right) < \sum_{h=1}^{H} w_{h}^2 y_{h} \left( S_{sh}^2 + R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right),$$

$$\sum_{h=1}^{H} w_{h}^2 y_{h} \left( R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right) < \sum_{h=1}^{H} w_{h}^2 y_{h} \left( R_{sh}^2 S_{sh}^2 - 2 R_{sh} S_{sh} y_{sh} \right). \quad \text{(22)}$$

When the condition (22) is satisfied, the modified separated ratio estimator will be more efficient than the separated ratio estimator. Note that a difference in efficiency between these latter MSEs of the estimators is the ratio $R_{sh}$ and $R_{sh}$.  

**Application**

We use the dataset from a census of all farms in Jefferson County, Iowa in $n^3$ to demonstrate the relative efficiency of the modified estimators compared with the existing estimators. In this population $y_{hi}$ represents acres in corn and $x_{hi}$ acres in the farm. The population consists of two strata with stratum size 1,580 and 430. Here the sample sizes of the two strata are $n_1 = 70$ and $n_2 = 30$, respectively. Table 1 shows the population characteristics.

<table>
<thead>
<tr>
<th>Stratum</th>
<th>$N_h$</th>
<th>$\bar{y}_{hi}$</th>
<th>$\bar{x}_h$</th>
<th>$S_{sh}^2$</th>
<th>$S_{sh}^2$</th>
<th>$S_{xyh}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,580</td>
<td>82.56</td>
<td>19.4</td>
<td>312</td>
<td>2,055</td>
<td>494</td>
</tr>
<tr>
<td>2</td>
<td>430</td>
<td>244.85</td>
<td>51.63</td>
<td>922</td>
<td>7,357</td>
<td>858</td>
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**Table 1** Populations Characteristics

<table>
<thead>
<tr>
<th>Population</th>
<th>$\bar{y}_{hi}$</th>
<th>$\bar{x}_h$</th>
<th>$S_{sh}^2$</th>
<th>$S_{sh}^2$</th>
<th>$S_{xyh}$</th>
</tr>
</thead>
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<tr>
<td>2,010</td>
<td>117.28</td>
<td>26.30</td>
<td>620</td>
<td>7,615</td>
<td>1,453</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Estimators</th>
<th>Bias</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{y}_{at}$</td>
<td>0</td>
<td>3.9405</td>
</tr>
<tr>
<td>$\bar{y}_{RS}$</td>
<td>-0.1184</td>
<td>3.0599</td>
</tr>
<tr>
<td>$\bar{y}_{RC}$</td>
<td>-0.0384</td>
<td>2.9221</td>
</tr>
<tr>
<td>$\bar{y}_{RC, SD}$</td>
<td>-0.0383</td>
<td>2.9214</td>
</tr>
<tr>
<td>$\bar{y}_{RS, SD}$</td>
<td>-0.1181</td>
<td>2.8898</td>
</tr>
<tr>
<td>$\bar{y}_{RC, SD}$</td>
<td>-0.0382</td>
<td>2.9202</td>
</tr>
</tbody>
</table>

From Table 2, the proposed combined ratio estimator gives the smallest absolute bias among the combined and separate ratio estimators. Whereas the modified separate ratio estimator gives smaller absolute bias than the original separate ratio estimator. In addition, the results show that the modified separate ratio estimator produces the smallest MSE and the proposed combined ratio estimator provides smaller MSE than the existing combined ratio estimators. It can be examined that all of the four condi-
tions are satisfied as follows:
\[
\sum_{h=1}^{l} \frac{W_h^2 \gamma_h S_{yh}^2}{2 \sum_{h=1}^{l} W_h^2} = 2.9078 < \frac{\bar{X} + C_s}{\bar{Y}} = 4.4828,
\]
\[
R^2_A - 2R^2_B = 0.4158 < 1 \quad \text{and} \quad R^2_A - 2R_B = 1.0184,
\]
\[
\sum_{h=1}^{l} \frac{W_h^2 \gamma_h s_{yh}R_{sh}}{2 \sum_{h=1}^{l} W_h^2} = -1.0507 < \sum_{h=1}^{l} \frac{W_h^2 \gamma_h (R_{sh}^2 s_{yh} - 2R_{sh} S_{yh})}{2 \sum_{h=1}^{l} W_h^2} = -1.0506.
\]

Therefore, the modified combined and separate ratio estimators are more efficient than the traditional ratio estimators for this data.

**Discussion**

Using the modified combined ratio estimator, the coefficient of variation and the mean of the auxiliary variable in the whole population must be known. To use the modified separate ratio estimator, the coefficients of variation and the means of the auxiliary variable in all strata are required. The bias of the modified separate ratio estimator is larger than that of the modified combined ratio estimator. Because the formula of the MSE and bias were derived by using the first two terms of Taylor series, the simulation study should be used to compare the accuracy and the efficiency of the estimators in the future. Since the conditions of the efficiency comparison among ratio estimators depend on some unknown parameters, sample estimates of these parameters may be used in practice.

**References**

Dependence Analysis for the Exchange Rate Data using Extreme Value Copulas

Jaruchat Busaba

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Abstract
This article considers the bivariate generalized extreme value (BGEV) distribution and the bivariate generalized Pareto distribution (BGPD) to model the tail probability and tail dependence of the financial return series based on monthly and daily maxima of BHT/USD, EUR/USD foreign exchange data, respectively. The selection and estimation of the copula is based on the maximum likelihood estimation (MLE) approach which is proposed for nine parametric models of dependence function for both distributions. The copula parameters are estimated by Inference For Margins (IFM) approach and then select best fitting model by Akaike Information Criterion (AIC) value.

Keyword: bivariate generalized extreme value distribution, bivariate generalized pareto distribution, parameter estimation, extreme value copulas, dependence function, tail probability, tail dependence.

Introduction
Extreme value theory (EVT) works with the extreme deviations from the mean of probability distributions. It is important to describe the shape of the tail part in order to make an accurate estimation of the tail probability, when modeling the distribution of the rarely events such as asset return, not yet seen disasters, etc. Recently, EVT is quick development which based on normal distribution in many situations. It has been widely used in the area of statistics and gradually in the financial, climate, hydrology and other fields; see Joe (1997), Coles (2001), McNeil (2005), etc.

Definitely, “Copula” approach is a great statistic tool which can be combined with EVT in the case of multidimensional variables. In 1999, Nelson proposed copula approach in his monograph, presenting the theory and basic introduction to this nonlinear dependence measure. Since then, copulas are very popular approach and rapid development (see Frees and Valdez (1998), Embrechts et al. (2002)). Especially, copulas reveal to be an excellent powerful tool in financial, insurance and related fields. A copula is a hidden dependence structure that couples a joint distribution with its margins. The fact that the theory of multivariate in EVT can be expressed in terms of copulas has been recently recognized (see McNeil 2005). A class of copulas well-known as extreme value copulas emerges as the class of natural limiting dependence structures for multivariate variables and these provide useful reference structures for modeling the behavior of variables that appear to show tail probability and tail dependence, especially with rare event. This article works with the tail behavior of the tails of financial return series from foreign exchange market using the EVT and concentrate on the tail probability and tail dependence analysis based on the extreme value copulas by using “evd” and “copula” package on R program.

This article is organized as follows. Section II presents the definition of univariate and bivariate EVT which can be used to model the maximum series distributions. Section III reviews the concept of copula function and extreme value copulas in accompany with their dependence functions that will be applied. In Section IV, the description of the tail probability which defined as joint survival function and quantifications of the magnitude of the tail dependence. In Section V, parameter estimation based on the MLE approach and the statistical estimation
of the copula parameters based on IFM approach. Section VI presents the results of an empirical application of foreign exchange return data. However, this also presents the procedure for the selection of the suitable copula which can be described tail probability and tail dependence characteristics. Finally, Section VII summarizes the major findings and introduces directions for further research.

Univariate and Bivariate extreme value theory

In 1928, Fisher-Tippett proposed Block Maxima and then Pickands (1975) and Balkema and De Haan (1974) proposed Threshold Exceedances. These are two kind approaches of EVT mainly.

Univariate Extreme Value Distribution

Block Maxima is the traditional approach for identifying extremes in data, which choose the largest (smallest) value during a certain period (annual, quarter, month, etc.) that constitute the extreme events for the model building which that distribution must be the generalized extreme value distribution or “GEV”.

For univariate GEV, let \(X_i, i = 1, 2, ..., n\) be a random sample coming from the distribution \(F(X)\). Define \(M_n = \max(X_1, X_2, ..., X_n)\) as the maxima (also denoted as block maxima). As stated in Fisher and Tippett (1928), if the block maxima of identically and independent distribution (i.i.d) random variables converge in to some non-degenerate distribution function \(H\) under an appropriate normalization, this distribution is called extreme value distribution, which belongs to one of the three types of class, widely known as Frechet, Weibull and Gumbel family, respectively. Jekinson (1955) unified the three families into a single family of models that have the distribution functions of the form:

\[
H(x; \mu, \sigma, \gamma) = \exp\left(-\left(1 + \frac{x - \mu}{\sigma}\right)^{-\gamma}\right)
\] (1)

where \(\mu, \sigma, \gamma\) is called location, scale, shape parameter, respectively, and \(1 + \gamma \frac{x - \mu}{\sigma} > 0\). When \(\gamma = 0\), it is Gumbel distribution, i.e., type I distribution. When \(\gamma > 0\), it is Frechet, i.e., type II distribution. When \(\gamma < 0\) corresponds to type III, also known as Weibull distribution. The generalization of three families into a single one greatly simplifies statistical implementation as shown in the simple form of (1).

For the univariate threshold Exceedances approach concerns about all observed data exceeding a certain threshold in the sample, which that distribution must be the generalized Pareto distribution or “GPD”. Let \(X_i, i = 1, 2, ..., n\) be a random sample coming from the distribution \(F(X)\). Then, for large enough \(u\), the distribution function of \((X-u)\) conditional on \(X > u\), the distribution function of the GPD is approximately

\[
H(x; \sigma, \gamma) = \exp\left(-\left(1 + \gamma \frac{x}{\sigma}\right)^{-\gamma}\right)
\] (2)

where \(\sigma, \gamma\) are called scale and shape parameters, respectively. Define on \(\{x; x > 0\}\) and \(1 + \gamma \frac{x}{\sigma}\), where \(\sigma = \sigma + \gamma (u - \mu)\). If \(\gamma < 0\), the distribution of excesses has an upper bound of \(u - \frac{\sigma}{\gamma}\). If \(\gamma > 0\), the distribution has no upper limit. The distribution is also unbounded if \(\gamma = 0\), which should again be interpreted by taking the limit \(\gamma \to 0\) in (2).

Next subsection presents BGEV and BGPD which are adopted to study the tail behavior of foreign exchange data.

Bivariate Generalized Extreme Value Distribution (BGEV)

Let \((X, Y)\) be a bivariate random sample vector represent the componentwise maxima or minima. Under the appropriate conditions the distribution of \((X, Y)\) can be approximated by a bivariate extreme value distribution (BGEV) with margins \(G_1\) and \(G_2\), respectively. By Pickands dependence function \(A(w)\) (see Berlaint et al., 2004),

\[
G(x, y) = \exp\left(\log(G_1(x))A\left(\frac{\log(G_1(y))}{\log(G_1(x))\log(G_1(y))}\right)\right)
\] (3)
where $A(w)$ is called the dependence function between the margins.

**Bivariate Generalized Pareto Distribution (BGPD)**

Let $(X, Y) = (Z_x - u_x, Z_y - u_y)$ be a random vector of exceedances where $(Z_x, Z_y)$ be the observed random variable, $(u_x, u_y)$ a given threshold. Its cumulative distribution function (cdf) as in the paper of Rootzen and Tajvidi (2006),

$$H(x, y) = \frac{1}{\log G(0,0)} \times \log G(x, y) / G(x \wedge 0, y \wedge 0).$$

(4)

For some BGEV, $G$ with non-degenerate margins and with $0 < G(0,0) < 1$.

The theory of BGEV and BGPD with the copula methodology are combined, then apply the class of extreme value copulas to explore the extremal dependence function of these data set.

**Copula function and the extreme value copulas**

**Copula function**

In 1959, the copula was first proposed by Sklar. In this article, $(X, Y)$ is bivariate random vector and $G$ is the distribution of $(X, Y)$ with marginal distribution $F_X(X), F_Y(Y)$. The Sklar’s Theorem assures the existence of a distribution function $C$ on $[0,1]^2$ for all $(x, y) \in R \times R$ such that:

$$G(x, y) = C(F_X(X), F_Y(Y))$$

where $C$ is called the copula associated with $X$ and $Y$ which couples the joint distribution $G$ with its margins. Equation (5) is equivalent to $G(F_X^{-1}(u), F_Y^{-1}(v)) = C(u, v)$ as a consequence of the Sklar’s Theorem, where $u = F_X(X), v = F_Y(Y)$ are marginal distribution of $(X, Y)$ (See Nelsen, (1999)).

The theory of multivariate EVT can be expressed in terms of copulas. Let $M_X = \max(X_1, ..., X_n)$ and $M_Y = \max(Y_1, ..., Y_n)$ be the maxima of $(X, Y)$ component. The object of interest is the vector of componentwise block maxima: $M = (M_X, M_Y)$.

In particular, the possible multivariate limiting distributions for $M$ under certain appropriate normalizations are interested. The outcome is similar to the univariate case, which can find a non-degenerate distribution function so that the bivariate extreme distribution $G$ can be connected by an extreme value copula (EV copula) $C_0$:

$$G(x, y) = C_0(F_X(x; \mu_x, \sigma_x, \gamma_x), F_Y(y; \mu_y, \sigma_y, \gamma_y)), \quad \mu_x, \sigma_x, \gamma_x,$$

(6)

where $\mu_x, \sigma_x, \gamma_x$ are GEV parameter and $F$ is GEV margin.

In 1997, Joe presented the unique copula $C_0$ of $F$ exists and satisfies:

$$C_0(u', v') = C_0(u, v), \quad t > 0. \quad (7)$$

**The extreme value copula**

In 1981, Pickands pointed out a bivariate copula is an extreme value (EV) copula if and only if it takes the form:

$$C_0(u, v) = P(F_x(x) \leq u_x, F_y(y) \leq u_y)$$

$$= \exp \left( \ln(u) A \left( \frac{\ln v}{\ln(uv)} \right) \right), \quad (8)$$

where $A(w)$ is called the dependence function.

According to bivariate case, $A(w)$ is one-dimensional and (8) simplifies to

$$-\log G(x, y) = \frac{1}{x + \frac{1}{y}} A \left( \frac{x}{x + y} \right), \quad (9)$$

where

$$A(w) = \int_0^1 \max \{a(1-w), (1-a)w\} S(da).$$

The finite positive measure on interval $S$ is equivalent to

$$\int_0^1 aS(da) = \int_0^1 (1-a)S(da) = 1.$$
foreach \( a \in [0,1] \). The dependence function \( A(w) \) involve in an EV copula must satisfy three properties:

(i) \( A(0) = A(1) = 1 \),

(ii) \( \max(w, 1-w) \leq A(w) \leq 1 \) for \( 0 \leq w \leq 1 \),

(iii) \( A(w) \) is convex function in the region \( 0 \leq w \leq 1 \).

The upper and lower bounds of \( A(w) \) have intuitive interpretations. If \( A(w) = 1 \) for all \( w \), then the copula is independent copula. If \( A(w) = \max(w, 1-w) \), then the copula is perfectly dependent.

The following are nine of extreme value copulas commonly used and it is convenient to prove that all of them are satisfied with (7).

(i) **Logistic model** or “log” (Gumbel, 1960):

The corresponding copula function is given by

\[
C(u, v) = \exp \left\{ - \left[ (-\ln u)^r + (-\ln v)^r \right] \right\},
\]

(10)

with \( 0 < r \leq 1 \). Independence and complete dependence correspond to \( r = 1 \) and \( r = \infty \), respectively. In this model the variables are exchangeable.

(ii) **Asymmetric logistic model** or “alog” (Tawn, 1988):

The copula function is

\[
C(u, v) = \exp \left\{ -(1-\theta) \ln u - (1-\phi) \ln v - \left[ (\theta \ln u)^r + (\phi \ln v)^r \right]^r \right\},
\]

(11)

with \( \theta \geq 0 \), \( \phi \leq 1 \), and \( 0 < r \leq 1 \). Independence dependence correspond to \( \theta = \phi = 1 \) and \( r = \infty \). Complete dependence correspond to \( \theta = 0 \) or \( \phi = 0 \) or \( r = \infty \).

(iii) **HuslerReiss Model** or “hr” (Husler and Reiss, 1989):

The corresponding copula function is

\[
C(u, v) = \exp \left\{ -\ln \Phi \left\{ \frac{1}{r} + \frac{1}{2} \log \frac{\ln u}{\ln v} \right\} - \ln \Phi \left\{ \frac{1}{r} + \frac{1}{2} \log \frac{\ln v}{\ln u} \right\} \right\},
\]

(12)

where \( \Phi \) is the standard normal distribution function and \( r > 0 \). Independence is obtained in the limit as \( r \to 0 \) and complete dependence is obtained as \( r \to \infty \).

(iv) **Negative Logistic Model** or “neglog” (Galambos, 1975):

The copula function is

\[
C(u, v) = \exp \left\{ -\ln u - \ln v + \left[ \frac{1}{(\ln u)^r} + \frac{1}{(\ln v)^r} \right]^{-r} \right\},
\]

(13)

where \( r > 0 \). This is a special case of the bivariate asymmetric negative logistic model. Independence is obtained in the limit as \( r \to 0 \) and complete dependence is obtained as \( r \to \infty \).

(v) **Asymmetric Negative Logistic Model** or “aneglog” (Joe, 1990):

The corresponding copula function is given by

\[
C(u, v) = \exp \left\{ -\ln u - \ln v + \left[ \frac{1}{(\theta \ln u)^r} + \frac{1}{(\phi \ln v)^r} \right]^{-r} \right\},
\]

(14)

where \( r > 0 \) and \( 0 < \theta, \phi \leq 1 \). When \( \theta = \phi = 1 \) the asymmetric negative logistic model is approaches equivalent to the negative logistic model. Independence is obtained in the limit as either \( r, \theta \) or \( \phi \) approaches zero. Complete dependence is obtained in the limit when \( \theta = \phi = 1 \) and \( r \to \infty \).

(vi) **Bilogistic Model** or “bilog” (Smith, 1990):

The copula function is

\[
C(u, v) = \exp \left\{ -\ln u(1-q)^{-r} - \ln v(1-q)^{-r} \right\},
\]

(15)

where \( q = q(\ln u, \ln v; \alpha, \beta) \) is the root of the equation

\[
(1-\alpha) \ln u(1-q)^{\beta} - (1-\beta) \ln v(1-q)^{\alpha} = 0,
\]

\( 0 < \alpha, \beta < 1 \). When \( \alpha = \beta \), the bilogistic model is equivalent to the logistic model with dependence parameter \( r = \alpha = \beta \). Complete dependence is obtained in the
Independence is obtained as $\alpha = \beta$ approaches one, and when one of $\alpha, \beta$ is fixed and the other approaches one. Different limits occur when one of $\alpha, \beta$ is fixed and the other approaches zero.

(vii) Negative Bilogistic Model or ‘negbilog’ (Coles and Tawn, 1994):

The copula function is

$$C(u,v) = \exp \left( -\ln u - \ln v + \ln (q)^{\alpha} + \ln (1-q)^{\beta} \right),$$

(16)

where $q = q(\ln u, \ln v; \alpha, \beta)$ is the root of the equation

$$(1+\alpha)\ln u (q)^{\alpha} - (1+\beta)\ln v (1-q)^{\beta} = 0,$$

$\alpha > 0, \beta > 0$. When $\alpha = \beta$, the negative bilogistic model is equivalent to the negative logistic model with dependence parameter $r = \frac{1}{\alpha} = \frac{1}{\beta}$. Complete dependence is obtained in the limit as $\alpha = \beta$ approach zero. Independence is obtained as $\alpha = \beta$ approaches one, and when one of $\alpha, \beta$ is fixed and the other approaches infinity. Different limits occur when one of $\alpha, \beta$ is fixed and the other approaches zero.

(viii) Coles and Tawn Model or “ct” (Coles and Tawn, 1991):

The copula function is

$$C(u,v) = \exp \left( -\ln \left[ 1 - B(q; \alpha, \beta) \right] \right),$$

(17)

where $q = \alpha \ln v / (\alpha \ln v + \beta \ln u)$ and $B(q; \alpha, \beta)$ is the beta distribution function evaluated at $q$ with $\alpha$ and $\beta$. Complete dependence is obtained in the limit as $\alpha = \beta$ tends to infinity. Independence is obtained as $\alpha = \beta$ approaches zero, and when one of $\alpha, \beta$ is fixed and the other approaches zero. Different limits occur when one of $\alpha = \beta$ is fixed and the other tends to infinity.

(ix) Asymmetric Mixed model or “amix” (Tawn, 1988):

The dependence function is

$$C(u,v) = uv \left\{ \exp \left( \left( \ln u \right) (\ln v) d \right) \right\},$$

(18)

with $d = \frac{\ln u (\alpha + \beta) + \ln v (\alpha + 2\beta)}{(\ln u \ln v)^2}$, where $\alpha$ and $\alpha + 3\beta$ are non-negative, and where $\alpha + \beta$ and $\alpha + 2\beta$ are less than or equal to one. Complete dependence cannot be obtained. Independence is obtained when both parameter are zero.

The tail probability and the tail dependence

Tail probability

From (3) and (4), the tail probability estimation of BGEV and BGPD are calculated from the identity:

$$P(X > x, Y > y) = 1 - H_x(x) - H_y(y) + G(x, y)$$

(19)

is defined as joint survival function, which can obtain tail probability exceeding estimation for those.

Tail dependence

Tail dependence is a kind of dependence measure which can calculate from copulas. In the event, if model the tail dependence, its' structure must be considered also. The tail dependence of $(X, Y)$ with respective distribution $G(x, y)$ assuming BGEV distribution and $H(x, y)$ assuming BGPD can be measured as follows:

$$\lambda_u = \lim_{c \to -\infty} \left[ 1 - 2c + C_0(c, c) \right] / (1-c)$$

(20)

and

$$\lambda_l = \lim_{c \to 0} C_0(c, c) / c$$

(21)

where $c$ is $qth$-quantile. $\lambda_u$ and $\lambda_l$ are measures of upper and lower tail dependence, respectively. If $\lambda_u \geq 0$ claims the upper tails of $(X, Y)$ are asymptotically dependent. If $\lambda_l \geq 0$ claims the lower tails of $(X, Y)$ are asymptotically dependent. To consider the estimation of $\lambda_u$ and to obtain the relationship between $\lambda_u$ and the dependence function $A(w)$ (F. Gabriel et al., 2006):

$$\hat{\lambda}_u = 2 - 2A(1/2).$$

(22)

Parameter estimation for EV distributions and copulas

A traditional approach, maximum likelihood estimation (MLE), is used to estimate the parameter in the BGEV and BGPD model by maximizing the log-likelihood function of the distribution. Set $l(\mu, \sigma, \gamma)$ and $l(\sigma, \gamma)$ as the sample log-likelihood function of the BGEV distribution and BGPD, respectively. The maximum
log-likelihood estimate of parameter of BGEV and BGPD as is in (24) and (25),

\[
(\hat{\mu}, \hat{\sigma}, \hat{\gamma}) = \arg \max \{ l(\mu, \sigma, \gamma) \}
\]

\[
= \text{arg max} \sum_{i=1}^{m} \log h(\mu, \sigma, \gamma)(x_i),
\]

(23)

where \( x_i \) is the \( i^{th} \) block maximum from the underlying data, \( i = 1, \ldots, m \). \( m \) is the block size based on the original series data. \( h(\mu, \sigma, \gamma) \) is the density of the GEV distribution.

The maximization must be subject to the parameter constraints that \( \sigma > 0 \) and \( 1 + \gamma \left( \frac{x_i - \mu}{\sigma} \right) > 0 \) for all \( i \).

\[
(\hat{\sigma}, \hat{\gamma}) = \arg \max \{ l(\sigma, \gamma) \}
\]

\[
= \text{arg max} \sum_{i=1}^{m} \log h(\sigma, \gamma)(x_i),
\]

(24)

where \( x_i \) is the \( i^{th} \) over threshold data, \( i = 1, \ldots, m \). \( m \) is the number of excesses over threshold \( u \). \( h(\sigma, \gamma) \) is the density of the GPD.

To estimate the copulas parameters, there are several popular and widely used approaches: (i) Exact maximum likelihood approach (EML), (ii) Inference functions for margins (IFM), (iii) Canonical maximum likelihood approach (CML) and (iv) Nonparametric approach. In this article, I use IFM to implement model and parameter estimation for extreme value copulas by assuming their margins are GEV distributed and GPD.

Set \( l(\theta) \) as the log-likelihood function of copula.

The maximum log-likelihood estimate of parameter \( \theta \) is:

\[
\hat{\theta} = \arg \max l(\theta) = \arg \max \sum_{i=1}^{m} \ln c(\hat{u}_i, \hat{v}_i; \theta),
\]

(25)

where \( \hat{u}_i, \hat{v}_i \) represents the estimated value of the two margins. \( c(\cdot, \cdot) \) is the density function of the copula. In IFM, the estimation of \( \hat{\theta} \) depends on the choice of marginal distribution. As the margins are GEV distributed and GPD, (3) and (4) give me two estimates for the distribution \( H_x(x), H_y(y) \). Then institute \( m \) estimated value of into (5) to estimate the parameter \( \theta \) of the copula function.

Results comparison

The daily closing prices of BTH/USD and EUR/USD foreign exchange data are used to analyze the tail probability characteristic and extremal dependence function using extreme value copulas. The data set is selected from January 3, 2000 to December 30, 2012 with 3391 effective observations for each index (http://www.federalreserve.gov). Define \( \{S_i\} \) as the daily market closing price and transform it to the continuously compounded return series (log-returns) as \( R_i = (\ln(S_i) - \ln(S_{i-1})) \times 100 \). The results are described into three subsections as follows;

**The parameter estimations of the GEV and GPD model**

The estimation results of \( (\mu, \sigma, \gamma) \) of GEV model and \( (\sigma, \gamma) \) of GPD model based on MLE approach are shown in Tab 1. For GEV model, BHT/USD and EUR/USD correspond to Weibull distribution \( (\gamma < 0) \).

**Table 1** the parameter estimation results using the ml approach based on gev and gpd model

<table>
<thead>
<tr>
<th>Model</th>
<th>BHT/USD Parameter</th>
<th>ML</th>
<th>EUR/USD Parameter</th>
<th>ML</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEV</td>
<td>( \hat{\mu} )</td>
<td>-0.8922 (0.2326)</td>
<td>( \hat{\mu} )</td>
<td>-0.8010 (0.1367)</td>
</tr>
<tr>
<td></td>
<td>( \hat{\sigma} )</td>
<td>2.7023 (0.1551)</td>
<td>( \hat{\sigma} )</td>
<td>1.5642 (0.0926)</td>
</tr>
<tr>
<td></td>
<td>( \hat{\gamma} )</td>
<td>-0.2097 (0.0317)</td>
<td>( \hat{\gamma} )</td>
<td>-0.1638 (0.0424)</td>
</tr>
<tr>
<td>GPD</td>
<td>( \hat{\sigma} )</td>
<td>0.5691 (0.1876)</td>
<td>( \hat{\sigma} )</td>
<td>0.5107 (0.1781)</td>
</tr>
<tr>
<td></td>
<td>( \hat{\gamma} )</td>
<td>0.0927 (0.2480)</td>
<td>( \hat{\gamma} )</td>
<td>0.1165 (0.2363)</td>
</tr>
</tbody>
</table>

The standard deviation estimates as shown in the blanket are relative low which implies that my block size choice is also appropriate for the parameter estimation of GEV, and they are good responsibility for GPD also.

**The parameter estimation of the copulas and related dependence function**

Table 2 and III are summary estimations for the parametric models discussed in Section III. Not only the value of the objective function (20) is given, but also an AIC goodness-of-fit measure,

\[
\text{AIC} = -2L + 2 \frac{n_p}{n},
\]

(26)

where \( L \) has been defined in (23) and (24), and \( n_p \) is the number of parameters.
Table 2 Summary of dependence function estimation for BGEV.

<table>
<thead>
<tr>
<th>Model</th>
<th>Parameters</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>log</td>
<td>$\hat{r} = 0.9990$</td>
<td>1377.486</td>
</tr>
<tr>
<td>alog</td>
<td>$\hat{\theta} = 0.6900, \hat{\phi} = 0.6799, \hat{r} = 1.0000$</td>
<td>1371.383</td>
</tr>
<tr>
<td>hr</td>
<td>$\hat{r} = 0.2005$</td>
<td>1376.220</td>
</tr>
<tr>
<td>neglog</td>
<td>$\hat{r} = 0.0530$</td>
<td>1366.106</td>
</tr>
<tr>
<td>aneglog</td>
<td>$\hat{\theta} = 0.1105, \hat{\phi} = 0.0013, \hat{r} = 0.1507$</td>
<td>1371.288</td>
</tr>
<tr>
<td>bilog</td>
<td>$\hat{\alpha} = 10.8941, \hat{\beta} = 9.5691$</td>
<td>1368.200</td>
</tr>
<tr>
<td>ct</td>
<td>$\hat{\alpha} = 0.0019, \hat{\beta} = 0.1222$</td>
<td>1372.330</td>
</tr>
<tr>
<td>amix</td>
<td>$\hat{\alpha} = 0.0007, \hat{\beta} = 0.0774$</td>
<td>1378.964</td>
</tr>
</tbody>
</table>

Table 3 Summary of dependence function estimation for BGPD.

<table>
<thead>
<tr>
<th>Model</th>
<th>Parameters</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>log</td>
<td>$\hat{r} = 0.9994$</td>
<td>495.0349</td>
</tr>
<tr>
<td>alog</td>
<td>$\hat{\theta} = 0.7040, \hat{\phi} = 0.6947, \hat{r} = 0.9998$</td>
<td>497.6283</td>
</tr>
<tr>
<td>hr</td>
<td>$\hat{r} = 0.2034$</td>
<td>493.5208</td>
</tr>
<tr>
<td>neglog</td>
<td>$\hat{r} = 0.0524$</td>
<td>493.5208</td>
</tr>
<tr>
<td>aneglog</td>
<td>$\hat{\theta} = 0.0884, \hat{\phi} = 0.0014, \hat{r} = 0.3538$</td>
<td>498.2955</td>
</tr>
<tr>
<td>bilog</td>
<td>$\hat{\alpha} = 0.9449, \hat{\beta} = 0.9981$</td>
<td>496.3350</td>
</tr>
<tr>
<td>negbilog</td>
<td>$\hat{\alpha} = 15.8405, \hat{\beta} = 15.7989$</td>
<td>495.5213</td>
</tr>
<tr>
<td>ct</td>
<td>$\hat{\alpha} = 0.0017, \hat{\beta} = 0.1515$</td>
<td>496.4902</td>
</tr>
<tr>
<td>amix</td>
<td>$\hat{\alpha} = 0.6046, \hat{\beta} = -0.2013$</td>
<td>503.3025</td>
</tr>
</tbody>
</table>

From Table 2, the three best fitting models for BGEV are neglog, negbilog and bilog model, which their AIC are 1366.106, 1368.200 and 1369.625, respectively. Next, tail probability, dependence functions and tail dependence are calculated from parameters of these models.

Figure 1 Parametric estimations of the dependence function $A(w)$ for BGEV. In Fig. 1, the three best fitting; neglog, negbilog and bilog, estimations of the dependence function are represented. It can be seen that the “neglog” model provides best results from the represent of dependence function.

From Table 3, the three best fitting models for BGPD are hr, neglog and log. In Fig. 2, the three best fitting estimations of the dependence function are represented. It can be seen that the “hr” and “neglog” models provide similar results and it seems all of them are able to represent the dependence function.

Tail probability and Tail dependence

Table 4 gives the estimates of tail probability which is exceeding over 95th and 99th quantile under difference levels for BGEV and BGPD. These results show that the probability of simultaneously exceeding respective quantile of two extremal return data is quite low and they are very similar. The $A(1/2)$ presents the information of tail dependence between the variables, results of all model
shows $\hat{\alpha}(1/2) \approx 0.5$ that means variables are strong dependence (see the value of $\hat{\alpha}_u$).

### Table 4
Tail probability, dependence function and tail dependence under different models for bgev and bgpd

<table>
<thead>
<tr>
<th>Model</th>
<th>Tail Probability exceeding p&lt;sup&gt;th&lt;/sup&gt;quantiles</th>
<th>$\hat{\alpha}(1/2)$</th>
<th>$\hat{\alpha}_u$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>95&lt;sup&gt;th&lt;/sup&gt;</td>
<td>99&lt;sup&gt;th&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>BGEV</td>
<td>neglog</td>
<td>0.11830</td>
<td>0.06851</td>
</tr>
<tr>
<td>BGPD</td>
<td>hr</td>
<td>0.10026</td>
<td>0.020053</td>
</tr>
<tr>
<td></td>
<td>neglog</td>
<td>0.10026</td>
<td>0.020053</td>
</tr>
</tbody>
</table>

According to $\hat{\alpha}_u$ in section IV which claim the upper tails of variables are independent, $\hat{\alpha}_u \geq 0$.

### Conclusions

The combination, in this article, between extreme value theory and extreme value copulas to make analysis on the extremely dependence for the selected data obtained from the foreign exchange market. The estimation of the GEV distribution for monthly maxima and the GPD for daily maxima using MLE approach. Then the calibration of copula functions to recover the tail probability distribution and tail dependence properties by comparing different model of extreme value copula. The result shows that EV copula which are selected, are all suitable copulas that have the desired property to measure tail probability and tail dependence of empirical financial management variables.

Finally, the application of multivariate EVT to the field of financial management and related fields are currently quite an active research topic and it provides a lot of opportunities for exploration.

### Acknowledgment

This article was written when I was in the Center for Mathematical Sciences, Mathematical Statistics, at Lund University. I would like to thank Nader Tajvidi for the invitation to uncertainty modeling and giving me many good suggestions.

### References

Parameters Estimation Methods for the Negative Binomial-Crack Distribution and Its Application

Pornpop Saengthong¹, Winai Bodhisuwan²
Received: 29 March 2013 Accepted: 15 May 2013

Abstract
In this paper we study four parameters negative binomial-Crack (NB-CR) distribution. This new formulation distribution contains as special cases three parameters distribution, namely, negative binomial-inverse Gaussian (NB-IG), negative binomial-Birnbaum-Saunders (NB-BS) and negative binomial-length biased inverse Gaussian (NB-LBIG). The objective of our research is to estimate the parameters for NB-CR distribution by using maximum likelihood estimation and the method of moments. These methods are illustrated with an application to accident data.

Keywords: negative binomial-Crack distribution, parameter estimation, maximum likelihood estimation, method of moments count data

Introduction
With the huge growth in the collection and storage capabilities of data due to technological advances, count data have become widely available in many disciplines. The standard distribution for modeling count data has been the Poisson distribution, which is a proper model for counting the number of occurrences over a time interval at random when not many occurrences are observed within a short period of time. Also, they occur at a constant rate through time, and one occurrence of the phenomenon does not alter the probability of any future occurrence. Equality of mean and variance, called equal dispersion, is a quintessential characteristic of the Poisson distribution.

However, many count data often exhibit overdispersion, with a variance larger than the mean; in this case, an extension to the Poisson model is more appropriate. The negative binomial (NB) distribution is a popular alternative distribution for modeling overdispersed count data because it is more flexible in accommodating overdispersion in comparison with the Poisson model.

The NB distribution is a mixture of Poisson and gamma distribution. Applications using the NB distribution can be found in many areas, for instance, economics, accident statistics, biostatistics and actuarial science. Although, the NB distribution allows for over-dispersion, it does not take care of excess zeros in the data. Studied on a tool for analyzing crash data characterized by a large amount of zeros. They pointed out that traditional statistical distributions or models, such as the Poisson and the NB distributions, cannot be used efficiently in models for count data with many zeros. The Poisson distribution tends to under-estimate the number of zeros given the mean of the data, while the NB may over-estimate zeros, but under-estimate observations with a count.

The problem of overdispersion and excess zeros is usually solved by introducing mixed Poisson or mixed NB distribution. Several studies show that mixed Poisson and mixed NB distribution provided a better fit on count data compared to the Poisson and the NB distribution. These include the Poisson-inverse Gaussian, negative binomial-inverse Gaussian, negative binomial-Lindley and negative binomial-Beta Exponential. Therefore, in order to provide another competitive alternative to the models above, a new mixed model is considered. We
propose the negative binomial-Crack (NB-CR) distribution which is a new mixed NB distribution obtained by mixing the distribution of $NB(r,p)$ where, $p = \exp(-a)$ with a distribution of $CR(\lambda, \theta, \gamma)$. This last distribution has recently been studied\textsuperscript{10,11}. The new mixed distribution has a heavy tail, seems to be skewed positively and may be considered as a competitive alternative for modeling overdispersed count data.

The purpose of this paper is to investigate the properties of the NB-CR distribution and its application. Parameters estimation is implemented using maximum likelihood estimation (MLE), method of moments (MoM) and present the comparison analysis between the Poisson, NB and NB-CR distributions based on a real data set using a goodness of fit test.

**NB-CR distribution**

This section describes the characteristics and some special cases of the NB-CR distribution.

**Characteristics of the NB – CR distribution**

As mentioned earlier, the NB-CR distribution is a mixture of the NB and Crack distributions. First we present the NB distribution and some of its properties. The probability mass function (pmf) of NB distribution is given by

$$f(x) = \binom{r+x-1}{x} p^r (1-p)^x, \quad x = 0, 1, 2, \ldots$$

where $r > 0$ and $0 < p < 1$. The mean and variance of this distribution can be given as

$$E(X) = \frac{r(1-p)}{p} \quad \text{and} \quad Var(X) = \frac{r(1-p)}{p^2} \quad \text{.}$$

The Crack distribution is a mixture of inverse Gaussian distribution and length biased inverse Gaussian which has the density function\textsuperscript{10,11}:

$$g(x) = \frac{1}{\theta \sqrt{2\pi}} \left[ \frac{\theta^{3/2}}{x^3} + (1-\gamma) \left( \frac{\theta^2}{x^2} \right) \right] \exp \left[ -\frac{1}{2 \theta} \left( \frac{x - \lambda}{\theta} \right)^2 \right], \quad x > 0$$

where $\lambda > 0$, $\theta > 0$, and $0 < \gamma < 1$. (3)

A random variable $X$ is assumed to follow a NB-CR $(r, \lambda, \theta, \gamma)$ distribution, when $X$ has a NB distribution with parameter $r > 0$ and $p = \exp(-a)$, where $a$ is distributed as CR with positive parameters $\lambda$, $\theta$ and $\gamma$, i.e., $X \sim NB(r, p = \exp(-a))$ and $a \sim CR(\lambda, \theta, \gamma)$. The pmf of $X$ is given by\textsuperscript{12}

$$h(x) = \binom{r+x-1}{x} \sum_{j=0}^{\infty} \left( \frac{\theta}{1+2\theta(r+j)} \right)^{r+j} \left( 1-\gamma \left( 1-\sqrt{1+2\theta(r+j)} \right) \right)^{j} \cdot x = 0, 1, 2, \ldots$$

where $r > 0$, $\lambda > 0$, $\theta > 0$, and $0 < \gamma < 1$.

The first moment (i.e., the mean) of the NB-CR $(r, \lambda, \theta, \gamma)$ is given by

$$E(X) = r \frac{(1-\gamma(1-\delta))\exp(\lambda(1-\delta))}{\delta} - r \quad \text{(5)}$$

The second moment of the NB-CR $(r, \lambda, \theta, \gamma)$ is given as

$$E(X^2) = \exp(\lambda) \left[ \frac{(r^2 + r)(1-\gamma(1-\delta))\exp(-\lambda \zeta)}{\zeta} + \frac{(2r^2 + r)(1-\gamma(1-\delta))\exp(-\lambda \delta)}{\delta} + r^2 \right], \quad \text{(6)}$$

where $\delta = \sqrt{1-2\theta}$ and $\zeta = \sqrt{1-4\theta}$.

The variance of the NB-CR $(r, \lambda, \theta, \gamma)$ is calculated as

$$\text{var}(X) = E(X^2) - (E(X))^2$$

$$= \exp(\lambda) \left[ \frac{(r^2 + r)(1-\gamma(1-\delta))\exp(-\lambda \zeta)}{\zeta} - \frac{r(1-\gamma(1-\delta))\exp(-\lambda \delta)}{\delta} - \frac{r^2(1-\gamma(1-\delta))\exp(-\lambda \delta)^2}{\delta} \right] \exp(\lambda) \quad \text{(7)}$$

**The special case**

Here, we consider some special cases of the NB-CR distribution. Let $X \sim NB-CR(r, \lambda, \theta, \gamma)$. Then, the pmf of
$X$ when $\gamma = 0$ [negative binomial-length biased inverse Gaussian (NB-LBIG) distribution] is given by

$$
\begin{align*}
    h(x) &= \sum_{j=0}^{x} \binom{x}{j} (-1)^j \\
    &\times \exp \left[ \frac{\lambda \left( 1 - \sqrt{1 + 2\theta (r + j)} \right)}{\sqrt{1 + 2\theta (r + j)}} \right], \quad x = 0, 1, 2, \ldots
\end{align*}
$$

(8)

where $r$, $\lambda$, and $\theta > 0$.

$X$ when $\gamma = \frac{1}{2}$ [negative binomial-Birnbaum-Saunders (NB-BS) distribution] is given by

$$
\begin{align*}
    h(x) &= \sum_{j=0}^{x} \binom{x}{j} (-1)^j \\
    &\times \frac{\lambda \left( 1 - \sqrt{1 + 2\theta (r + j)} \right)}{\sqrt{1 + 2\theta (r + j)}}, \quad x = 0, 1, 2, \ldots
\end{align*}
$$

(9)

where $r$, $\lambda$, and $\theta > 0$.

$X$ when $\gamma = 1$, $\lambda = \frac{\psi}{\mu}$, and $\theta = \frac{\mu^2}{\psi}$ [negative binomial-inverse Gaussian (NB-IG) distribution] is given by

$$
\begin{align*}
    h(x) &= \sum_{j=0}^{x} \binom{x}{j} (-1)^j \\
    &\times \exp \left[ \frac{\psi}{\mu} \left( 1 - \sqrt{1 + 2\frac{\mu^2}{\psi} (r + j)} \right) \right], \quad x = 0, 1, 2, \ldots
\end{align*}
$$

(10)

where $r$, $\mu$, and $\psi > 0$.

In order to study the behavior of the distribution for different value of $r$, $\lambda$, $\theta$, $\gamma$, the pmf is calculated. We show the graphs of the pmf of the NB-CR random variable of some values of parameters in Fig. 1.

The pmf of a NB-CR random variable ($X$) for some specified values of $(r, \lambda, \theta, \gamma)$

Parameter Estimation

In this section, the estimation of parameters for NB-CR ($r, \lambda, \theta, \gamma$) via the maximum likelihood estimation and the method of moments are provided. The R program [10] is used to obtain the solutions of $\lambda, \theta$ and $\gamma$.

Maximum Likelihood Estimation (MLE)

The log-likelihood function of the NB-CR ($r, \lambda, \theta, \gamma$) is given by

$$
\begin{align*}
    \log L(r, \lambda, \theta, \gamma) &= \sum_{i=1}^{n} \left( \log (r + x_i - 1) - \log x_i - \log (r - 1) \right) \\
    &+ \sum_{i=1}^{n} \left( \log \sum_{j=0}^{x_i} (-1)^j \exp \left[ \frac{\lambda \left( 1 - \sqrt{1 + 2\theta (r + j)} \right)}{\sqrt{1 + 2\theta (r + j)}} \right] \right) \\
    &\times \left[ 1 - \gamma \left( 1 - \sqrt{1 + 2\theta (r + j)} \right) \right].
\end{align*}
$$

(11)

It can be verified that the first partial derivatives equation (11) with respect to $r, \lambda, \theta$ and $\gamma$, we then obtain the following differential equations;
where \( \psi(k) = \frac{\Gamma'(k)}{\Gamma(k)} \) is the digamma function.

These four derivation equations cannot be solved analytically, as they need to rely on Newton-Raphson: a simple iterative numerical method to approximate MLE. In this paper, we obtained the MLE solutions of \( \hat{r}, \hat{\theta}, \hat{\theta} \) and \( \hat{\gamma} \) by solving the resulting equations simultaneously using nlm function in R package, namely stats13.

**Method of moments (MoM)**

For the method of moments, the parameters can be obtained by equating the sample and population moments. Because we have four parameters, we need the 3rd-moment and 4th-moment of (4), which are given by

\[
E(X^3) = \exp(\lambda) \left( \frac{(r^3 + 3r^2 + 2r)(1 - \gamma(1 - \delta))\exp(-\lambda \theta)}{\theta} \right) \left( 3r^3 + 6r^2 + 9r \right)(1 - \gamma(1 - \zeta))\exp(-\lambda \zeta) + \left( \frac{3r^3 + 3r^2 + r}{\delta} \right)(1 - \gamma(1 - \delta))\exp(-\lambda \delta) - r, 
\]

\[
E(X^4) = \exp(\lambda) \left( \frac{(r^4 + 6r^3 + 11r^2 + 6r)(1 - \gamma(1 - \kappa))\exp(-\lambda \kappa)}{\kappa} \right) - \left( \frac{4r^4 + 3r^3 + 2r^2 + 12r}{\theta} \right)(1 - \gamma(1 - \delta))\exp(-\lambda \theta) + \left( \frac{6r^4 + 18r^3 + 19r^2 + 7r}{\zeta} \right)(1 - \gamma(1 - \zeta))\exp(-\lambda \zeta) - \left( \frac{3r^4 + 4r^3 + 6r^2 + 7r}{\delta} \right)(1 - \gamma(1 - \delta))\exp(-\lambda \delta) + r^4, 
\]

where \( \theta = \sqrt{1 - 2\theta} \) and \( \kappa = \sqrt{1 - 8\theta} \).

The ith moment for the sample, \( m_i \), is equated as

\[
m_i = \frac{1}{n} \sum_{j=1}^{n} x_j^i 
\]

Then, the method of moments estimator is derived by solving equation \( m_i = E(X^i), m_1 = E(X^1), m_2 = E(X^2), \) and \( m_4 = E(X^4) \) using gmm function in R package, namely gmm.

**Results and Conclusion**

The number of injured from accidents on major roads in Bangkok of Thailand in 2007 was used to estimate the parameters of the Poisson, NB and NB-CR distribution based on the MLE and MoM. Table 1 shows the observed and expected frequencies, grouped in classes of expected frequency greater than five for the chi-square goodness-of-fit test as criteria of comparison, computed as \( \chi^2 = \sum \frac{(O_i - E_i)^2}{E_i} \). Based on the
p-value, the MLE provides very poor fit for the Poisson distribution and the NB and acceptable fits for the NB-CR.

Table 1: Goodness-of-fit test from MLE for the accident data

<table>
<thead>
<tr>
<th>No. of injured</th>
<th>No. of accident</th>
<th>Fitting distribution</th>
<th>Poisson</th>
<th>NB</th>
<th>NB-CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1273</td>
<td>1187.6</td>
<td>1278.7</td>
<td>1278.9</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>300</td>
<td>410.5</td>
<td>278.1</td>
<td>280.1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>71</td>
<td>76.9</td>
<td>81.8</td>
<td>74.1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>26.1</td>
<td>23.3</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>8.9</td>
<td>13.2</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6+</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Estimated parameters:
- $\hat{\lambda} = 0.345$
- $\hat{\theta} = 0.586$
- $\hat{\phi} = 2.275$

Chi-squares:
- 106.236

Table 2: Goodness-of-fit test from MoM for the accident data

<table>
<thead>
<tr>
<th>No. of injured</th>
<th>No. of accident</th>
<th>Fitting distribution</th>
<th>Poisson</th>
<th>NB</th>
<th>NB-CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1273</td>
<td>1187.6</td>
<td>1278.7</td>
<td>1278.9</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>300</td>
<td>410.5</td>
<td>278.1</td>
<td>280.1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>71</td>
<td>76.9</td>
<td>81.8</td>
<td>74.1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>26.1</td>
<td>23.3</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>8.9</td>
<td>13.2</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6+</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Estimated parameters:
- $\hat{\lambda} = 0.345$
- $\hat{\theta} = 0.386$
- $\hat{\phi} = 2.116$

Chi-squares:
- 106.236

Acknowledgment
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References


Fuzzy-Set Method For Grade Evaluation

R. Chonchaiya¹, A. Pongpullponsak²*
Received: 15 March 2013 Accepted: 15 May 2013

Abstract:
This paper is comparing 3 methods of student grading evaluation i.e. by instructor experiences, T-score and Fuzzy-set. The Instructor experiences method depends on the criteria strictly. The second Method is obtained by transforming the raw score into T-score. The third Method can be obtained by transforming the raw score into the fuzzy number by the expert opinion. The result shows that the Fuzzy Method is the compromised method between the criteria referenced and the T-score Method since it is not only the expert experience dependence as in the first method but also mathematically formulated as in the second method as well. Thus, the Fuzzy method is more reasonable.

Keywords: component, Grade evaluation, T-score, Fuzzy grading system

Introduction
As students find it is really difficult to be successful in each subject and get a good grade from any educational institute, the grading process is also really difficult for each teacher or professor to make it as standard as it should be. The question is how can we evaluate whether a student is good enough to get an A. Since grading does not mean a harsh process or feedback that might decrease the students’ motivation to study further but it should encourage them to continue learning instead.

When we have already got students’ aggregate test scores, we might apply the criterion referenced system or norm referenced system (sometimes we call group referenced system) to evaluate students’ academic abilities. Some questions are raised because of the fairness issue. For example, is it possible to claim that two students have the same intelligence level because their aggregate scores are equal?. To what degree does each test score explain the aggregate scores?. How can we formulate it and compute it mathematically?. How to translate a set of scores into letter-grades?. Letter-grades are recognized to be fuzzy descriptors of students’ performance.

From [1] and [6], there are some advantages and disadvantages of both method as follows:

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It is suitable for tracking the progress of the students within the curriculum.</td>
<td>1. Creating tests that are both valid and reliable requires fairly extensive and expensive time and effort.</td>
</tr>
<tr>
<td>2. Test item can be designed to match specific program objectives.</td>
<td>2. Results cannot be generalized beyond the specific course or program.</td>
</tr>
<tr>
<td>3. It reports how well of the students answer correctly on the lessons being study.</td>
<td>3. Criterion-referenced tests are specific to a program and cannot be used to measure the performance of large groups.</td>
</tr>
<tr>
<td>4. It is easy to calculate grade.</td>
<td>4. Fixed scales are arbitrary, so sometimes is meaningless.</td>
</tr>
<tr>
<td>5. It reduces competition between students.</td>
<td>5. This method can allow all students to receive the same grade and thus not provide information needed to screen students in competitive circumstances.</td>
</tr>
</tbody>
</table>

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² Department of Mathematics, Faculty of Science King Mongkut’s University of Technology Thonburi Bangkok, Thailand
* corresponding author: adisak.pon@kmutt.ac.th
Table 2 Benefits and drawbacks of group referenced system

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It allows for screening students according to their performance relative to their peers.</td>
<td>1. It does not provide feedback as to actual content mastered by student.</td>
</tr>
<tr>
<td>2. It is useful for competitive circumstances where students need feedback as to how they compare to their peers.</td>
<td>2. The curve grade based on single class meaningless unless provided in relation to group student is being scored against.</td>
</tr>
<tr>
<td>3. It is very easy for instructors to use.</td>
<td>3. It discourages cooperation, as competition becomes central.</td>
</tr>
<tr>
<td>4. It is generally appropriate in large courses.</td>
<td>4. It is not suitable to compare among many classes.</td>
</tr>
<tr>
<td>5. It is independent from the difficulty of the test.</td>
<td>5. It uses some complicated statistics.</td>
</tr>
</tbody>
</table>

The aim of this research is to develop a new reasonable method to grade each student in my Linear Algebra class. Actually, the grades have been given already, so the new grade from this method will not affect on their previous evaluation but, fortunately, we can compare the differences between the actual grade and the new grading result from another grading system. This research will focus on grading method using fuzzy logic.

**Literature Reviews**

Fuzzy concept has distracted people’s mind for many decades and become a popular and very interesting subject among computer engineers, mathematicians and statisticians as well as philosophers and psychologists. One of the reasons why fuzzy or vague concept cannot be formulated by ordinary mathematics easily is this concept does not include mathematics definite results. So, we need to know more different mathematical concepts to explain the mathematical modeling of the fuzzy idea.

The idea of fuzzy concept is related to the boundary-line view. A concept is fuzzy if there are some objects which cannot be classified either to the concept or to its complements but are members of the concepts’ boundary. The first successful approach to fuzziness was the notion of a fuzzy set proposed by. In this approach, sets are defined by partial membership in contrast to crisp membership used in classical definition of a set.

Fuzziness can occur in so many areas where human judgment, conclusion, and decision are involved, for example, engineering, medicine, artificial intelligence, pattern recognition, meteorology, computer science education, psychology, sociology etc.

There are some benefits to studying about fuzzy concept. One of them is to give us the interpretation of “non-random uncertainty” since the vague concept provides us a fantastic tool to measure the level of uncertainty or imprecision and this concept also helps us when we lack of information regarding a particular respond of the subject but we have to decide or give a conclusion.

has combined the traditional way of evaluation of students’ knowledge and success with the application of fuzzy logic and theory of fuzzy sets. He considered all the students activities and achievements and applied the “Centroid Method” or “Centroid clustering” where centroid is a point in the coordinate system where arithmetic average of scores earned in various activities of the students is used. It presents the average of centroid of each category, measured with the value being graded. That means the final scores or final results are affected by every activity.

**The Fuzzy-Set Method**

**Definition 1** [5] (membership function) For a set \( A \), we define a membership function \( \mu_\alpha \) such as

\[
\mu_\alpha(x) = \begin{cases} 
1, & \text{if and only if } x \in A \\
0, & \text{if and only if } x \notin A
\end{cases}
\]

We can say that the function \( \mu_\alpha \) maps each element in the universal set \( X \) to the set \([0,1]\), i.e.

\[
\mu_\alpha : X \to [0,1]
\]
More precisely, the membership function $\mu_A$ in crisp set maps whole members in the universal set to \{0,1\}

**Definition 2** [5] (membership function of fuzzy set) In a fuzzy sets $A$, each element is mapped to $[0,1]$ by a membership function

$$\mu_A : X \rightarrow [0,1],$$

where $[0,1]$ means the set of real numbers between 0 and 1 (including 0 and 1).

**Definition 3** [5] ($\alpha$-cut set) The $\alpha$-cut set $A_\alpha$ is made up of members whose membership is not less than $\alpha$, i.e.

$$A_\alpha = \{ x \in X | \mu_A (x) \geq \alpha \} .$$

Note that $\alpha$ is arbitrary. This $\alpha$-cut set is a crisp set.

**Definition 4** [5] (Fuzzy number) If a Fuzzy set is convex and normalized, and its membership function is defined in $R$ and piecewise continuous, then it is called a “Fuzzy number”. So fuzzy number (fuzzy set) represents a real number interval whose boundary is fuzzy.

**Definition 5** [5] (Triangular Fuzzy number) It is a fuzzy number represented with three points as follows: $\tilde{A} = (a_1, a_2, a_3)$ This representation is interpreted as membership functions and holds the following conditions (see Figure 1).

(i) it is an increasing function from $a_1$ to $a_2$
(ii) it is a decreasing function from $a_2$ to $a_3$
(iii) $a_1 \leq a_2 \leq a_3$

$$\mu_A (x) = \begin{cases} 
0 & \text{for } x < a_1 \\
\frac{x - a_1}{a_2 - a_1} & \text{for } a_1 \leq x \leq a_2 \\
1 & \text{for } a_2 \leq x \leq a_3 \\
\frac{a_3 - x}{a_3 - a_2} & \text{for } a_3 \leq x \leq a_3 \\
0 & \text{for } x > a_3 
\end{cases}$$

**Definition 6** [5] (Trapezoidal Fuzzy number) The trapezoidal fuzzy number $\tilde{A} = (a_1, a_2, a_3, a_4)$ is defined by

The membership function of this fuzzy number will be interpreted as follows (Figure 2).

**Definition 7** [9] (Centroid Method) This procedure (also called center of area or center of gravity) is the most prevalent and physically appealing of all the defuzzification methods. It is given by the algebraic expression

$$x^* = \frac{\int \mu_A (x) \cdot x dx}{\int \mu_A (x) dx},$$

where $\int$ denotes an algebraically integration.

![Figure 1 Triangular Fuzzy number](image1.png)

![Figure 2 Trapezoidal Fuzzy number](image2.png)
The Main Results

We will compare the result of 2 “traditional” grading systems. Considering from Table 1 and Table 2, we have seen the differences between the numbers of each grade which are given by using those 2 methods. Sometimes, evaluation using the group referenced system seems to work but you might come across with the problems such as “too high” quality for getting an A or “too generous” to give a D to a student (i.e. too low criteria to get an F). Moreover, if we use the criterion referenced system we might be struggle with how to set the criteria and for hardworking student who can just nearly get an A but they cannot since, sometimes, they missed only 0.05 points to achieve our criteria, we might feel so sorry because it looks a bit unfair to those kind of students.

Table 3 The grading using criterian reference system

<table>
<thead>
<tr>
<th>Interval</th>
<th>Group</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-100</td>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>75-79.99</td>
<td>B+</td>
<td>2</td>
</tr>
<tr>
<td>70-74.99</td>
<td>B</td>
<td>5</td>
</tr>
<tr>
<td>65-69.99</td>
<td>C+</td>
<td>5</td>
</tr>
<tr>
<td>60-64.99</td>
<td>C</td>
<td>9</td>
</tr>
<tr>
<td>45-59.99</td>
<td>D+</td>
<td>12</td>
</tr>
<tr>
<td>35-44.99</td>
<td>D</td>
<td>21</td>
</tr>
<tr>
<td>0 - 35</td>
<td>F</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 4 The grading using T-Score (group reference system)

<table>
<thead>
<tr>
<th>Interval</th>
<th>Group</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>89.5-100</td>
<td>A</td>
<td>5</td>
</tr>
<tr>
<td>75.50-89</td>
<td>B+</td>
<td>7</td>
</tr>
<tr>
<td>63.75-73</td>
<td>B</td>
<td>12</td>
</tr>
<tr>
<td>55-63</td>
<td>C+</td>
<td>14</td>
</tr>
<tr>
<td>43.5-52.5</td>
<td>C</td>
<td>14</td>
</tr>
<tr>
<td>37-43</td>
<td>D+</td>
<td>12</td>
</tr>
<tr>
<td>28-31.5</td>
<td>D</td>
<td>7</td>
</tr>
<tr>
<td>17-27.5</td>
<td>F</td>
<td>5</td>
</tr>
</tbody>
</table>

In our next step, we are developing a new grading concept using fuzzy concept to classify the group students’ performance. We define the membership function of the input and output as shown in Figure 3. We are considering the aggregate score as input, and see whether the grading result is reasonable for the students.
Table 6 The Grading using Fuzzy Method with the new membership function

<table>
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<th>Interval</th>
<th>Group</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>77-100</td>
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<td>11</td>
</tr>
<tr>
<td>72.5-76.5</td>
<td>B+</td>
<td>1</td>
</tr>
<tr>
<td>67.5-72</td>
<td>B</td>
<td>5</td>
</tr>
<tr>
<td>62.5-67</td>
<td>C+</td>
<td>5</td>
</tr>
<tr>
<td>57.5-62</td>
<td>C</td>
<td>9</td>
</tr>
<tr>
<td>52-57</td>
<td>D+</td>
<td>7</td>
</tr>
<tr>
<td>35-51.5</td>
<td>D</td>
<td>26</td>
</tr>
<tr>
<td>0-34.99</td>
<td>F</td>
<td>12</td>
</tr>
</tbody>
</table>

Our first experiment is not quite suitable if we want to use it in the real situation because there is "too high expectation" from the students to let them pass the exams. The reason why this thing happened is the centroid of the membership function of the output was changed to be a bit more, so the number of students who reserve the grade D will be less than it should be. As a result, we have tried the second attempt to improve the result to be more applicable and more reasonable for both sides, i.e. students and teachers. Instead of writing the membership function in terms of the score criteria, we set the condition by using the number from 1, 2, 3 to 9 to representing the different grades and defining the triangular membership functions without overlapping.

Conclusion

From the Table 5, we used the Fuzzy Method with the membership function in Figure 3 for the grade evaluation but it is not satisfactory since there are too many students who got an F. Thus we tried to improve the method using a new membership function as in Figure 4 and, finally, we got the very reasonable grade evaluation model for the only one input i.e. aggregate scores.

This new grading system can be useful for the teachers who have to mark students’ essays because sometimes the students’ marks do not only depend on their writing abilities but also the emotion of the marker as well. That means there is some fuzziness on marking because of the marker which is unfair to evaluate the students who have the same level of ability with a different grade.

We do not expect that this paper alone will change the negative attitudes toward fuzzy set theory and fuzzy logic by most researchers in the grading system. However, we consider it a necessary first step. To change the attitudes will require that the utility of fuzzy set theory and fuzzy logic for representing and dealing with concepts be properly demonstrated. This will not be possible without extensive research involving experts from both areas. We intend to make efforts to facilitate such cooperation in the future.

Future Work

To get a “more reasonable” Fuzzy grading system, we need to be fair with the students who have tried more attempts for their achievements or what we call development. Therefore, we will consider Midterm Exams and Final Exams and see whether there is any student who get a good progress. If the Final result is getting improved, we should reward them somehow. For example, If the Midterm and the Final scores of two students, says, Alice and Bob are 30, 20 and 20, 30 respectively, we should reward Bob a better grade since there is some development. Thus, our future work is finding an improved version of this fuzzy method and also explain the model understandably.

Suggestions

This method has been developed to solve some problem on evaluating students using vague questions. We might have seen some of the fuzzy questions in the Ordinary National Educational Test (O-NET), for example,

1. If you get sexually aroused, what should you do?

   (O-NET 54)

   a) Go play football.
   b) Ask parents for some advice.
   c) Try to sleep.
   d) Go out with the opposite gender.
   e) Go to the cinema with close friends.

   There are some unclear thought about how to answer this question. It depends on students’ experiences
and gender, i.e. boy students might choose the item a. as the correct answer but most of the girl students will not choose that choice because it is not girl preference. So the best answer of each student are different from the other but, in fact, every question has to have just only one correct answer.

2. Which item is the best leisure activities for family members’ happiness and health? (O-NET 53)
   a) Parents play golf and the children play games at home.
   b) Parents send their children to stay with grandparents then go for working.
   c) Parents send their children to the tutorial school and then go for shopping.
   d) Everyone goes for doing some exercise at a park and come back together to cook some meal for dinner.

The best answer of each student may vary because of their personal experience. Therefore, it is difficult to tell whether the item d. is the really best answer for this question.

It would be a better way to evaluate the students using fuzzy set method, since the Entrance examination questions are sometimes unclear. Although the newly developing grading system is difficult to understand for most of all school teachers since it needs a lot of understanding on Statistics and Fuzzy set concepts, it is still possible to use if they are trained to use it.

Actually, it is really difficult to find a good grade evaluation method which is reliable, mathematical formulated and fair, but the more difficult thing is how to train the teacher or instructor to teach well and also be a good evaluator at the same time.

References
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10. The Math Works™, MATLAB, 7.6.0 (R2009a), License Number 350306, February 12, 2009.
Improving of Test Statistic for the Risk Ratio in a Correlated 2 x 2 Table with Structural Zero

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Abstract
The purpose of this research was to develop test statistic for the risk ratio in a correlated 2 x 2 table with structural zero when sample size is small. We studied Wald test statistic, Logarithmic transformation test statistic, Fieller’s test statistic, Rao’s score test statistic and improving Wald test statistic. Also, we consider the performance of hypothesis testing for the risk ratio by power of the test and type I error rate close to the significant level. Simulation studies suggest improving Wald test statistic has type I error rate closest to significant level and powerful test when risk ratio value in alternative hypotheses are less.

Keywords: Power of tests, Test of hypothesis, Wald test

Introduction
The problem of correlated 2 x 2 table with a structural zero in one of the off diagonal cells, the structural zero means that it is theoretically impossible to observe for a particular cell sometimes appear in infection disease studies and two-step procedure studies. A typical example of calves; calves were first classified according to whether they got a primary pneumonia infection and then reclassified according to whether they developed a secondary infection within a certain time period after the first infection cleared up. In this case, the interest in evaluating the risk ratio between a secondary infection \((p_{11})\), given a primary infection and the primary infection \((p_{12})\), the responses taken from the same group of calves are not independent in Table 1.

Table 1  Example and probability of Agresti

<table>
<thead>
<tr>
<th>Primary infection</th>
<th>Secondary infection</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>n11 = 30 (p11)</td>
<td>n12 = 63 (p12)</td>
</tr>
<tr>
<td>No</td>
<td>n21 = 0</td>
<td>n22 = 63 (p22)</td>
</tr>
<tr>
<td>Total</td>
<td>n11 = 30 (p11)</td>
<td>n2. = 126 (p2.2)</td>
</tr>
</tbody>
</table>

Lui discussed the estimation of the risk ratio; he developed three asymptotic interval estimators using Wald test statistic, the logarithmic transformation and Fieller’s theorem. He concluded that when the probability of primary infection is small or moderate, the interval estimator using the logarithmic transformation outperform the two estimators when the sample size does not exceed 100\textsuperscript{2}. Gupta and Tian further studied confidence intervals for the risk ratio from Lui and derived a fourth confidence interval base on Rao’s score test. In addition, they compared performance of four test statistics and concluded that the confidence interval estimator using the Rao’s score test and the logarithmic transformation outperforming the other two estimators. In addition, the Rao’s score test statistic is more consistent than the other test statistics\textsuperscript{3}.

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\textsuperscript{*}  Corresponding author: E-mail: mangpor25@hotmail.com
This research is interested in study performance of test statistic for the risk ratio in a correlated 2 x 2 table with structural zero. We propose an improving Wald test statistic additional to Gupta and Tian when sample size is small.

**Test statistic for the risk ratio**

Consider a random sample of n subjects in table 1 is assumed to be trinomial distribution.

\[
f(n_1, n_2, n_{22}) = \frac{n!}{n_1! n_2! n_{22}!} p_1^{n_1} p_2^{n_2} p_{22}^{n_{22}}
\]

Then, the estimators of the probabilities are \( \hat{p}_1 = n_1/n, \hat{p}_2 = n_2/n \) and \( \hat{p}_{22} = n_{22}/n \)

Also \( p_1 = p_1 + p_{12}, p_{11} + p_{12}, p_{21} + p_{22} \) The risk ratio between a secondary infection, given a primary infection and the primary infection is defined as \( RR = (p_{11} / p_1) \)

And hypothesis testing for the risk ratio is \( H_0 : \varphi = 1 \) versus \( H_1 : \varphi \neq 1 \).

**Wald test statistic:**

\[
T_w = \frac{\sqrt{n} (\hat{\varphi} - \varphi)}{\sqrt{\text{Var}(\hat{\varphi})}}
\]

We will reject null hypothesis when \( |T_w| \geq Z_{1-\alpha/2} \) where \( Z_{1-\alpha/2} \) is the 100 \( 1-\alpha/2 \) percentile point of the standard normal distribution. Logarithmic transformation test statistic:

\[
T_l = \frac{\sqrt{n} (\ln(\hat{\varphi}) - \ln(\varphi))}{\sqrt{\text{Var}(\ln(\varphi))}} = \frac{\sqrt{n} (\ln(p_{11} / p_1) - \ln(p_{11} / p_1))}{1 - \hat{p}_{11}}
\]

We will reject null hypothesis when \( |T_l| \geq Z_{1-\alpha/2} \) where \( Z_{1-\alpha/2} \) is the 100 \( 1-\alpha/2 \) percentile point of the standard normal distribution.

**Fieller's test statistic:**

\[
T_f = \frac{\sqrt{n} \phi \left( \frac{n \hat{p}_{12} - \hat{p}_{21}}{n - 1} \right)}{\sqrt{\text{Var}(\hat{\phi})}}
\]

We will reject null hypothesis when \( |T_f| \geq Z_{1-\alpha/2} \) where \( Z_{1-\alpha/2} \) is the 100 \( 1-\alpha/2 \) percentile point of the standard normal distribution.

**Score test statistic:**

\[
T_s = \sqrt{n} (\ln(\hat{\varphi}) - \ln(\varphi)) = \frac{\sqrt{n} (\ln(p_{11} / p_1) - \ln(p_{11} / p_1))}{1 - \hat{p}_{11}}
\]

We will reject null hypothesis when \( |T_s| > \chi^2_{1, \alpha/2} \) where \( \chi^2_{1, \alpha/2} \) is upper \( \alpha \)-percentile of the central \( \chi^2 \)-distribution with one degree of freedom and \( p_{11}^0 \) is solution of \( U_2(\varphi, p_{11}) = 0 \).

**Improving the Wald test statistic:**

In case of small sample, we have adding constant, \( c = 0.46 \sigma^2 / n \), tail probability of normal by following Guan[4]. The properties of the mean and the variance is

\[
\text{E}(\hat{\varphi} + c) = \text{E}(\hat{\varphi}) + c \text{ and Var}(\hat{\varphi} + c) = \text{Var}(\hat{\varphi})
\]

\[
T_{W1} = \frac{\sqrt{n} (\ln(p_{11} / p_1) - \ln(\varphi) + 0.46 \sigma^2 / n)}{\sqrt{\text{Var}(\ln(\varphi))}}
\]

We will reject null hypothesis when \( |T_{W1}| \geq Z_{1-\alpha/2} \) where \( Z_{1-\alpha/2} \) is the 100 \( 1-\alpha/2 \) percentile point of the standard normal distribution.

**Methods of evaluating tests**

The worth test statistic must be control the type I error with the most power of the test.
Methods
A. Generate data set according to trinomial distribution.
B. Select two sample sizes \( n = 25 \) (small size) and 50 (moderate size) [2].
C. Select five parameters \( \varphi = 0.25, 0.75, 1.0, 1.25 \) and 1.75.
D. Select three parameters \( p_1 = 0.25, 0.5 \) and 0.75.
E. Select nominal level \( (\alpha) = 0.05 \)
F. Compare the performance of test statistic by considering the value of empirical type I error and empirical power of the test with R program. We generate 10,000 data sets for each combination of sample size and parameter.

Results of simulation
To compare the empirical type I error value of five tests about the risk ratio test, When sample size \( n = 25 \) improving Wald test has empirical type I error value closest to significant level. Also, when sample size \( n = 50 \) Rao’s score test and improving Wald test have empirical type I error value close to significant level (Table 2). In addition, when risk ratio value in alternative hypotheses are less than 1 and primary infection rate are low (0.25, 0.5), the empirical power of Wald test is the most powerful and improving Wald test is the second most powerful test. When risk ratio value great than 1 and primary infection rate are low (0.25, 0.5), Fieller’s test is the most powerful. When primary infection rate is high (0.75), all five tests almost the same power irrespective of the risk ratio and sample size (Table 3).

Conclusion and comments
This research is preliminary for adding the tail probability of normal for test statistic for the risk ratio in a correlated 2 x 2 table with structural zero when sample size is small.

Acknowledgments
Thanks to the professors at the department of statistics for the guidance of this paper. We are grateful to the Graduate School Chiang Mai University, Faculty of Science, Department of Statistics and Science Achievement Scholarship of Thailand for supporting this research.

Table 2 The empirical type I error of the tests at significant level \( (\alpha) = 0.05 \).

<table>
<thead>
<tr>
<th>( n )</th>
<th>( p_1 )</th>
<th>( T_W )</th>
<th>( T_L )</th>
<th>( T_F )</th>
<th>( T_S )</th>
<th>( T_RW )</th>
</tr>
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<tbody>
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<td>0.25</td>
<td>0.1179</td>
<td>0.0287</td>
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<td>0.0399</td>
</tr>
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<td>------</td>
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<td>( \phi )</td>
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<td>0.0479</td>
<td>0.2555</td>
<td>0.2838</td>
<td>0.1667</td>
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<td></td>
<td>0.50</td>
<td>0.8012</td>
<td>0.8749</td>
<td>0.9287</td>
<td>0.8273</td>
<td>0.8471</td>
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<tr>
<td></td>
<td>0.75</td>
<td>0.1147</td>
<td>0.0823</td>
<td>0.1673</td>
<td>0.1149</td>
<td>0.0623</td>
</tr>
</tbody>
</table>

References
Optimization of Climate Dowscaling Using Gradient Descent with Momentum and Quasi-Newton Methods

Wachiraporn Permpoonsinsup¹, Dusadee Sukawat²

Received: 15 March 2013  Accepted: 15 June 2013

Abstract
This paper presents two optimization methods in training algorithm to minimize error of the feed forward neural network. Gradient descent with momentum and Quasi-Newton methods are applied to optimize weights in iteration of a training network model. Data from a global model are downscaled to four provinces in Thailand namely: Chaingmai, Bangkok, Ubonratchathani and Phuket. The results of experiments show that the Quasi-Newton method can minimize the error better than Gradient descent with the momentum method. Moreover, the number of hidden nodes of the network structure also affected the regression between the output and observed data.

Keywords: component, Downscaling, Artificial Neural Network, Gradient Descent, Quasi-Newton

Introduction
Artificial neural networks (ANNs) are mathematical models which can identify and represent nonlinear relationship between input and output data¹. ANNs are trained by supervised learning. There are many optimization methods available for minimizing the error of objective function in ANN models. In this study, the gradient descent with momentum and the quasi-Newton back propagation method are presented. They are applied to optimize the weight between the input and hidden layers, and between the hidden and output layers. The data used in training are obtained from the 20th Century Reanalysis V2 reanalysis data of National Oceanic and Atmospheric Administration (NOAA)². Although, the global climate models (GCM) can simulate temperature changes, the models are mainly project at coarse resolutions. Because data from the global model has coarse resolution, the data are interpolated before feeding to ANN model. Furthermore, interpolation is used to downscale the air temperature from a global model at 850 hPa (about 1.5 km above the ground) to Chaingmai, Bangkok, Ubonratchatani and Phuket of Thailand. Performance of the network is measured by mean square error. To minimize the error, ANNs are adjusted for the connection weights. Output data from the model are compared with observation data of the Thai Meteorological Department and then retraining the network to optimize the weight and reduce the error of the network.³ has proposed the model that applied a neural network with a backpropagation algorithm for forecasting hourly water levels in the Chao Phraya River at Bangkok. Furthermore,⁴ presented a new approach using an artificial neural network technique to improve rainfall forecast performance and ANN model were used for real time rainfall forecasting and flood management in Bangkok, Thailand.⁵ has utilized a neural network model for monthly rainfall prediction for Chao Phraya River. In addition,⁶ developed a time series forecasting model for a case study. The type of ANN implemented was multilayer perceptron with the quick-propagation training algorithm using time series factors.

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* Corresponding author: E-mail: wachirapond@gmail.com
This paper is organized as follows. Section II shows structure of the neural network model. Section III defines optimization methods. Next, Section IV designs methodology and data. Section V discusses the results. Finally, Section VI concludes the results of the models.

**Artificial Neural Network**

**Neural Network Model Structure**

The feedforward neural networks are the most widely used form of neural network in many practical applications. In this paper, a multilayer feedforward neural network is proposed in three layers; input, hidden and output layers. Mathematically, the output network of the structure can be written as

\[ y = f_1 \left[ \sum_{j=0}^{n} w_{1j} f_2 \left( \sum_{i=0}^{m} w_{ij} x_i + b_j \right) + b_1 \right] \]  

(1)

where \( x_i \) is the \( i \)-th net input, \( y \) is output, \( w_{ij} \) is weight connection between input \( i \) and hidden neuron \( j \), \( w_{jk} \) is weight connection between hidden \( j \) and output neuron \( k \), \( n \) is the number of neuron in the input layer, \( m \) is the number of neurons in the hidden layer, \( f_1 \) and \( f_2 \) are the transfer functions, \( b_1 \) and \( b_2 \) are bias.

The activation function of neural network which is most used is the sigmoid function. It is very useful in neural networks trained by backpropogation and is defined as

\[ f(x) = \frac{1}{1 + e^{-x}} \]  

(2)

\[ f'(x) = f(x) \left[ 1 - f(x) \right] \]  

(3)

where \( x \) is the net input, \( f \) is the sigmoid function.

**Performance of the Network**

The training of a neural network produces a small error on the training data set. A backpropagation algorithm is used for the training of the neural networks. The objective of training is to reduce the error between the desired output and the neural network output. The performance of the network is defined as

\[ E = \text{MSE} = \frac{1}{N} \sum_{i=1}^{N} (y_i - t_i)^2 \]  

(4)

where \( E \) is mean square error, \( y_i \) is network output data, \( t_i \) is observed data, \( n \) is the number of output data.

**Optimization Learning**

**Gradient Descent with Momentum Algorithm (GDMA)**

Gradient descent with momentum algorithm is a network training function that updates weight and bias values according to gradient descent momentum and an adaptive learning rate.

The simplest gradient descent algorithm which is known as the steepest descent modifies the weights at time step \( k \) according to

\[ w_{k+1} = w_k - \alpha g_k \]  

(5)

A momentum term is added into the neural network model in learning algorithms. The new weight vector \( w \) is adjusted as

\[ w_{k+1} = w_k - \alpha g_k + \mu w_k \]  

(6)

where \( w \) is a weight vector in the network, \( k \) is iterative number, \( \alpha \) is the learning rate which is a small positive number, \( g \) is the gradient operator with respect to the weights, \( \mu \) is the momentum parameter.

**Quasi-Newton Algorithm (QNA)**

The quasi-Newton method is based on Newton’s method and it approximates an inverse Hessian. The quasi-Newton algorithm operates in the BFGS (Broyden, Fletcher, Golub, Shanno) formula for updating the Hessian matrix. Iteratively, the update learning for this algorithm is

\[ w_{k+1} = w_k - \eta_k d_k \]  

(7)

\[ d_k = -B_k g_k \]  

(8)

Where \( B_k \) is a positive definite matrix, \( d_k \) is the directions for approximating Newton’s direction. \( \eta_k \) is the step size. \( w_k \) and \( w_{k+1} \) are iterated on the gradients \( \nabla f(w_k) \) and \( \nabla f(w_{k+1}) \) then it can be written as

\[ \nabla f(w_{k+1}) - \nabla f(w_k) = H(w_k)(w_{k+1} - w_k) \]  

(9)

In iteration, \( B_{k+1} \) is defined as
\[ B_{k+1} q_k = z_k \]  
(10)

where

\[ z = w_{k+1} - w_k \]  
(11)

\[ q = \Delta f(w_{k+1}) - \Delta f(w_k) \]  
(12)

To calculate the matrix \( B_{k+1} \) from previous \( B_k \) by vector \( q \) and \( z \), it can be written as

\[
B_{k+1} = B_k + z^T \left( q^T B_k q - B_k q^T B_k q \right) + q B_k q^T + z^T \left( z^T z \right) - \left( B_k q^T B_k q \right)
\]
(13)

**Methodology and data**

**Interpolation Method**

The method to downscale the large-scale to small-scale data in this paper is linear interpolation. Linear interpolation can calculate the value at an unknown data point between each pair of data points on a straight line. If a pair of data points is given by the coordinates \((x_0, y_0)\) and \((x_1, y_1)\), linear interpolation is

\[ y = y_0 + \frac{x - x_0}{x_1 - x_0} (y_1 - y_0) \]  
(14)

**The Steps of Approach by Backpropagation Method**

Phase 1. The air temperature data are downscaled by linear interpolation method. Then the data are passed to the neural network model.

Phase 2. Forward processes, the input data are fed into feedforward neural network and compute the network output. Then the network output are compared with the observed data by Eq. (4) to calculate the error performance.

Phase 3. Backward processes, if error of the network does not satisfy the predefined value (Epoch=1000), then optimize the weights by Eq. (6) or Eq. (7) and go to Phase 2. Otherwise stop iteration.

**Experiment Design**

In this paper, the parameter is monthly air temperature data from the 20th Century Reanalysis V2 reanalysis data of National Oceanic and Atmospheric Administration (NOAA), Department of Commerce, USA at 850 hPa from summer (March to June) and winter (November to February) from 2001 to 2010 are processed. The domain in this study is between latitude 0°N to 20°N and longitude 90°E to 105°E. By linear interpolation, data are downscaled from 2° lat × 2° long grid to 0.1° lat × 0.1° long grid. The data from 2001 to 2008 are used for training, the data of 2009 for testing and the data of 2010 for validation in the neural network model. Eventually, the results are compared with the observed data of the Thai Meteorological Department. Table 1 presents the positions of the stations for downscaling.

<table>
<thead>
<tr>
<th>Provinces</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiang Mai</td>
<td>18.4°N</td>
</tr>
<tr>
<td>Ubon Ratchathani</td>
<td>15.1°N</td>
</tr>
<tr>
<td>Bangkok</td>
<td>13.4°N</td>
</tr>
<tr>
<td>Phuket</td>
<td>8.8°N</td>
</tr>
</tbody>
</table>

Table II and Table III show the model design. The model design consists of algorithm, architecture network and season. There are two algorithms in the model that is GDMA and QNA. Furthermore, architectures of the models have the pattern as input node-hidden node-output node.

<table>
<thead>
<tr>
<th>Model</th>
<th>Model</th>
<th>Model</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
</tr>
<tr>
<td>Algorithm</td>
<td>GDMA</td>
<td>QNA</td>
<td>GDMA</td>
</tr>
<tr>
<td>Architecture</td>
<td>1-2-1</td>
<td>1-2-1</td>
<td>1-10-1</td>
</tr>
<tr>
<td>Season</td>
<td>Summer</td>
<td>Summer</td>
<td>Summer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Model</th>
<th>Model</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>VI</td>
<td>VII</td>
<td>VIII</td>
</tr>
<tr>
<td>Algorithm</td>
<td>GDMA</td>
<td>QNA</td>
<td>GDMA</td>
</tr>
<tr>
<td>Architecture</td>
<td>1-2-1</td>
<td>1-2-1</td>
<td>1-10-1</td>
</tr>
</tbody>
</table>
Results and Discussion

Gradient descent with momentum and quasi Newton methods are optimization methods which are applied in the training phase to optimize the weight in the neural network. To implement the algorithms, Encog Machine Learning Framework is used. Moreover, the goal of training algorithms is to minimize the error between network output and the desired output. In this section, the error is calculated for a supervised neural network. Mean square error (MSE) is the goal to minimize. The fitting between network output and the desired output is determined by considering the regression R values which measure the correlation between output data and observed data. If R is closed to 1 it means that the model can generalize network output well. Table 4 shows the results of the experiments.

Table 4 Regression of model

<table>
<thead>
<tr>
<th>Model</th>
<th>CHIANG MAI</th>
<th>UBON RATCHATHANI</th>
<th>BANGKOK</th>
<th>PHUKET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>summer</td>
<td>winter</td>
<td>summer</td>
<td>winter</td>
</tr>
<tr>
<td>I</td>
<td>0.38727</td>
<td>0.35406</td>
<td>0.27434</td>
<td>0.49786</td>
</tr>
<tr>
<td>II</td>
<td>0.45573</td>
<td>0.45332</td>
<td>0.30519</td>
<td>0.56679</td>
</tr>
<tr>
<td>III</td>
<td>0.40971</td>
<td>0.31151</td>
<td>0.38005</td>
<td>0.51820</td>
</tr>
<tr>
<td>IV</td>
<td>0.60937</td>
<td>0.66156</td>
<td>0.54078</td>
<td>0.57053</td>
</tr>
</tbody>
</table>

Conclusions and recommendation

In this paper, the 850 hPa grid-point temperature data from NOAA global model are downscaled to Chiang Mai, Ubon Ratchathani, Bangkok and Phuket of Thailand by linear interpolation. The data between 2001-2010 are divided into summer and winter. After downscaling by linear interpolation, the data are fed into the feedforward neural network. In network learning, weights are adjusted by GDMA and QNA.

In the experiments, the model with the 1-10-1 structure and trained by QNA has the highest regression. So it can conclude that QNA is better than GDMA and the number of node in hidden layer affected the regression between output and observed data.

For recommendation, the results show that most regressions of GDMA and QNA are less than 60%. In future work, QNA should be used to improve the process for minimizing the error and increasing the regression. Furthermore, as the number of node in the hidden layer is also significantly affect the performance from Table IV, the network should be designed to appropriately cover all nodes in the hidden layer.

Acknowledgment

This paper has been financially supported by the Department of Mathematics, Faculty of Science, King Mongkut’s University of Technology Thonburi.

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Estimation of Tropical Cyclone Wind Using a Modified Jelesnianski’s Pressure Model

Sasiwimon Pornprapai¹, Dusadee Sukawat²*

Received: 15 March 2013 Accepted: 15 June 2013

Abstract

In this paper, a parametric wind model for estimation of the gradient wind speed of tropical cyclone is developed. The model is based on the gradient wind model and the Jesnianki’s pressure model. The model parameters are the pressure of the storm center, the pressure of environment and the radius of maximum wind speed. The case study is typhoon Vamei (2001). Results from the model show that the gradient wind speed of tropical cyclone has good accuracy.

Keywords: Wind Model, Tropical Cyclone, Jelesnianki’s Pressure Model, Typhoon Vamei

Introduction

Cyclones, typhoon and hurricane are the names given in different parts of the world to tropical storms. Each year, many areas of the world are struck by tropical cyclones. Tropical cyclones can cause immense damage loss in life and property. C.Raktham¹ studied numerical simulation of associated atmospheric dynamic processes and tracking of the tropical storm Vicente during September 14-18, 2005 by employing the Weather Research Forecasting Model (WRF). W. Wannawong² studied tropical cyclone wind wave, storm surge and current characteristics in the South Chaina Sea. The model are based on the Wave Model Cycle 4 (WAMC4) and the POM model. In Thailand there is no mathematical model for the purpose of tropical cyclone wind estimation. Thus it is necessary to develop a wind model for Thailand. In this paper, a parametric wind model of tropical cyclone is developed.

The severity of a tropical cyclone is described in terms of categories ranging from 1 (weakest) to 5 (strongest) related to the zone of maximum wind gusts as show in Table 1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Maximum wind Speed (km/h)</th>
<th>Central Pressure (hPa)</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63-88</td>
<td>&gt;985</td>
<td>Negligible house damage.</td>
</tr>
<tr>
<td>2</td>
<td>89-117</td>
<td>985-970</td>
<td>Minor house damage. Significant damage to signs, trees.</td>
</tr>
<tr>
<td>3</td>
<td>118-159</td>
<td>970-955</td>
<td>Some roof and structural damage.</td>
</tr>
<tr>
<td>4</td>
<td>160-199</td>
<td>955-930</td>
<td>Significant roofing loss structural damage.</td>
</tr>
<tr>
<td>5</td>
<td>&gt;200</td>
<td>&lt;930</td>
<td>Extremely dangerous with widespread destruction.</td>
</tr>
</tbody>
</table>

Methodology

Tropical Cyclone Wind Model

The structure of the wind field in a tropical cyclone is examined from the momentum equation expressed in terms of cylindrical coordinate system.

\[ \frac{V^2}{r} + fV - \frac{1}{\rho} \frac{\partial P}{\partial r} = 0 \]  

(1)

Equation (1) is the gradient wind equation with the centrifugal force \( \frac{V^2}{r} \), the Coriolis force \( fV \) and the pressure gradient force \( -\frac{1}{\rho} \frac{\partial P}{\partial r} \).
The gradient wind speed is obtained by solving Eq. (1) for $V$ to yield

$$V = \sqrt{\left(\frac{fr}{2}\right)^2 + \frac{r}{\rho} \frac{\partial P}{\partial r} - \frac{fr}{2}}$$

(2)

where $f$ is the Coriolis parameter, $r$ is the radial distance from the center of the storm, $P(r)$ is the pressure at the distance $r$ and $\rho$ is the air density.

The pressure is computed from Jelesnianski’s model [5]

$$P = \frac{\rho V_{max}^2}{\gamma} \left(\frac{r}{R}\right)^3 + P_e : 0 \leq r < R$$

(3)

$$P = -\rho \left(\frac{V_{max}}{\gamma}\right)^2 \left(\frac{R}{r}\right)^2 + P_e : r \geq R$$

(4)

where $\gamma = 2V_{max}\sqrt{\frac{\rho}{3}(P_e - P)}$ and $V_{max}$ is the maximum wind speed, $R$ is the radius of maximum wind, $r$ is the radial distance from the center of the storm, $\rho$ is the air density, $P_e$ is the pressure at the environment, $P_e$ is the pressure at the storm center. Equation (3) represents the pressure within the radius of maximum wind and equation (4) is for the pressure outside the radius of the maximum wind.

The pressure gradient from differentiation of Eq. (3) and Eq. (4) are

$$\frac{\partial P}{\partial r} = \rho \left(\frac{V_{max}}{\gamma}\right)^2 \left(\frac{r}{R}\right)^2 : 0 \leq r < R$$

(5)

$$\frac{\partial P}{\partial r} = \rho \left(\frac{V_{max}}{\gamma}\right)^2 \left(\frac{R}{r}\right)^2 : r \geq R$$

(6)

Substitute Eq. (5) and Eq. (6) into Eq. (2)

$$V = \sqrt{\left(\frac{fr}{2}\right)^2 + \frac{r}{\rho} \frac{\partial P}{\partial r} - \frac{fr}{2}} : 0 \leq r < R$$

(7)

$$V = \sqrt{\left(\frac{fr}{2}\right)^2 + \frac{r}{\rho} \left(\frac{V_{max}}{\gamma}\right)^2 \left(\frac{R}{r}\right)^2 - \frac{fr}{2}} : r \geq R$$

(8)

In this research Eq. (7) and Eq. (8) are used to estimate the gradient wind speed of tropical cyclone.

**Steps to Solve the Model Equations**

Step 1: Input pressure at the storm center ($P_e$), the pressure of the environment ($P$), the distance from the center of the storm ($r$), the air density and the maximum wind speed.

Step 2: Calculate the parameter $\gamma$ from

$$\gamma = 2V_{max}\sqrt{\frac{\rho}{3}(P_e - P)}$$

Step 3: Substitute the parameter $\gamma$ from Step 2 into Eq. (5) and Eq. (6) to calculate the pressure gradient.

Step 4: Substitute the pressure gradient from Step 3 into Eq. (7) and Eq. (8) to calculate the gradient wind speed.

These steps are shown in Figure 1.

**Figure 1** Flow chart for calculation of the gradient wind speed.
**Experiment Case**

In this research, the study case is typhoon Vamei, because typhoon Vamei caused strong winds and heavy rainfall. Observation data of typhoon Vamei are shown in Table II and the track is shown in Figure 2.

<table>
<thead>
<tr>
<th>Name</th>
<th>Case</th>
<th>Date/Time</th>
<th>Position</th>
<th>Maximum Wind Speed (m/s)</th>
<th>Minimum Pressure (hPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAMEI</td>
<td>1</td>
<td>27/12/2001/00</td>
<td>1.5 105.1</td>
<td>33.44</td>
<td>976</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>27/12/2001/06</td>
<td>1.5 104.4</td>
<td>33.44</td>
<td>976</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>27/12/2001/12</td>
<td>1.6 103.7</td>
<td>23.15</td>
<td>991</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>27/12/2001/18</td>
<td>1.6 102.9</td>
<td>20.58</td>
<td>994</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>28/12/2001/00</td>
<td>1.7 102.2</td>
<td>15.43</td>
<td>1000</td>
</tr>
</tbody>
</table>

![Figure 2 Typhoon Vamei tracks](image2.png)

**Results and Discussion**

The gradient wind speeds from this model are shown in Figure 3.

![Figure 3 The gradient wind speed with the radial distribution](image3.png)
The maximum wind speeds from the model are shown in Table 3. The mean absolute error between observed maximum wind speed and the maximum wind speed from the model is 1.94. Results from the model show that the gradient wind speed of tropical cyclone has good accuracy (error < 20%)\(^8\).

### Table 3

The maximum wind speed from the model compared with the maximum wind speed from observed data.

<table>
<thead>
<tr>
<th>Name</th>
<th>Case</th>
<th>Observed Maximum Wind Speed (m/s)</th>
<th>Maximum Wind Speed from Model (m/s)</th>
<th>Absolute Error (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAMEI</td>
<td>1</td>
<td>33.44</td>
<td>33.31</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>33.44</td>
<td>33.31</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>23.15</td>
<td>26.96</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>20.58</td>
<td>24.34</td>
<td>3.76</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>15.43</td>
<td>17.29</td>
<td>1.86</td>
</tr>
<tr>
<td>Mean Absolute Error</td>
<td></td>
<td></td>
<td></td>
<td>1.94</td>
</tr>
</tbody>
</table>

### Conclusion

A tropical cyclone wind model is developed based on the gradient and Jesnianki’s pressure models. The parameters in this model are the pressure of storm center, the pressure of the environment and the radius of maximum wind. Typhoon Vamei (2001) is used as the study case. Results from the application of the model show that the wind speeds from the model are good enough for practical use.

For recommendation, estimated wind fields in tropical cyclones from various models should be compared.

### Acknowledgment

The first author would like to thank the Department of Mathematics, King Mongkut’s University of Technology Thonburi and Office of the Higher Education Commission for financial support.

### References

A Numerical Study of Typhoon Xangsane (0615) Development by Weather Research and Forecasting Model

Wikanda Supasanun\textsuperscript{1}, Dusadee Sukawat\textsuperscript{2}

Received: 15 March 2013 Accepted: 15 June 2013

Abstract

This research simulates the development of typhoon Xangsane (0615) in terms of vertical vorticity of the storm. The Weather Research and Forecasting (WRF) model is used in the simulations. The Rankine vortex wind bogussing is used to enhance the weak observed wind speed before input into WRF model. Results show that with bogus wind, the simulation provides accurate timing of the intensification of Xangsane from tropical to typhoon.

Keywords: component, Wind bogussing, WRF model, Typhoon Xangsane

Introduction

Tropical cyclones have great effects on long shore or offshore structures and frequently cause losses of lives and properties. Thus, it is of great importance to simulate tropical cyclone development. In this research, the development of typhoons Xangsane (0615) is used in a model simulation. The vortex bogussing is a method to improve the initial data by increasing weak observed wind speed of tropical storm before input into the model. The Rankine vortex is used in\textsuperscript{1} to bogus tropical cyclone wind in a single level primitive equation (SILEPE) model. A rankine vortex is applied in bogussing tropical cyclone forecasts by MM5 model in\textsuperscript{2} which results in better wind speed forecast.

Methodology and data

\textbf{A. Rankine Vortex Equations}

Assuming the initial position, the central sea level pressure, the maximum tangential wind speed $c_\text{m}$, and the radius at which the maximum tangential wind speed occur $R_\text{m}$, the tangential wind of a typhoon can be calculated according to\textsuperscript{1} and\textsuperscript{4}. This wind can be described as a function of the radial distance of the storm $r$ as

\begin{align}
    c &= c_\text{m} \frac{r}{R_\text{m}} \quad \text{for } r \leq R_\text{m} \quad (1) \\
    c &= c_\text{m} \left( \frac{r}{R_\text{m}} \right)^{-\alpha} \quad \text{for } r > R_\text{m} \quad (2)
\end{align}

where $c$ is the tangential wind speed and the value of $\alpha$ has been determined empirically from observed tropical cyclones. In this paper $\alpha$ is 0.6.

The tangential wind speed of a typhoon can be calculated in the west–east direction or zonal wind ($u$) and the north–south direction or meridional wind ($v$) as

\begin{align}
    u &= c \cos \theta \quad (3) \\
    v &= c \sin \theta \quad (4)
\end{align}

where $\theta$ is the angle between the wind speed and the north direction.

The geopotential height is defined as $z=gh$, and assumed to be related to the wind field by the gradient wind relationship\textsuperscript{5}

\begin{equation}
    \frac{\partial z}{\partial r} = f + c^2 \frac{1}{r} \quad (5)
\end{equation}

\begin{flushright}
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\textsuperscript{*} Corresponding author: E-mail: wikanda.s@rmutk.ac.th
\end{flushright}
After replacing $c$ from Eq. (1) and Eq. (2) into Eq. (5) and integrating,

$$
\int dz = \left( f c_m + \frac{c_m^2}{R_m} \right) \frac{r}{R_m} dr, \quad r \leq R_m
$$

$$
\int dz = \frac{f c_m}{c_1} \left( \frac{r}{R_m} \right)^{1-\alpha} dr + \frac{c_m^2}{c_2} \left( \frac{r}{R_m} \right)^{2-2\alpha} dr, \quad r > R_m
$$

We have

$$
z(r) = \frac{f c_m}{c_1} \left( \frac{r}{R_m} \right)^{1-\alpha} + c_1, \quad r \leq R_m
$$

$$
z(r) = \frac{f c_m}{c_1} \left( \frac{r}{R_m} \right)^{1-\alpha} - \frac{c_m^2}{c_2} \left( \frac{r}{R_m} \right)^{2-2\alpha} + c_2, \quad r > R_m
$$

Assuming continuity of geopotential height at the radius of maximum of wind, $c_1$ and $c_2$ can be eliminated from both of the equations. This will lead to the geopotential height at the distance $r$ from the storm center, $z(r)$, which is calculated from the following equations

$$
z(r) = z(R) - \left\{ \frac{f c_m}{2(1-\alpha)} \left( \frac{R}{R_m} \right)^{1-\alpha} \left[ (1+\alpha) - (1-\alpha) \left( \frac{r}{R_m} \right)^2 \right] \right\}, \quad r \leq R_m
$$

$$
z(r) = z(R) - \left\{ \frac{f c_m}{(1-\alpha)} \left( \frac{R}{R_m} \right)^{1-\alpha} - \left( \frac{r}{R_m} \right)^{1-\alpha} \right\}, \quad r > R_m
$$

### B. Weather Research and Forecasting (WRF) Model

The WRF model is used to simulate vertical vorticity at the 850 hPa. The WRF model is developed primarily by the National Center for Atmospheric Research (NCAR) and the National Centers for Environmental Prediction (NCEP). Other contributors include the Forecast Systems Laboratory (FSL), Center for Analysis and Prediction of Storms (CAPS), the Air Force Weather Agency (AFWA), the Federal Aviation Administration (FAA) and the Naval Research Laboratory (NRL). This is a fully-compressible, nonhydrostatic model, and is conservative for scalar variables.

### C. Vorticity

The vertical component of vorticity is defined as the circulation about a closed contour in the horizontal wind components $u$ and $v$.

The expressions for the vertical component of vorticity is

$$
\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}
$$

(10)

The central-difference approximation for computation of vorticity at grid point $(i, j)$ transforms Eq. (10) into

$$
\zeta_{i,j} = \frac{v_{i+1,j} - v_{i-1,j}}{2dx} \left[ \frac{u_{i+1,j} - u_{i,j-1}}{2dy} \right]
$$

(11)

### D. Experiment Case

The experiment case (Table 1) in this paper is tropical cyclone Xangsane (0615). Data for this storm are obtained from the Joint Typhoon Warning Center (JTWC) and the initial condition from the Joint Typhoon Warning Center (JTWC) at 850 hPa. The initial time of simulation is 26/09/2006 00UTC and the ending time of simulate is 27/09/2006 06UTC. The domain in this study between latitude $0^\circ$ to $23^\circ$N and longitude $95^\circ$E to $125^\circ$E.

<table>
<thead>
<tr>
<th>Date and Time</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Maximum Wind Speed (m/s)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 09 26 00UTC</td>
<td>15.3 N</td>
<td>112.5 E</td>
<td>18.01</td>
<td>Tropical Storm</td>
</tr>
<tr>
<td>2006 09 26 06UTC</td>
<td>15.6 N</td>
<td>111.6 E</td>
<td>25.72</td>
<td>Tropical Storm</td>
</tr>
<tr>
<td>2006 09 26 12UTC</td>
<td>15.7 N</td>
<td>110.7 E</td>
<td>30.86</td>
<td>Tropical Storm</td>
</tr>
<tr>
<td>2006 09 26 18UTC</td>
<td>15.6 N</td>
<td>109.7 E</td>
<td>33.44</td>
<td>Typhoon</td>
</tr>
<tr>
<td>2006 09 27 00UTC</td>
<td>15.6 N</td>
<td>108.6 E</td>
<td>38.58</td>
<td>Typhoon</td>
</tr>
<tr>
<td>2006 09 27 06UTC</td>
<td>15.7 N</td>
<td>107.4 E</td>
<td>43.72</td>
<td>Typhoon</td>
</tr>
</tbody>
</table>

The steps for the simulation of typhoon Xangsane
development are shown in Figure 1

![Diagram of simulation process]

**Figure 1** Steps of the simulation.

**Results and discussion**

Wind speeds from the simulations of the typhoon development with and without bogus at 850 hPa on 26/09/2006 at 18UTC are shown Figures 2 and 3, respectively. Wind speed patterns in both figures are similar. However, the vorticity development in bogus case is better than that of no bogus case.

![Figure 2](image1)

**Figure 2** The simulated wind of typhoon Xangsane with no bogus wind on 26/09/2006 at 18UTC.

![Figure 3](image2)

**Figure 3** The simulated wind of typhoon Xangsane with bogus wind on 26/09/2006 at 18UTC.

The vorticity of typhoon Xangsane as simulated with no bogus, bogus wind and vorticity computed from JTWC data are shown in Table 2 and Figure 4.

**Table 2** The vorticity of the typhoon Xangsane.

<table>
<thead>
<tr>
<th>Date and Times</th>
<th>$\zeta$ (10^-5 V&quot;)</th>
<th>Type</th>
<th>$\zeta$ (10^-5 V&quot;)</th>
<th>Type</th>
<th>$\zeta$ (10^-5 V&quot;)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 09 26 00UTC</td>
<td>0.60</td>
<td>Tropical Storm</td>
<td>0.42</td>
<td>Tropical Storm</td>
<td>1.29</td>
<td>Tropical Storm</td>
</tr>
<tr>
<td>2006 09 26 06UTC</td>
<td>0.68</td>
<td>Tropical Storm</td>
<td>0.56</td>
<td>Tropical Storm</td>
<td>1.81</td>
<td>Tropical Storm</td>
</tr>
<tr>
<td>2006 09 26 12UTC</td>
<td>1.67</td>
<td>Tropical Storm</td>
<td>1.31</td>
<td>Tropical Storm</td>
<td>2.71</td>
<td>Tropical Storm</td>
</tr>
<tr>
<td>2006 09 26 18UTC</td>
<td>3.21</td>
<td>Typhoon</td>
<td>2.03</td>
<td>Tropical Storm</td>
<td>3.45</td>
<td>Typhoon</td>
</tr>
<tr>
<td>2006 09 27 00UTC</td>
<td>3.77</td>
<td>Typhoon</td>
<td>2.47</td>
<td>Typhoon</td>
<td>3.98</td>
<td>Typhoon</td>
</tr>
<tr>
<td>2006 09 27 06UTC</td>
<td>4.05</td>
<td>Typhoon</td>
<td>2.92</td>
<td>Typhoon</td>
<td>4.34</td>
<td>Typhoon</td>
</tr>
</tbody>
</table>

Results from the simulations show that the bogus wind can provide realistic values of vorticity when compare with the JTWC data.

![Figure 4](image3)

**Figure 4** Comparison of the simulated vorticity for typhoon Xangsane.
Conclusions

Observed wind speeds from satellites are usually weaker than real wind speed around a tropical cyclone. To correct this problem, a wind bogussing method is applied to the observed wind speed before input into the WRF model. Simulation of vorticity during the development of typhoon Xangsane shows that the simulation with bogus wind provides better results than without bogus wind.

Acknowledgment

The first authors would like to thank the Rajamangala University of Technology Krungthep (RMUTK) for the scholarship and the Mathematical Department of King Mongkut’s University of Technology Thonburi (KMUTT) for computer facilities.

References

The Noise Model Prediction by Allan Variance

Taddown Nabnean

Received: 18 March 2013 Accepted: 15 June 2013

Abstract

This article deals with the ability of Allan variance to predict noise models in any frequency system. Five noise types were modeled and simulated by computer. The Allan variance is able to identify these noise models. Any type of five noises can be identified by the Allan variance via “sigma-tau” plot. In this study, RMSE was used to measure the potential of Allan Variance.

Keywords: allan variance, noise model

Introduction

The frequency oscillator plays a very important role in telecommunication, global positioning system and scientific instruments, but noise decrease the frequency stability of these systems. The Ability to predict noise models will make the system work more efficient and solve any problems from noise by getting rid of noise source.

A frequency oscillator normally generates a sine wave signal as shown in (1), which ignores amplitude fluctuation and unity amplitude.

\[ u(t) = \sin(2\pi f_0 t + \phi(t)) \]  

(1)

Where \( \phi(t) \) is the time dependent phase fluctuations and \( f_0 \) is the oscillator nominal frequency. In accuracy or stability measurements another reference frequency source with a higher order of stabilize than oscillator under test. The reference source is ideal with zero term \( \phi(t) \). The fractional frequency \( y(t) \) is yielded by the comparison of the frequency in the oscillator under test and the reference which \( y(t) \) is defined by (2)\(^2\).

\[ y(t) = \frac{f(t) - f_0}{f_0} = \frac{1}{2\pi f_0} \frac{d\phi}{dt} = \frac{dx}{dt} \]  

(2)

where \( f(t) \) is the time variant frequency of oscillator under measurement and \( x(t) \) is time fluctuation. The relation between time fluctuations and phase fluctuations is determine with \( \phi(t) = 2\pi f_0 x(t) \).

In order to measure the frequency stability, the statistical variances were used. Allan variance is normal time domain frequency stability\(^3\). The definition of Allan variance satisfies (3)\(^4\), in which \( y_i \) is order i of fractional frequency averaged over sampling or interval time, \( \tau \) and \( M \) is the number of fractional frequency averaged.

\[ \sigma^2_x(\tau) = \frac{1}{2(M - 1)} \sum_{i=1}^{M-1} [y_i - y_j]^2 \]  

(3)

The fractional frequency data average over time \( \tau \) with the nonoverlap sample were used to calculate Allan variance. With the plot of Allan variance and sampling time, sigma-tau, the noise models can be determined.

The ment Sigma-tau plot in Figure 1 shows some measure of frequency stability versus the time over which the frequency is averaged. The plot was shown in \( \log \sigma_x \) or square root of Allan variance versus log tau and slope of the plot equal \( \mu / 2 \) The \( \mu \) was used to determine the noise models, which the white and flicker phase modulation, \( \mu \) is equal -2 and white frequency modulation, flicker frequency modulation and random walk the m are -1, 0 and 1 respectively.
Methodology

We use program AlaNoise 3.0 to simulate data which have noise models white and flicker phase modulation, white frequency modulating. The size of time series 100, 200, 500 and 1,000 were selected with 100 repeat times. Each time series was used to calculate the Allan variance and the results were plotted. The slope in the sigma-tau plot shows the noise models of plotted data. The corrected predictions of noise models use statistical parameter RMSE.

Results, Discussion and Conclusion

All of m (100 values in each noise model) from the sigma-tau plot were compared with theory by the RMSE as shown in Table 1 and Figure 2. The trend of RMSE decreased slightly in the Flicker phase modulation, Random Walk frequency modulation, White phase and frequency modulation with the increasing of the time series size and the Flicker frequency modulation. The values of RMSE increase while the size of time series increases. The lowest RMSE was found in the Flicker phase modulation noise model.

The RMSE of five noise models with a time series 100, 200, 500 and 1000

<table>
<thead>
<tr>
<th>Size of time series</th>
<th>White Phase Modulation</th>
<th>Flicker Phase Modulation</th>
<th>White Frequency Modulation</th>
<th>Flicker Frequency Modulation</th>
<th>Random Walk Frequency Modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.266</td>
<td>0.170</td>
<td>0.342</td>
<td>0.459</td>
<td>0.476</td>
</tr>
<tr>
<td>200</td>
<td>0.248</td>
<td>0.161</td>
<td>0.313</td>
<td>0.472</td>
<td>0.399</td>
</tr>
<tr>
<td>500</td>
<td>0.219</td>
<td>0.156</td>
<td>0.321</td>
<td>0.476</td>
<td>0.408</td>
</tr>
<tr>
<td>1000</td>
<td>0.212</td>
<td>0.149</td>
<td>0.258</td>
<td>0.499</td>
<td>0.407</td>
</tr>
</tbody>
</table>

Table 1 shows the reasonableness in order to use the Allan variance in prediction because the minimum RMSE is 0.149 in the Flicker Phase Modulation and the other not access 0.5 and with the reasons before, the Allan variance suitable for predict the noise model efficiency.

References

Monitoring Air Quality by Statistical Control Charts

Ahmad, M. I.; AL-Toubi, A. I. and Al-Saadi, M. S.
Received: 21 March 2013 Accepted: 15 June 2013

Abstract
The Exponentially Weighted Moving Average (EWMA) control charts are used to monitor the air quality data of urban and industrial areas of Muscat. Weekly 8-hours maximum concentrations of Carbon Monoxide (CO) over a period of one year were found to have significant first order autocorrelation. Therefore, Box-Jenkins ARIMA models were fitted and residuals were taken to apply EWMA. It was observed that the data in both areas are within the international standard limit.

Keywords: ARIMA, EWMA, Air Quality, Control Charts

Introduction
The Statistical control charts were primarily developed for quality management of manufacturing process. However, these could be used to monitor the environmental data but the methodology of the construction of such charts should be modified because the environmental data usually exhibit the property of autocorrelation while the control charts are commonly made under the assumption of independence of successive observations. In the present study we made such analysis by taking air quality data on pollutant concentration of Carbon Monoxide (CO) over a period of one year from Muscat in urban area of Rawi and in industrial area of Al-Rusail. The data was taken from the Directorate of Oman Ministry of Environment.

Data
We had concentrations of the pollutant recorded at 8 hourly intervals. The series of 8-hours maximum over a week were constructed and presented in Figure 1. For urban area, the average of weekly maximum was 1.003 ppm and standard deviation was 0.407 ppm and for the industrial area it was 1.187 ppm with a standard deviation of 0.508 ppm. For both urban area and industrial area the pollutants were within the international standard of air quality and were found non significant using t-test.

EWMA Control Charts

The Exponentially Weighted Moving Average (EWMA) is a statistic for monitoring the process that averages the data in a way that gives less and less weight to data as they are further removed in time. The statistic that is calculated is as:

\[ \text{EWMA}_t = \lambda Y_t + (1-\lambda) \text{EWMA}_{t-1} \]  

for \( t = 1, 2, ..., n \).

where:
- \( \text{EWMA}_t \) is the mean of historical data (target)
- \( Y_t \) is the observation at time \( t \)
- \( n \) is the number of observations to be monitored including \( \text{EWMA}_0 \)
- \( 0 < \lambda \leq 1 \) is a constant that determines the depth of memory of the EWMA.

Figure 1 Time Series Plot of weekly-Urban; weekly-Industrial
The control limits for EWMA are:

\[
\begin{align*}
\text{UCL} &= \mu_0 + L\sigma \sqrt{\frac{\lambda}{2-\lambda}} \left[1 - \left(1 - \lambda\right)^{2L}\right] \\
\text{CL} &= \mu_0 \\
\text{LCL} &= \mu_0 - L\sigma \sqrt{\frac{\lambda}{2-\lambda}} \left[1 - \left(1 - \lambda\right)^{2L}\right]
\end{align*}
\]  

(2)

(3)

(4)

where the factor \( L \) is either set equal 3 or chosen.

The data are assumed to be independent. The EWMA charts for CO for urban and industrial area are in Figure 2 (a) and Figure 2 (b).

Control Charts for Autocorrelated Data

If the data are not independent, then these are fitted with a suitable model such as Auto-Regressive Integrated Moving Average (ARIMA) models which have the general form as:

\[\theta_p (B) (1-B)^d Zt = \theta_q (B) \]

(5)

where \( d \) is positive integer or zero, \( B \) is the backshift operator, \( \theta_p, \theta_q, \theta_q \) are parameters and \( \text{at white noise} \) [3, 4]. Then the residuals from these models are used to construct control charts.

The ARIMA(0,2,1) models for the CO data were identified and fitted to each of the urban and industrial areas. The residuals from these models were normally distributed. The EWMA control chart is applied to these residuals and are presented in the Figures 3 (a) and Figure 3 (b) respectively.

Conclusion

We found that weekly maximum CO of both urban area and industrial area had significant first order autocorrelation.

Therefore, an appropriate modification of existing statistical quality control techniques, in particular, the EWMA chart was very necessary for environmental process management and monitoring. When we used the control chart on the assumption of no autocorrelation then we found that there are huge difference in the amount of CO between urban area and industrial area since most of the observations were seen to be out of control. However when we applied these control charts by assuming that the data of CO were autocorrelated which was done by first fitting appropriate ARIMA models and that model was ARIMA (0, 2, 1). After that we draw the EWMA chart for the residual and we found that the observations are within the control limit. This leads us to say that there is no evidence that the air quality data of industrial area is different from urban area. This means that the air quality in industrial area has not been affected by pollution alarmingly. Based on our analysis, we found that the data in both areas are within the national standard limit.
Figure 3 (a) : EWMA Chart of weekly maximum Co for Industrial area

Figure 3 (b) : EWMA Chart of weekly maximum Co for Urban area

References
Classification of Thai Independent Study in Statistics Using Data Mining Techniques

Phimphaka Taninpong\textsuperscript{1,2}, Nattira Muangmala\textsuperscript{2}

Received: 18 March 2013       Accepted: 15 May 2013

Abstract
In this paper, the empirical study of the classification of Thai independent study in statistics is discussed. Our purpose is to classify the undergraduate independent study researches into three groups: sample survey, statistical analysis, and operational research and related field. Several classification techniques, such as support vector machine, Naïve Bayesian, Decision Tree, k-Nearest Neighbor and RBF network, are used in this paper. We also employed the feature selection techniques in order to find the best subset of features that help improve the accuracy of the classification model. The experimental results show that the RBF network algorithm gives a best accuracy when the Chi-square is employed as the feature selection method.

Keywords: Document Classification, Independent Study, Data Mining, Text Mining

Introduction
Nowadays, huge volume of documents are stored in the database system and can be retrieved via the internet such as theses and dissertations, electronic books, news, emails, etc. Since the documents are continuously increasing, categorization of those documents is required in order to improve the efficiency of document retrieval. Text categorization helps to automatically assign the category to a document that its category is unknown. In the data mining perspective, text categorization is also called text classification which employs the statistical learning method, machine learning technique to build the classification model. Consequently, the model will be used to assign the category to a new document. However, text classification has several challenging problems. First, text is sparse data which has a high dimensionality feature space. As the features are words in the document, the feature space may contain several hundreds to thousands of terms. Second, the contents of the document are overlapped and it is difficult for us to determine the separation line between the categories. In our department of statistics, the independent studies in statistics of the undergraduate students were stored in the database system and can be retrieved via the web application. Since the year 2010, we categorized independent study of the undergraduate students into three groups: Sample Survey, Statistical Analysis, and Operational Research and related field. And, they are already classified into three groups using manual classification. However, the independent study researches proposed during the year 2004-2009 have not been classified into three groups. Thus, the objectives of this study are two fold: (1) build the automatic classification model for classifying the Thai independent study reports and (2) classify the Thai undergraduate independent study in statistics during the year 2004-2009 into three groups. In addition, the best classification model will be used to classify automatically the independent study in statistics in the future in order to avoid the manual classification.

The organization of this paper is as follows. The related work on the Thai document classification is given in Section 2 and our research methodology is described in Section 3. Experiments and new results are obtained in Section 4 and Conclusion and future work are discussed in Section 5.

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Related Work

A document is unstructured data in which data is the text. Thus, the text classification techniques is used to classify such text document. Text classification techniques which are widely used including Support Vector Machine\(^1\), Naïve Bayesian\(^2\), etc. However, most of them are applied to the English document classification. For Thai document classification,\(^3,4,5\) presented the comparative study of the impact of feature selection method and the data mining algorithm to an automatic classification of Thai document. Their results show that the support vector machine give the highest accuracy as reported in\(^2\). They employed the feature selection method in order to reduce the processing time while preserve the accuracy of the model. And, the results show that the information gain help improve the efficiency of the model. Our work is similar to\(^3,4,5\) in such the way that we present the empirical study of the classification of Thai independent study by using various feature selection method and data mining algorithm.

Methodology

Figure 1 shows the framework of the classification of Thai independent study which requires three processes: (1) preprocessing helps prepare the data before performing the classification, this process consists of tokenization, stop word removing, feature scoring, feature selection. (2) training process constructs the classification model using the preprocessed data, (3) testing process uses the classification model to classify the test data. The detail of each step is elaborately described in the following subsection.

A. Preprocessing

Each independent study document consists of title, abstract, contents, etc. In this work, we consider only the title of the independent study. For training data, each title is preprocessed before it is used for learning. The testing data is also preprocessed before it is classified. Since, titles are unstructured text data, the features are referred to words in the title. The preprocessing process consists of four steps: tokenization, stop word removing, feature scoring and feature selection. The detail of each step is described below.

1. Tokenization

Tokenization is the process that breaks the stream of characters into words or tokens. The token delimiters could be character spaces, tabs and newlines, which are not counted as tokens. For Thai text, we employed the SWATH program which is developed by\(^6\) in order to separate the titles into several words. Figure 2 shows an example of Thai text segmentation.
2. Stop Word Removing

Stop words removing eliminates non significant words such as “ณ” (at), “กู” (me), “ฉัน” (I), etc. In this work, we used a list of Thai stop words which is proposed by7. Figure 3 shows an example of stop words removing.

3. Feature Scoring

Statistically, titles can be represented as a vector space model which is a vector of weighted word frequencies such as term frequency, term frequency-inverse document frequency, or a binary value showing the existence of a word. Term frequency \((tf)\) is the number of each word’s occurrence in a document. Term frequency-inverse document frequency \((tf-idf)\) can be used to compute weighting of words. The \(tf-idf\) weight assigned to word \(j\) is the term frequency \((tf)\) proportioned by a scale factor according to the word \(j\)'s importance. The scale factor is called the inverse document frequency, read \(^8\) for more detail.

In this work, we use the binary value to simplify the manipulation of categorical data and eliminate the need for data normalization. However, the feature space can be represented in the form of word by document matrix and it is depicted in Figure 4.

B. Feature Selection Methods

As more number of documents, more number of words are extracted and the feature space could contain more than several hundreds to thousands words. A high dimensionality feature space has a lot impact to the processing time as well as the accuracy of the classification model. The feature selection method is required to select only the effective words for classification. The feature selection methods which are widely used including information gain (IG), chi-square (CHI), gain ratio, etc.

Information gain measures the number of bits of information obtained for category by knowing the presence or absence of word in a title. The information gain of word \(w\), \(IG(w)\), is defined in (1) below.

\[
IG(w) = \sum_{j=1}^{c} p(c_j) \log \frac{p(c_j)}{P(w)} + \sum_{j=1}^{c} p(c_j \mid w) \log p(c_j \mid w)
\]

(1)

where \(p(c_j)\) is the probability that class \(c_j\) was observed in the dataset, \(p(w)\) is the probability that word \(w\) occurs in the dataset whereas \(P(w)\) is the probability that word \(w\) does not occur in the dataset. \(p(c_j \mid w)\) is the probability that class \(c_j\) will contain word \(w\).

Gain ratio is an extension of information gain which selects words that have maximized the ratio of its gain divided by its entropy \(^9\). The gain ratio of word \(w\) is defined in (2):

\[
Gain(w) = \frac{H(class) - H(class \mid w)}{H(w)}
\]

(2)

where \(H\) is the entropy.

Chi-square statistics measures the lack of independence between word \(w\) and class \(c_j\). The detail of using chi-square statistics to compute the goodness of word for classification is described in \(^10\).

C. Classification Techniques

The classification technique is the supervised learning technique that learns from the dataset which each instance has already been classified. In this work, we employed Neural Network, Support Vector Machine, Naïve Bayesian, Decision tree, k-Nearest Neighbor algorithm. The detail of each algorithm is described as follows.
Neural network is commonly used in supervised learning. A simple neural network structure which consists of the input, hidden and output layers. The input and hidden layers can have multiple nodes, but there will be only a single output. The basic function is to sum up the values of its inputs, and transform them with a function to produce the output.

Multilayer neural nets use the output of single perceptrons as inputs to the subsequent perceptrons. In other words, the outputs of each perceptron are the inputs of the next layer, and all layers between the first layer and the last layer are called the hidden layer. This allows the system to learn more complex features. In this work, we employed the RBF network in Weka which is the neural network that uses the radial basis function as the activation function.

Support Vector Machine (SVM) is a robust machine learning methodology which shows high performance on text classification. The basic concept is to find two hyperplanes that separate two classes of data in data space while maximizing the margin between them.

The SVM can be constructed as a linear or non-linear model. Given that the training dataset $X$ contains $n$ labeled sample vectors $\{(x_1, y_1), ..., (x_n, y_n)\}$, where each $x_i$ is a feature vector of the document $i$ and each $y_i$ is the class label of the document $i$. The linear SVM uses a weight vector $w$ and a bias term $b$ to classify a new example $x$, by creating a predicted class label $f(x)$ as given in (3) below.

$$f(x) = \text{sign}(\langle w, x \rangle + b)$$

For the non-separable case, the training errors are allowed so that the linear SVM finds the vector $w$ by minimizing the objective function over all $n$ training samples as shown in (4).

$$T(w, \xi) = \frac{1}{2} ||w||^2 + C \sum_{i=1}^{n} \xi_i$$

under the constraints that

$$\forall i \in \{1, ..., n\}: y_i (\langle w, x_i \rangle + b) \geq 1 - \xi_i, \xi_i \geq 0$$

In this work, we employed the Platt’s SMO algorithm in Weka with default parameter for building the support vector machine classification model.

Naïve Bayesian employed in this work is the Naïve Bayesian with nominal attributes and we used NaiveBayes in Weka with default parameter. Equation (5) shows how to predict the class of a testing document and (6) shows how to calculate the probability to indicate whether a document is in class $c$.

$$c(x) = \arg \max_{c \in C} P(C = c) \prod_{i=1}^{n} P(X_i = x_i | C = c)$$

where $n$ is the number of words in the dataset, $N$ is the number of documents in a class $c$, and $N$ is the total number of documents in the training data.

The probability of the word $w_i$ would be in the class $c$ can be defined as:

$$P(X_i = x_i | C = c) = \frac{N_{ic}}{N_c}$$

where $C$ is the class, $N_{ic}$ is the number of documents in class $c$ that word $x_i$ occurs, $N_c$ is the total number of documents in class $c$.

Decision Tree techniques find the classification rules based on the tree structure. The decision tree consists of internal node, or so-called non-leaf node, and terminal node, or so-called leaf node. Each internal node denotes a test on a word, each branch represents an outcome of the test. The root node is an internal node which is the best splitting word. And, each leaf node has a class label. The algorithm is repeated to find the best splitting word until a given subset contains documents of only one class. Finally, the classification rules are induced from the final decision tree. In this work, we used J48 in Weka as it implements C4.5 which is the well known decision tree algorithm.

The $k$-Nearest Neighbor technique finds the $k$ closest documents to the testing document by measuring the distance between documents. There are many ways to measure the distance for determining the similarity between documents. In this work, the Euclidean distance is used and $k$ is set to 3 since it gave the best accuracy in
our experiments. If the voting scheme is used, the testing document will be assigned the class label which is the majority class of $k$-Nearest Neighbor.

**Experimental Results**

In this work, three experiments are conducted using two datasets in order to build the classification model and test the model. The detail of the experimental setup including datasets, and the evaluation metrics are described below.

A. **Experimental Setup**

1. **DataSet**: two datasets are described as follows.

   a) First dataset: This dataset is used to train the classification model and test the model using 10 folds cross validation. It contains the title of the undergraduate independent study in statistics during the year 2010-2012.

   b) Second dataset: This dataset contains the titles of the undergraduate independent study in statistics during the year 2004-2009. This dataset did not used to build the classification model because the research category has not been assigned to each independent study but we aim to group this dataset into three groups using the model constructed from the first dataset.

Table 1 shows the statistics of the number of titles in each group and the total number of words of the independent study dataset for each year.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sample Survey</th>
<th>Statistical Analysis</th>
<th>OR and Related field</th>
<th>Total</th>
<th>Number of Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>19</td>
<td>123</td>
</tr>
<tr>
<td>2005</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>28</td>
<td>139</td>
</tr>
<tr>
<td>2006</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>39</td>
<td>205</td>
</tr>
<tr>
<td>2007</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>45</td>
<td>252</td>
</tr>
<tr>
<td>2008</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>56</td>
<td>291</td>
</tr>
<tr>
<td>2009</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>58</td>
<td>338</td>
</tr>
<tr>
<td>2010</td>
<td>32</td>
<td>20</td>
<td>18</td>
<td>70</td>
<td>680</td>
</tr>
<tr>
<td>2011</td>
<td>31</td>
<td>31</td>
<td>11</td>
<td>73</td>
<td>478</td>
</tr>
<tr>
<td>2012</td>
<td>23</td>
<td>19</td>
<td>14</td>
<td>56</td>
<td>478</td>
</tr>
</tbody>
</table>

2. **Evaluation Metrics**: Several evaluation measures are used to compare the classification performance of different learning methods. The basic measures are accuracy, true positive, and false positives.

   a) Accuracy: the percentage of all titles which are correctly classified.

   b) True Positive of class $j$: the percentage of correctly classified titles for class $j$, where $j=1,2,3$.

   c) False Positive of class $j$: the percentage of titles which are not in the class $j$ and incorrectly classified as class $j$, where $j=1,2,3$.

B. **Experiment I: Investigating the accuracy of the learning method**

This experiment aims to investigate the classification results of the learning method using the training dataset. In this work, we also compare the classification results using the various feature selection methods. The goodness of the words for the classification are measured by the feature selection method, and the score are ranked in the descending order. In this work, we selected only top $k$ features for classification and the number of selected features ($k$) is varied from 10 to 40 percent of the total features with the increment by 10. Table II shows that the feature selection method has a slightly impact to the accuracy of the learning method since there was a small variation of the accuracy between each feature selection methods. In this work, we assessed the different of the accuracy when using the various feature selection methods by the analysis of the variance (ANOVA). The result shows that there was no significant difference in the accuracy of the various feature selection methods at significance level of 0.05. Table 2 also shows that the RBF learning algorithm gave the highest accuracy when the Chi-square was used as the feature selection method. In addition, the experimental result shows that the RBF algorithm with 30 percent of total features gave the best results.
Table 2 accuracy (%) of the learning methods

<table>
<thead>
<tr>
<th>Feature Reduction/Number of features</th>
<th>SVM</th>
<th>NB</th>
<th>RBF</th>
<th>DT</th>
<th>kNN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without using feature Reduction</td>
<td>90.45</td>
<td>86.93</td>
<td>75.88</td>
<td>81.41</td>
<td>79.40</td>
</tr>
<tr>
<td>Chi-Square</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85 (10%)</td>
<td>90.45</td>
<td>86.93</td>
<td>89.95</td>
<td>85.93</td>
<td>80.90</td>
</tr>
<tr>
<td>170 (20%)</td>
<td>87.44</td>
<td>90.45</td>
<td>91.46</td>
<td>83.42</td>
<td>80.90</td>
</tr>
<tr>
<td>255 (30%)</td>
<td>87.94</td>
<td>89.95</td>
<td>92.96</td>
<td>83.92</td>
<td>82.41</td>
</tr>
<tr>
<td>340 (40%)</td>
<td>88.44</td>
<td>88.44</td>
<td>91.96</td>
<td>82.41</td>
<td>78.89</td>
</tr>
<tr>
<td>Average</td>
<td>88.57</td>
<td>88.94</td>
<td>91.58</td>
<td>83.92</td>
<td>80.78</td>
</tr>
<tr>
<td>Gain Ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85 (10%)</td>
<td>84.42</td>
<td>84.42</td>
<td>86.93</td>
<td>83.92</td>
<td>78.39</td>
</tr>
<tr>
<td>170 (20%)</td>
<td>86.93</td>
<td>84.42</td>
<td>89.45</td>
<td>85.93</td>
<td>78.89</td>
</tr>
<tr>
<td>255 (30%)</td>
<td>88.44</td>
<td>87.44</td>
<td>90.45</td>
<td>82.41</td>
<td>84.42</td>
</tr>
<tr>
<td>340 (40%)</td>
<td>88.44</td>
<td>88.44</td>
<td>87.44</td>
<td>86.43</td>
<td>84.42</td>
</tr>
<tr>
<td>Average</td>
<td>87.06</td>
<td>86.18</td>
<td>88.57</td>
<td>84.67</td>
<td>81.53</td>
</tr>
<tr>
<td>Information Gain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85 (10%)</td>
<td>88.44</td>
<td>86.43</td>
<td>86.44</td>
<td>85.93</td>
<td>80.40</td>
</tr>
<tr>
<td>170 (20%)</td>
<td>90.95</td>
<td>90.95</td>
<td>91.46</td>
<td>86.43</td>
<td>81.91</td>
</tr>
<tr>
<td>255 (30%)</td>
<td>88.44</td>
<td>90.45</td>
<td>90.45</td>
<td>82.41</td>
<td>84.42</td>
</tr>
<tr>
<td>340 (40%)</td>
<td>90.94</td>
<td>90.45</td>
<td>89.95</td>
<td>82.41</td>
<td>79.90</td>
</tr>
<tr>
<td>Average</td>
<td>88.94</td>
<td>89.32</td>
<td>90.08</td>
<td>84.30</td>
<td>81.66</td>
</tr>
</tbody>
</table>

Table 3 classification table

<table>
<thead>
<tr>
<th>Predict</th>
<th>Sample Survey</th>
<th>STAT Analysis</th>
<th>Operation Research and related field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Survey</td>
<td>84</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>STAT Analysis</td>
<td>1</td>
<td>62</td>
<td>3</td>
</tr>
<tr>
<td>Operation Research and related field</td>
<td>1</td>
<td>2</td>
<td>39</td>
</tr>
</tbody>
</table>

Table 3 shows the classification table and the result shows that most of the sample survey and operational research topics are correctly classified. Table 4 shows that the overall accuracy of the model is 92.96 percent and most of the sample survey researches are correctly classified since the TP rate is 97.67 percent whereas the statistical analysis researches are misclassified more than 10 percent.

Table 4 testing results

<table>
<thead>
<tr>
<th>Group</th>
<th>TP Rate</th>
<th>FP rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Survey</td>
<td>97.67</td>
<td>6.20</td>
</tr>
<tr>
<td>STAT Analysis</td>
<td>88.57</td>
<td>3.10</td>
</tr>
<tr>
<td>Operation Research and related field</td>
<td>90.69</td>
<td>1.92</td>
</tr>
<tr>
<td>Overall</td>
<td>92.96</td>
<td>11.10</td>
</tr>
</tbody>
</table>

C. Experiment II: Investigating the impact of the feature space representation.

Since features are lost during tokenization and stop word removing, for example, the word "ความน่าเป็น" which should be in the extracted feature list is lost. Thus, we combined single word into word bigram which is a pair of consecutive words. The objective of this experiment is to compare the accuracy of the learning methods between the single word representation and word bigram representation. Table 5 shows the accuracy of the learning methods using word bigram representation and the result shows that the RBF learning algorithm also gave the highest accuracy when the chi-square was used as the feature selection method. In addition, the experimental result shows that the RBF algorithm with 20 percent of total features gives the best result. Table 6 shows that the accuracy of using single word as feature representation is higher than that of using word bigram representation.

Table 5 accuracy (%) of the learning methods

<table>
<thead>
<tr>
<th>Feature Reduction/Number of features</th>
<th>SVM</th>
<th>NB</th>
<th>RBF</th>
<th>DT</th>
<th>3NN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without using feature Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chi-Square</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>240 (10%)</td>
<td>87.44</td>
<td>87.44</td>
<td>88.94</td>
<td>82.91</td>
<td>75.88</td>
</tr>
<tr>
<td>480 (20%)</td>
<td>87.94</td>
<td>90.95</td>
<td>90.95</td>
<td>83.42</td>
<td>81.91</td>
</tr>
<tr>
<td>720 (30%)</td>
<td>86.93</td>
<td>88.94</td>
<td>88.44</td>
<td>83.42</td>
<td>74.37</td>
</tr>
<tr>
<td>960 (40%)</td>
<td>87.44</td>
<td>88.44</td>
<td>83.42</td>
<td>81.91</td>
<td>73.37</td>
</tr>
<tr>
<td>Average</td>
<td>87.44</td>
<td>88.94</td>
<td>87.94</td>
<td>82.92</td>
<td>76.38</td>
</tr>
<tr>
<td>Gain Ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>240 (10%)</td>
<td>78.89</td>
<td>77.39</td>
<td>79.40</td>
<td>78.89</td>
<td>70.35</td>
</tr>
<tr>
<td>480 (20%)</td>
<td>82.41</td>
<td>81.91</td>
<td>80.90</td>
<td>82.91</td>
<td>70.35</td>
</tr>
<tr>
<td>720 (30%)</td>
<td>88.94</td>
<td>83.42</td>
<td>87.44</td>
<td>83.42</td>
<td>73.37</td>
</tr>
<tr>
<td>960 (40%)</td>
<td>85.93</td>
<td>75.38</td>
<td>77.89</td>
<td>83.42</td>
<td>67.34</td>
</tr>
<tr>
<td>Average</td>
<td>84.04</td>
<td>79.53</td>
<td>81.41</td>
<td>82.16</td>
<td>70.35</td>
</tr>
<tr>
<td>Information Gain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>240 (10%)</td>
<td>89.45</td>
<td>87.44</td>
<td>90.45</td>
<td>82.41</td>
<td>77.89</td>
</tr>
<tr>
<td>480 (20%)</td>
<td>87.94</td>
<td>90.45</td>
<td>90.95</td>
<td>83.42</td>
<td>83.92</td>
</tr>
<tr>
<td>720 (30%)</td>
<td>89.45</td>
<td>88.44</td>
<td>86.93</td>
<td>82.41</td>
<td>79.40</td>
</tr>
<tr>
<td>960 (40%)</td>
<td>87.94</td>
<td>87.94</td>
<td>81.41</td>
<td>82.41</td>
<td>76.88</td>
</tr>
<tr>
<td>Average</td>
<td>88.57</td>
<td>88.57</td>
<td>87.44</td>
<td>82.66</td>
<td>79.52</td>
</tr>
</tbody>
</table>
Table 6: comparison of accuracy (%) between feature representation using single word and word bigram

<table>
<thead>
<tr>
<th>Feature Representation</th>
<th>SVM</th>
<th>NB</th>
<th>RBF</th>
<th>DT</th>
<th>3NN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Word</td>
<td>87.94</td>
<td>89.95</td>
<td>92.96</td>
<td>83.92</td>
<td>82.41</td>
</tr>
<tr>
<td>Word Bigram</td>
<td>87.94</td>
<td>90.95</td>
<td>90.95</td>
<td>83.42</td>
<td>81.91</td>
</tr>
</tbody>
</table>


This experiment aims to automatically assign the class label to the second dataset. In this experiment, we employed the RBF algorithm with 30 percent of total features selected by Chi-square as it gave the highest accuracy as shown in Table 5. Table 7 shows the number of independent study documents which are classified into each group. As we observed that only one independent study document was classified as operational research in the year 2004 and 2005. We therefore investigated the title of independent study and found that there are no independent study researches in the field of operational research during the year 2004-2005. Thus, the classification model classified incorrectly, the reason is that the classification model is trained on a small training dataset and the selected features may inadequate for classification

Table 7: classification of the undergraduate independent Study in statistics during 2004-2009

<table>
<thead>
<tr>
<th>Year</th>
<th>Sample Survey</th>
<th>STAT Analysis</th>
<th>Operation Research and related field</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>2005</td>
<td>22</td>
<td>3</td>
<td>1</td>
<td>26</td>
</tr>
<tr>
<td>2006</td>
<td>25</td>
<td>10</td>
<td>4</td>
<td>39</td>
</tr>
<tr>
<td>2007</td>
<td>29</td>
<td>11</td>
<td>5</td>
<td>45</td>
</tr>
<tr>
<td>2008</td>
<td>34</td>
<td>17</td>
<td>5</td>
<td>56</td>
</tr>
<tr>
<td>2009</td>
<td>27</td>
<td>21</td>
<td>10</td>
<td>58</td>
</tr>
</tbody>
</table>

Conclusion and future work

This paper presents the classification of Thai undergraduate independent study in statistics using the data mining techniques. The RBF algorithm is selected for constructing the classification model since it gives the best results. And, the classification model is used to classify the titles of the independent study during the year 2004-2009 which have never been assigned the group label. However, there are many titles were misclassified into other groups. We investigated this problem and observed that the training dataset contains a small number research’s titles. And, this could affect the accuracy of the model a lot. Future work will investigate the impact of skewed class distribution of the training dataset to the accuracy of the classification model. In addition, we will improve the accuracy of the classification model by considering other features such as advisor name, words in the abstract, etc. Moreover, we will conduct more experiments using clustering techniques, which is unsupervised learning method, in order to group the documents into more than three groups. The clustering results will show the best number of research groups for our department.

References

The Comparison of Point Estimation for Parameter for Geometric Distribution Data in Small Sample Size

Yadpirun Supharokonsakun

Received: 18 February 2013       Accepted: 15 June 2013

Abstract

The objective of this research is to compare two point estimation methods: Maximum Likelihood Method (MLE) and Bayesian Method (Baye). When data is Geometric distribution, the parameters (p) are 0.1, 0.3, 0.5, 0.7 and 0.9, whereas the sample sizes (n) are 3, 5, 8, 10, 12, 15, 18, 23, 25, 28 and 30. In each situation, the data has been simulated and repeated for 1,000 times. The Mean Absolute Error is used as a criterion for comparison.

According to the results, when the sample sizes are 3, 5, 8 and 10, on overall MLE yields the least mean absolute error when parameter equal to 0.1. Whereas parameter larger than or equal to 0.3, on overall Baye yields the least mean absolute error. when the sample size equal to 12, 15, 18, 20, 23, 25, 28 and 30, on overall MLE yields the least mean absolute error when parameter equal to 0.1 and 0.3. Whereas parameter larger than or equal to 0.5, on overall Baye yields the least mean absolute error.

Keywords: Geometric Distribution, Point Estimation

Introduction

In general, when we do research, it is impossible to investigate every unit or population. We are interested in multiple limitations, such as restrictions on budget and time. Thus, we can study the characteristics of population by simple random sampling from the mentioned population. The features of sample come from statistics calculated from sample data. It can be said that statistical inference is to infer the statistics of the sample data to the population itself.

According to the statistical principle, statistics can be classified into two parts: descriptive and inferential statistics. The descriptive statistics is used for planning, designing operating, collecting and presenting data including evaluating and calculating primarily the collected data. The inferential statistics is concerned with data analysis which comprises estimation and hypothesis testing and may include forecasting or prediction and model building. Therefore, the inferential statistics must be used to analyze the data collected in order to sum up not only the facts or characteristics of parameter as a whole, but also the available data.

Statistical hypothesis testing will be used to test the value of data or interesting matters in order to prove that it is true or not. The estimation will be done when we want to know the amount of unknown value, such as the estimated average cost per month of Phetchabun Rajabhat University’s students. The estimation can be divided into two methods: point and interval estimation. The purpose of these two methods is to estimate a parameter which is the same. However, we can get only a single value through the point estimation while the interval estimation provides us a set in the range of estimation which is commonly referred to “Confidence Interval.”

Moreover, the concepts used in statistical inference can be divided into two categories: classical and Bayes inferences. In the past, many researches were investigated through the comparison of various estimations. The most popular category is the maximum likelihood which is easy to compute and provides a good estimation. In addition, the Bayesian inference is also a popular approach because it provides an approximation which is close to a true parameter value. Furthermore, it is a new concept to use prior knowledge to assist in estimating values.
The researcher would like to study and compare how to estimate a parameter by using the point estimation through the maximum likelihood method and the Bayes inference as the data are geometrically distributed. Anyway, such a kind of research has never done before.

**Literature Review**

P. Arkhom compared the method of estimating parameter interval by using three methods: Pivotal Quantity Method, Bayes' Estimator Method and Minimize Method with small sample sizes of Poisson Distribution. The findings revealed Bayes' Estimator Method indicated the smallest interval.

P. Krittaya compared two interval estimation methods for parameter of Poisson distribution. There were Maximum Likelihood Method and Bayesian Estimation Method which used Gamma prior distribution when the data were small sample size. The findings revealed the Bayesian yieded an average width of interval was less than the Maximum Likelihood method for each case studied.

T. Manlika to compare point estimation methods for parameter of binomial distribution by using three methods: Maximum likelihood method, Bayesian method and Minimax method. The findings revealed the Bayesian method should be used for small sample size. For parameter p between 0.30 to 0.50 all three method gave similar result. Anyway, the maximum likelihood method should be considered because it is easier and more convenient that the others.

**Objective**

To compare two point estimation methods: Maximum Likelihood Method (MLE) and Bayesian Method (Baye).

**The Point Estimator**

**A. Abbreviations and Acronyms**

The Maximum Likelihood Estimator of Geometric Distribution

Let \( x_1, x_2, \ldots, x_n \) are random samples with a geometric distribution is defined as \( X \sim \text{Geo}(p) \), the distribution function of \( X \) were following (1)

\[
f(x \mid p) = p(1-p)x^{-1}
\]

By \( x = 1, 2, 3, 0 < p \leq 1 \) and the Maximum Likelihood Estimator were following (2)

\[
\hat{p}_{\text{MLE}} = \frac{n}{\sum_{i=1}^{n} x_i} = \frac{1}{\bar{X}}
\]

**B. The Posterior of Geometric Distribution.**

Let \( x_1, x_2, \ldots, x_n \) are random samples with a geometric distribution is defined as \( X \sim \text{Geo}(p) \), the distribution function of \( X \) from (1). When \( p \sim \text{Beta}(\alpha, \beta) \), we have the posterior function distribution were following (3)

\[
p \mid X \sim \text{Beta}\left(\alpha + n, \sum_{i=1}^{n} x_i - n + \beta\right)
\]

**Criteria Used In The Comparison**

The Mean Absolute Error are used as criteria for comparison. The criteria for a selection from these methods were their performance on the lowest mean absolute error in each of the simulation following (4)

\[
|e_i| = |p_i - \hat{p}_i|
\]

When \( e_i \) is absolute error, \( p_i \) is parameter and \( \hat{p}_i \) is estimates of the parameters.
Research Methodology
The data were generated through the Monte Carlo simulation technique with the following steps.
1. Set the sample size (n) and parameter (p).
2. Generated data.
4. Calculates the mean absolute error for each estimation method.
5. Compare the mean absolute error for each estimation method.
6. Concludes the result in each case.

Result
Table 1 showed that for the sample size equal to 3, 5, 8 and 10, on overall MLE yields the least mean absolute error when parameter equal to 0.1. Whereas parameter larger than or equal to 0.3, on overall Baye yields the least mean absolute error. when the sample size equal to 12, 15, 18, 20, 23, 25, 28 and 30, on overall MLE yields the least mean absolute error when parameter equal to 0.1 and 0.3. Whereas parameter larger than or equal to 0.5, on overall Baye yields the least mean absolute error.

<table>
<thead>
<tr>
<th>n</th>
<th>p</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
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<td>0.113854 a</td>
</tr>
<tr>
<td>0.3</td>
<td>0.201694 a</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.759002 a</td>
<td></td>
</tr>
<tr>
<td>0.7</td>
<td>0.2011905 a</td>
<td></td>
</tr>
<tr>
<td>0.9</td>
<td>7.766667 a</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.1</td>
<td>0.052990 a</td>
</tr>
<tr>
<td>0.3</td>
<td>0.201694 a</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.759002 a</td>
<td></td>
</tr>
<tr>
<td>0.7</td>
<td>0.2011905 a</td>
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<tr>
<td>0.9</td>
<td>7.766667 a</td>
<td></td>
</tr>
<tr>
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<td>0.066676 a</td>
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<td>15</td>
<td>0.1</td>
<td>0.042066 a</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.584174 a</td>
<td></td>
</tr>
<tr>
<td>0.7</td>
<td>2.182243 a</td>
<td></td>
</tr>
<tr>
<td>0.9</td>
<td>12.873810 a</td>
<td></td>
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<tr>
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<td>12.100000 a</td>
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<tr>
<td>23</td>
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<td>0.024960 a</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.606365 a</td>
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<tr>
<td>0.7</td>
<td>2.163981 a</td>
<td></td>
</tr>
<tr>
<td>0.9</td>
<td>12.100000 a</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>0.1</td>
<td>0.022557 a</td>
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<td>0.3</td>
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<td>0.584174 a</td>
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</tr>
<tr>
<td>0.7</td>
<td>2.182243 a</td>
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<td>12.873810 a</td>
<td></td>
</tr>
<tr>
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</tr>
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<td>0.154588 a</td>
<td></td>
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<tr>
<td>0.5</td>
<td>0.577110 a</td>
<td></td>
</tr>
<tr>
<td>0.7</td>
<td>2.000246 a</td>
<td></td>
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<tr>
<td>0.9</td>
<td>9.236242 a</td>
<td></td>
</tr>
<tr>
<td>30</td>
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<td>0.020811 a</td>
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<tr>
<td>0.3</td>
<td>0.154426 a</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.573016 a</td>
<td></td>
</tr>
<tr>
<td>0.7</td>
<td>1.955711 a</td>
<td></td>
</tr>
<tr>
<td>0.9</td>
<td>10.361900 a</td>
<td></td>
</tr>
</tbody>
</table>

a. Least mean absolute error
Conclusion
The findings revealed the of point estimation for parameter for geometric distribution data in small sample size, when the parameter is a small size, it will show MLE better than Baye. If the parameter is big, should use Baye better than MLE.

Acknowledgment
This research has been successfully completed by the financial support of Research and Development Institution of Phetchabun Rajabhat University.

Most of all, the researcher would appreciate all professors in the Mathematics Program, Faculty of Science and Technology, Phetchabun Rajabhat University.

Thanks for inspiring my family and help to achieve everything.

References
To measure the satisfaction level of outpatients by Jonckheere-Terpstra

Chunchom Pongchavalit*, Sureepon Janbamrung², Isaree Joijumpod³
Received: 18 February 2013 Accepted: 15 May 2013

Abstract
This research is to measure the satisfaction level of outpatients that use the services of a private hospital. The tool used in this survey is the random of sample selection of 158 people. All are not in a serious illness and can read or write. The selection used the stratified sampling which separates in three, first is 81 normal medical benefits second is 61 social security medical benefits and third is 16 immigrants medical benefits. The test of Jonckheere -Terpstra show that the general benefits are greater than the social security benefits and the social security service is greater than the immigrants benefits, general benefits (GW) > social security benefits (SW) > immigrants benefits (AW).

Keyword : satisfaction, general medical benefits, social security medical benefits, Immigrants medical benefits

Introduction
The development of the country depends on a population with medical care. When the population has good health and sanitation, they will have the power to drive the country towards improvement in other fields. Therefore the developments of healthcare is constantly being adapted to be current. The governments have initiated a program for the improvement in hospital services. These changes have the objectives for the ones using the services to have the most satisfaction. The satisfaction in services is very important to the efficiency of the work process. This research survey the satisfaction of the people who use the service of the hospital. To analyze whether this private hospital can answer the customers’ needs in many ways or not, how is it satisfactory? And what is the level of satisfaction. The sample groups are outpatients which are suitable because the efficiency of the hospital system can be reflected by the ones who are using the services. Applewhite ¹ have suggested that satisfactory means happiness from working, the happiness of working together with others and a good attitude toward ones work. Schermerhorn² also suggests that satisfaction is a level of positive and negative feelings of a person for varied aspects of work, the given task, the system organization and the relationship between colleagues.

Methodology
This research is to measure the satisfaction level of 158 outpatients that use the services of a private hospital. Using the stratified sampling separated by, first is 81 normal medical benefits second is 61 social security medical benefits and third is 16 immigrants medical benefits. These patients were in the medical care in the month of October in the year of 2011, the time of services were between 8.00 a.m. to 4.00 p.m. which all in all had 37,228 patients.

A. Formula use in this research
1. Jonckhere Terpstra
Test mean of more than two populations
Test different of means in each group

\[ H_0 : GW = SW = AW \]
\[ H_1 : GW > SW > AW \]

\[ z = \frac{J - \frac{8}{N} \sum_{i=1}^{n} \frac{n_i^2}{N} - \frac{2}{N} - \frac{2}{N^2} \left( \sum_{i=1}^{n} \left( \frac{n_i^2}{N} \right) + 3 \right)}{\sqrt{\frac{N^2}{N^2} \left( \sum_{i=1}^{n} \left( \frac{n_i^2}{N} \right) + 3 \right)}} / 72 \]
where \( N = \) the amount of observe in total group
\( n_i = \) the amount of observe in each group
\( J = \) the value of Jonckheere Terpstra

2. Proportional Allocation
\[ nW = nN_i \]

3. Total approximate
\[ T_{prop} = N\bar{p}_{prop} \quad \text{and} \quad \hat{V}(T_{prop}) = \frac{(N - n)}{n} \sum_{i=1}^{J} N_i S_i^2 \]

4. Proportion approximate
\[ P_{prop} = \frac{\sum_{i=1}^{J} n_i}{n \cdot N} \]

5. Variance in each level
\[ \hat{V}(P_{prop}) = \frac{1}{N} \sum_{i=1}^{J} N_i S_i^2 - \frac{1}{N} \sum_{i=1}^{J} N_i p_i \bar{q}_i = 1 \]
\[ n_{prop} = \frac{N \sum_{i=1}^{J} N_i S_i^2}{N^2 + \sum_{i=1}^{J} N_i S_i^2} \]

The amounts of general benefits are 81 persons, the social benefits are 61 persons and the immigrants’ benefits are 16 persons.

Result
From data collection of opinion scale classified by the satisfaction level of outpatients that used the services of a private hospital.

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean</th>
<th>SD</th>
<th>Level of satisfy</th>
</tr>
</thead>
<tbody>
<tr>
<td>The officer shows the attentiveness</td>
<td>4.20</td>
<td>0.62</td>
<td>high</td>
</tr>
<tr>
<td>The officer has the attitude that is friendly</td>
<td>4.33</td>
<td>0.62</td>
<td>high</td>
</tr>
<tr>
<td>The officer pays attention to person come to use service</td>
<td>4.27</td>
<td>0.64</td>
<td>high</td>
</tr>
<tr>
<td>The officer is dresses clean</td>
<td>4.51</td>
<td>0.57</td>
<td>highest</td>
</tr>
<tr>
<td>Manners</td>
<td>4.36</td>
<td>0.60</td>
<td>high</td>
</tr>
<tr>
<td>Questions answered</td>
<td>4.10</td>
<td>0.66</td>
<td>high</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean</th>
<th>SD</th>
<th>Level of satisfy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manners of doctor and nurse</td>
<td>4.32</td>
<td>0.55</td>
<td>high</td>
</tr>
<tr>
<td>Doctor pays attention to listen to symptoms</td>
<td>4.33</td>
<td>0.61</td>
<td>high</td>
</tr>
<tr>
<td>The doctor in using equipment or tools that relate to checking cures</td>
<td>4.47</td>
<td>0.61</td>
<td>high</td>
</tr>
<tr>
<td>Advice</td>
<td>4.35</td>
<td>0.62</td>
<td>high</td>
</tr>
</tbody>
</table>

B. Instrument
The tools used were a questionnaire to measure the satisfaction level of outpatients that use the services of a private hospital.
Meaning of mean
- 4.51-5.00 satisfy highest
- 3.51-4.50 satisfy high
- 2.51-3.50 satisfy medium
- 1.51-2.50 satisfy low
- 1.00-1.50 satisfy lowest
Table 3 Compare Satisfy level of general benefits, social benefits and immigrants benefits about hospital

<table>
<thead>
<tr>
<th>Ask</th>
<th>general benefits</th>
<th>social benefits</th>
<th>immi-grants benefits</th>
<th>Level of satisfy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>1</td>
<td>4.26</td>
<td>0.61</td>
<td>4.09</td>
<td>0.62</td>
</tr>
<tr>
<td>2</td>
<td>4.30</td>
<td>0.62</td>
<td>4.22</td>
<td>0.64</td>
</tr>
<tr>
<td>3</td>
<td>4.34</td>
<td>0.61</td>
<td>4.34</td>
<td>0.61</td>
</tr>
<tr>
<td>4</td>
<td>4.30</td>
<td>0.61</td>
<td>4.22</td>
<td>0.62</td>
</tr>
</tbody>
</table>

That means satisfy level in each benefits about hospital is high.

Next compare general benefits (GW), social security benefits (SW) and immigrants benefits (AW) at significant 0.05

Hypothesis:

\[ H_0 : GW = SW = AW \]
\[ H_1 : GW > SW > AW \]

Table 5 Compare three benefits by Jonckheere Terpstra at significant 0.05

<table>
<thead>
<tr>
<th>Test</th>
<th>value of statistic (N&gt;20)</th>
<th>value Sig</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonckheere Terpstra Test For Order Alternative</td>
<td>- 4.02</td>
<td>0.00</td>
<td>Reject : ( H_0 )</td>
</tr>
</tbody>
</table>

From the test of Jonckheere-Terpstra show that the general benefits are greater than the social security benefits and the social security service is greater than the immigrants’ benefits. \( GE > SW > AW \).

Conclusion

Satisfaction of the staff services were at a high level. Care from the doctor at a high level. General medical benefits were more satisfying than the social security medical benefits. And for the immigration medical benefits, the services of the hospital staff were at a very high level. The patients were very satisfied with the enthusiasm of the staff, the staffs were friendly and took good care of the patients. Also staffs dressed appropriately and tidy which give the satisfaction level high. When use the test of Jonckheere Terpstea to aid this research it appear that this private hospital have different services with the different medical benefits. The patients might be satisfied using the services of the hospital but not the same when each medical benefit is in comparison. The results show that the general medical benefit is better than the social security medical benefits. And a social security medical benefit is better than the immigrants’ medical services.

References

The Development of Hot-deck Corrected Item Mean (HDD-CIM) for Estimating Missing Data

Paitoon Muliwan1*, Nipaporn Chutiman2, Prapas Pue-on3

Received: 15 March 2013        Accepted: 15 May 2013

Abstract
The purpose of this study was to develop the hot-deck corrected item mean (HDD-CIM) for missing data estimation and compare its under missing complete at random (MCAR) and simple random sampling with two methods, namely; Corrected item mean (CIM) and hot-deck (HDD). The secondary data from a survey of public information about the prevalence of drugs, 2011, a survey by the Bureau of Statistics Mahasarakham Province were used and the comparisons were made with three sample sizes (100, 200 and 500) and four levels of percentage of missing data (5%, 10%, 15% and 20%). It appears that the HDD-CIM method has most efficiency in estimating missing data.

Keywords: Missing data, MCAR, Simple random sampling, Corrected item mean (CIM), hot-deck (HDD)

Introduction
Missing data a problem in many field1 of research, and the researcher must consider to appropriate process for management of missing data in every case. Sometimes it may not be a serious problem that may be regarded as a trivial matter, nevertheless the experiments showed that, if each variable with random missing data, only 10% the unit of analysis will cut off 59% (Roth, 1995). Missing completely at random (MCAR) is a process in which the missingness of the data is completely independent of both the observed and the missing values, The study found that if the missing data mechanism is MCAR, then the results from many missing data procedures would be valid. On the other hand, if data are not MCAR, care must be exercised in employing routine missing data procedures. Thus, statistical tests of MCAR are important and of interest (Jamshidian and Jalal, 2010; Little, 1988). The study found that CIM is the best technique and easy to compute and yields good estimates of scale score of person, although one should bare in mind the overestimation of the scale quality. In general the performance of CIM is best and it shows that there is much to gain when measurement models are used for the imputation of missing values to test-items (Huisman, 2000). Hot-deck (HDD) as a replacement for the loss information by donor from same research / explore, so the survey are similar to the units with missing data. It was found that the HDD is the smallest bias and highest precision (Montree Piriyakul, 2005), the disadvantage of this method is a practical way and less theory to support. Although flexible and widely used by practitioners to handle item non-response. But may have a theoretical objection (Montree Piriyakul, 2005). And the hot deck is widely used by practitioners to handle item non-response. Its strengths are that it imputes real (and hence realistic) values, it avoids strong parametric assumptions, it can incorporate covariate information, and it can provide good inferences for linear and non-linear statistics if appropriate attention is paid to propagating imputation uncertainty. A weakness is that it requires good matches of donors to recipients that reflect available covariate information; finding good matches is more likely in large than in small samples (Andridge, R. R. and Little, R. J. A., 2010). Therefore, the objective was to take advantage of these

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two methods to develop a method for estimating the lost data with the HDD-CIM. This study using secondary data from a survey of public information about the prevalence of drugs by the Bureau of Statistics Mahasarakham Province 2011, there were 2,970 records.

Methods

The sample was selected from the population of 2,970 records by simple random sampling with 100, 200 and 500, generated missing data using MCAR at 5%, 10%, 15% and 20%. Calculated mean square error (MSE) from Eq(1).

\[
MSE = \frac{\sum_{i=1}^{n} (\theta_i - \hat{\theta}_i)^2}{n}
\]

where \(\theta_i\) is the old value and \(\hat{\theta}_i\) is the new value and \(n\) is number of missing value. And to compare the results of the estimation of missing data between CIM, hot-deck (HDD) and HDD-CIM.

CIM replaces missing values by the item mean which is corrected for the ability of the respondent, i.e., the score on the observed items of the respondent compared with the mean score on these items.

The operation of CIM as shown from Eq(2).

\[
CIM_{vi} = \frac{\bar{x}_i^{(j)} \times \sum_{i \in \text{obs}(v)} x_{ij}}{\sum_{i \in \text{obs}(v)} \bar{x}_i^{(j)}}
\]

where \(\bar{x}_i^{(j)}\) is the mean score on item i for non-missing data and \(\text{obs}(v)\) is the collection of observed items.

Hot-deck deterministic method (HDD) uses the complete case for which the distance function is minimized. When several complete cases are at the same minimal distance of the currently considered incomplete case, the complete case which is nearest to the incomplete case with respect to its place in the data matrix is used as a donor case.

The operation of HDD as shown from Eq(3).

\[
d_{iv}^2 = \sum_{i \in \text{obs}(v)} (x_{vi} - x_{vi})^2
\]

where \(V\) is incomplete and \(V^1\) a complete case.

HDD-CIM is a mix methods by using CIM to replace missing value, calculate the distance between the survey data as a way to decide by HDD.

The operation of the HDD-CIM, as shown below.

Step 1: replace missing data with the mean of the variables according to CIM for the temporary file following Eq(4).

\[
CIM_{vi} = \frac{\bar{x}_i^{(j)} \times \sum_{i \in \text{obs}(v)} x_{ij}}{\sum_{i \in \text{obs}(v)} \bar{x}_i^{(j)}}
\]

where \(\bar{x}_i^{(j)}\) is the mean score on item i for non-missing data and \(\text{obs}(v)\) is the collection of observed items.

Step 2: Calculate the distance between the survey and the HDD can be calculated using the following Eq(5).

\[
d_{iv}^2 = \sum_{i \in \text{obs}(v)} (x_{vi} - x_{vi})^2
\]

where \(V\) is incomplete and \(V^1\) a complete case.

Step 3: use the complete case for which the distance function is minimized. When several complete cases are at the same minimal distance of the currently considered incomplete case, the complete case which is nearest to the incomplete case with respect to its place in the data matrix is used as a donor case.

Results

This study by experiment performed with real data. The secondary data from a survey of public information about the prevalence of drugs, 2011, a survey by the Bureau of Statistics Mahasarakham Province were used. The sample was selected from the population by simple random sampling and to compare the results of the estimation of missing data between the HDD-CIM, CIM and hot-deck (HDD) by using the mean square error (MSE). In the ex-
In experiments, the percentage of missing data are 5%, 10%, 15% and 20%, and three sample sizes are 100, 200 and 500. Table 1 presents the average values of the MSE of the imputation techniques for all factors of the design.

Table 1 Mean Square Error of CIM, HDD and HDD-CIM classified by sample sizes and percentage of missing data.

<table>
<thead>
<tr>
<th>Sample sizes</th>
<th>Percentage of missing data</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CIM</td>
</tr>
<tr>
<td>100</td>
<td>5</td>
<td>3.0798</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2.8944</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>2.0867</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>2.8628</td>
</tr>
<tr>
<td>200</td>
<td>5</td>
<td>3.1830</td>
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<tr>
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<td>10</td>
<td>3.0852</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>2.9263</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>3.1714</td>
</tr>
<tr>
<td>500</td>
<td>5</td>
<td>3.0589</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>3.0766</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>3.0132</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>2.8856</td>
</tr>
</tbody>
</table>

Bold numbers mean having the most efficiency.

From Table 1 it follows that across all factors HDD-CIM is the best technique. For each independent variable separately, HDD-CIM also performs the best, closely followed by CIM and HDD in varying order. This means that the HDD-CIM has the most efficiency for all factors.

Table 2 Mean Square Error of CIM, HDD and HDD-CIM classified by percentage of missing data.

<table>
<thead>
<tr>
<th>Percentage of missing data</th>
<th>Methods</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>CIM</td>
</tr>
<tr>
<td>5</td>
<td>3.1072</td>
</tr>
<tr>
<td>10</td>
<td>3.0187</td>
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<tr>
<td>15</td>
<td>2.9154</td>
</tr>
<tr>
<td>20</td>
<td>2.9732</td>
</tr>
</tbody>
</table>

From Table 2 When classify by percentage of missing data. 20% of missing data also performs best, closely follows by 15%, 10% and 5% in varying order.

Figure 1 Mean Square Error of CIM, HDD and HDD-CIM classified by percentage of missing data.
Summary and Concluding

We demonstrated the effectiveness of the proposed HDD-CIM method using sample sizes and percentage of missing data. In table 1-2 HDD-CIM has the lowest mean square error. This means that the HDD-CIM has most efficiency for each sample size and each percentage of missing data.

References


Student Retirement Analysis Using Decision Tree Techniques

Pattariya Supaudon¹, Nipaporn Chutiman², Bungon Kumphon³*
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Abstract
This study presents the work of data mining in predicting the retirement feature of students by applying decision tree technique to choose the best model for prediction. Three widely used measures the quality of tree are recall rate, precision and F-measure. The results show 94.96 % of correction to predict the student’s retirement.

Keywords: retirement, data mining, decision tree, rule

Introduction
Data mining is the process of analyzing data from different perspectives and summarizing the results as useful information. It is defined as the nontrivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data¹. Decision tree analysis is a popular data mining technique that can be used in many areas of education. It offers comprehensive characteristics analysis of students and contains rules to predict the target variables². One critical question in any educational institution is the following What are the risk factors or variables that are important for predicting the results (pass/fail) of students?

Although many risk factors that affect results are obvious, subtle and non-intuitive relationships can exist among variable that are difficult, or impossible to identify without applying more sophisticated analysis.

Modern data mining models such as decision trees can more accurately predict risk than current models, educational institutions can predict the results more accurately, which in turn can result in quality education. An indicator of potential weaknesses in the higher education system may be a large number of dropouts in the first years of studies. The strategic goal of educational institute should therefore be planning, management and control of education processes with the purpose of improving the efficiency of studying. The retirement trends have to be recognized and the causes (course, previous knowledge, assessment) isolated. Also, the typical student profile is to be determined in order to plan the number of potential students in lifelong learning programs or those that need additional motivation. It is possible to follow the retirement trend throughout several years in order to check the effectiveness of corrective activities.

Graduation, especially timely graduation is an increasingly important policy issue³. College graduates earn twice as much as high school graduates and six times as much as college dropouts⁴ (Murphy and Welch, 1993)⁴. In addition to the financial rewards, the spouses of college graduates are more educated and their children do better in schools and colleges. Graduation rates are considered as one of the institutional effectiveness⁴. Student’s retirement due to different reasons; academic trouble, academic preferences, their financial position, parental income, parent occupation, grade at the first year⁵⁻⁷. (Pattarapong (2010), Aorathai (2007), Kao and Thomson (2003)). The remainder of this paper is organized as follows. Section 2 discusses data and methodology of decision tree. Section 3 presents the data analysis, and some conclusions are stated in the last Section.
Data and Methodology

The secondary data, with ten variables as in Table 1, were employed from the registrar section, Chalerm Phrakiat Sakhon Nakhon Provience Campus, Kasetsart University. The sample of 7,333 students during 2004 – 2011 academic years was split into two groups as training data set and testing data set. The four ratios between training data set (5,833 students) and testing data set (914 students), X, were 50:50 (X₁), 60:40 (X₂), 80:20 (X₃) and 90:10 (X₄).

Table 1 The influence variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
</table>
| Faculty (Fc)              | nominal | A = Natural resource and Agro-industry  
B = Science and Engineering  
C = Liberal Arts and Management Sciences |
| Type of entrance (Te)     | nominal | 1 = University self-admit  
2 = Entrance |
| Gender (Ge)               | nominal | Male, Female |
| Father occupation (Fo)    | nominal | 0 = not indicate  
1 = Government service  
2 = State enterprise  
3 = Employee  
4 = Business  
5 = Agriculture |
| Mother occupation (Mo)    | nominal | 0 = not indicate  
1 = Government service  
2 = State enterprise  
3 = Employee  
4 = Business  
5 = Agriculture |
| GPAX from high school (Gh)| ordinal | 1 = less or equal 2.00  
2 = 2.01 – 2.50  
3 = 2.51 – 3.00  
4 = 3.01 – 3.50  
5 = greater or equal 3.51 |
| GPAX at the first semester (Gf)| ordinal | 1 = less or equal 2.00  
2 = 2.01 – 2.50  
3 = 2.51 – 3.00  
4 = 3.01 – 3.50  
5 = greater or equal 3.51 |
| Parent relationship (Pr)  | nominal | 1 = stay together  
2 = separate, divorce  
3 = father or mother deceased  
4 = father and mother deceased  
5= not indicate |
| Scholarship (Sc)          | nominal | 0 = no  
1 = yes |
| Student status (Ss)       | nominal | 0 = retire  
1 = not retire (NR) |

Decision trees are a highly flexible modeling technique. For instance, to build regression models and neural networks models, the missing values have to be inserted into training data while decision trees can be built even with missing values. Decision trees are intended for the classification of attributes regarding the given target variable. Decision trees are attractive because they offer, in comparison to neural networks, data models in readable, comprehensible form – in fact, in the form of rules. They are used not only for classification but also for prediction. The tree techniques provide insights into the decision making process as shown in Fig. 1. This model, make use of the software Weka the J4.8 algorithm (J4.8 implements a later and slightly improved version called C4.5) for predictive data mining. The condition to choose the attribute or variable in the tree, for the first node, is $\text{max \{information gain\}}$ where $i$ is the number of attributes.

Then the second value would be the second node, respectively. Sometimes, the over fitting can occur because of the complicated nodes and branches in the tree or the small size of training data set or creating decision rules that work accurately on the training set based on insufficient quantity of samples. Pruning tree (reduced error pruning: REP) or clustering are used to solve that problem.

Data Analysis

The parameters in this study are binary splits, number of folds (N) and the number of leaf (M) as M=2, 4, 6; N = 3, 4, 6. Defined $T_{ij}$ and $j=1, 2, 3, 4$ as

- $T_{1}$ is model building with REP, binary, M=2, N=3,
- $T_{2}$ is model building with REP, not binary, M=4, N=6,
- $T_{3}$ is model building with REP, not binary, M=2, N=3,
- $T_{4}$ is model building with REP, not binary, M=6, N=4,

$X$’s are the four ratio set of data as mentioned in Section 2. So, sixteen models were studied to predict the drop out of the student.
The recall rate (R), precision (P) and F-measure are three widely used measures for finding the quality of tree which can define as:

\[ R = \frac{C' \cap C}{C}, \]

\[ P = \frac{C' \cap C}{C'}, \]

\[ F = \frac{2PR}{P+R}, \]

where \( C \) is the set of samples in the class and \( C' \) is the set of samples which the decision tree puts into the class. Table 2 shows the results of the quality for decision tree. Two candidates model --- viz. \( T_{2X1} \) and \( T_{4X1} \) with the best results of R, P and F are considered. \( T_{4X1} \) is selected as a predictive model because of the smaller size of tree compared to another. The best tree is Show in Figure 2 and Table 3 is a testing result compared to the true data (testing data set). The benefit is the rule to predict the student’s retirement with 94.96% of correction. For example, if \( Gf > 2.01 \) imply that “not retire”. If \( Gf \leq 2 \), not get scholarship, \( Fc = A \), \( Mo > 4 \), \( Gh > 3 \) and \( Te \leq 1 \) mean “retire”.

### Table 2
<table>
<thead>
<tr>
<th>Model</th>
<th>Precision</th>
<th>Recall</th>
<th>F-measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retire NR</td>
<td>Retire NR</td>
<td>Retire NR</td>
<td>Retire NR</td>
</tr>
<tr>
<td>( T_{1X1} )</td>
<td>64.1</td>
<td>84.4</td>
<td>57.3</td>
</tr>
<tr>
<td>( T_{1X2} )</td>
<td>65.0</td>
<td>84.2</td>
<td>52.5</td>
</tr>
<tr>
<td>( T_{1X3} )</td>
<td>63.5</td>
<td>85.2</td>
<td>55.2</td>
</tr>
<tr>
<td>( T_{1X4} )</td>
<td>57.3</td>
<td>84.7</td>
<td>52.1</td>
</tr>
<tr>
<td>( T_{2X1} )</td>
<td>66.7</td>
<td>84.8</td>
<td>52.7</td>
</tr>
<tr>
<td>( T_{2X2} )</td>
<td>61.5</td>
<td>87.6</td>
<td>65.9</td>
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<tr>
<td>( T_{2X3} )</td>
<td>64.8</td>
<td>85.4</td>
<td>55.5</td>
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<tr>
<td>( T_{2X4} )</td>
<td>56.3</td>
<td>84.8</td>
<td>52.8</td>
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<tr>
<td>( T_{3X1} )</td>
<td>64.8</td>
<td>84.4</td>
<td>51.5</td>
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<td>( T_{3X2} )</td>
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<td>83.4</td>
<td>46.5</td>
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<td>( T_{4X1} )</td>
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<tr>
<td>( T_{4X4} )</td>
<td>60.2</td>
<td>83.8</td>
<td>47.2</td>
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</table>

### Table 3
<table>
<thead>
<tr>
<th>Correction</th>
<th>Recall</th>
<th>Precision</th>
<th>F-measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retire NR</td>
<td>94.96</td>
<td>25.00</td>
<td>99.20</td>
</tr>
<tr>
<td>Retire</td>
<td>65.00</td>
<td>95.60</td>
<td>36.10</td>
</tr>
</tbody>
</table>
Figure 2 show the tree diagram for analysis.

Conclusion
This study introduced the data mining approach to modeling retirement feature and some implementation of this approach. The key to gaining a competitive advantage in the educational industry is found in recognizing that student databases, if properly managed, analyzed and exploited, are unique, valuable assets. The obtained data should, in the earliest stage, be used to raise awareness on the possibilities and need to use the data mining models and methods at the institution in which this research has been carried out. Data mining uses predictive modeling, database segmentation, market basket analysis and combinations to more quickly answer questions with greater accuracy.

The future research will be directed towards the design of an applicative solution to allow observation and classification of each student at the university into a particular retirement and dropout category depending on his/her characteristics. The fuzzy module based on certain attributes of students’ previous knowledge is the interesting idea.

Acknowledgment
Financial support was provided by the graduate studies, Mahasarakham University. The authors also thank anonymous reviewers for their constructive comments and suggestions.

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Experimental study of working fluids in thermosyphon heat exchanger with annular fins for thermal performance enhancement

Siriporn Setwong¹, Teerapat Chompookham², Pattanapol Meena³*

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Abstract
This research study aims to investigate the effect of working fluids on thermal performance in a thermosyphon heat exchanger with and without annular fins. The thermosyphon heat exchangers were formed from the evaporator, adiabatic and condenser sections in which the lengths were 20, 10 and 20 cm respectively, made from steel, the tube had an outside diameter of 20 mm and a thickness of 3 mm. Distilled water, ethanol and R134a were used as the working fluids with a filling ratio of 50% by total volume of the evaporator section. The temperature of the hot air in the evaporator section was controlled at 60, 70 and 80 °C. The results show that when the variable temperature increased from 60, 70 to 80°C the heat transfer rate and thermal effectiveness also increased. In addition, it was found that at all operating temperatures, the highest heat transfer rate and thermal effectiveness were with R134a as the working fluid. Moreover, the thermosyphon heat exchanger with annular fins had a higher heat transfer rate and thermal effectiveness than the thermosyphon heat exchanger without fins under all variables.

Keywords: Annular fins, Heat exchanger, Thermosyphon, Thermal performance, Working fluid

Introduction
For quite a few years, thermosyphon heat exchangers (TPHEx) have become an important subject for energy conservation. Due to it being a passive device with high efficiency thermal conductivity, low cost and easy construction. They make use of the highly efficient thermal transport process of evaporation and condensation to maximize the thermal conductance between a heat source and a heat sink. They have a range of applications in thermal engineering, such as air preheater, air conditioning systems, waste heat recovery and water heater¹-³. A schematic of the working principle of the TPHEx is shown in Fig. 1. An operating TPHEx may be divided into three distinct sections, namely the evaporator, adiabatic and condenser sections. Energy is added into the evaporator section where the working fluid reaches its boiling temperature and begins to boil. The buoyant vapor of the working fluid rises through the adiabatic section to the condenser, where it condenses. The condensate then drains back into the evaporator section by gravitation. This process of evaporation and condensation of the working fluid repeats itself continuously as long as heat is supplied to the evaporator and an opportunity for its removal from the condenser exists⁴-⁵.

Due to the operating principle of a TPHEx, the main factors that affect the thermal performance of a thermosyphon are inclination angle, operating temperature and pressure, filling ratio, aspect ratio and working fluid. In this research, the experiments were related to the working fluid and operation in a low temperature range (200 to 550 K). Most thermosyphon applications fall within this range⁶. There were many studies that have attempted to

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investigate the thermal performance of thermosyphons [3, 6-9]. Such as Pipatpaiboon et al.⁶ that presents a case study for the design, construction and testing of a thermosyphon heat exchanger (TPHE) in a Thai bio-diesel factory to reduce the temperature of the bio-diesel after the drying process under actual operating conditions. The temperature of the bio-diesel passing though the evaporator section was 120°C and the mass flow rates of the bio-diesel were set at 0.07, 0.15 and 0.21 kg/s. They found that the maximum heat transfer rate was 12.48 kW/m² and the experimental effectiveness was 0.38 at a mass flow rate for bio-diesel at 0.21 kg/s with R134a as the working fluid. The TPHE could reduce the temperature of the bio-diesel from 120 to 81°C. Nimmol and Ritthong [7] studied the development of a paddy drying system using thermosyphon heat pipes (THPs). In this study, R-134a was used as the working fluid and the temperatures of the energy sources were 60, 70 and 80°C, and the characteristics of the thermosyphon heat pipes (finned and unfinned) on the change in moisture content and quality of paddy were then investigated and discussed. Paddy with an initial moisture content of around 26% (d.b.) was used as the test material. The experiments were performed until a paddy moisture content of 14% (d.b.) was obtained under each drying condition. The results obtained from the experiments showed that, compared with hot air and unfinned thermosyphon heat pipes, the rate of moisture reduction in the paddy was higher when hot water and finned thermosyphon heat pipes were employed.

![Schematic of the working principle of the TPHE](image)

There have been some publications related to the experimental work on the performance of thermosyphon with different working fluids. Li et al.¹⁰ studied the heat transfer characteristics of a TPCT at low temperature differences with R11, R22 and water as the working fluids. Nuntaphan et al.¹¹ selected R123, methanol and acetone as the working fluids for use in an experiment about using the oscillating heat pipe technique as an extended surface in wire on a tube heat exchanger for heat transfer enhancement. The most common thermosyphon working fluid at a low operating temperature range is water, due to its good thermo physical properties, availability, low cost, non-toxic and environmentally neutral properties, as well as having the added benefit of being safe to use during handling¹². Moreover, earlier work also studied possible working fluids for low to intermediate operating temperatures that included R-11, R-12, R-22 and R113¹³-¹⁶. However, with these there were negative environmental impacts and/or toxicity. Most of them have been prohibited and replaced by more environmentally friendly and low to non-toxic fluids, such as R134a and 3 M Fluorinert™ liquids¹⁷.

Thus, the objectives of this research were to investigate a passive heat transfer enhancement
technique with annular fins on a thermosyphon wall and the effect of working fluids on the thermal performance of the TPHEx with annular fins. R134a, ethanol and distilled water were selected as working fluids. The results are compared with the heat transfer rate and thermal effectiveness of a thermosyphon heat exchanger with and without fins and using all working fluids.

Thermosyphon heat exchanger analysis

Heat transfer rate of thermosyphon heat exchanger

The heat transfer rate of thermosyphon heat exchanger is as follows:

\[ Q_c = m_c C_p c (T_{e,in} - T_{c,in}) \]  
\[ Q_e = m_e C_p h (T_{h,in} - T_{h,out}) \]

Where

- \( Q_c \) is heat transfer rate of condenser section
- \( Q_e \) is heat transfer rate of evaporator section
- \( c \) refer to cold fluids and condenser section
- \( h \) refer to hot fluids

Thus, the heat transfer rate at the air side of the evaporator and condenser sections, respectively. In this study, the mathematical average of the heat transfer rate can be calculated from:

\[ Q_{avg} = 0.5(Q_c + Q_e) \]

When:

\( \dot{m}_c = (\rho v A)_c \) and \( \dot{m}_h = (\rho v A)_h \)

Where: \( A \) is the total surface area that can be represented by the following equation:

\[ A_f = 2\pi n \left( D_f^2 - D_b^2 \right) \]
\[ A_h = \pi D_h L \]

Thus:

\[ A_{in} = \eta A_f + A_b \]  
\[ A_{out} = \eta A_f + A_b \]

Where:

\[ \eta = \tan \left( \frac{2h_b}{f_k D_f} \right) \]

Then:

\[ \varphi = \frac{D_h}{2} \left( \frac{D_f}{D_h} - 1 \right) \left( 1 + 0.35 \ln \left( \frac{D_f}{D_h} \right) \right) \]

\[ \eta = \frac{\varphi}{2h_b} \sqrt{f_k} \]

Effectiveness of thermosyphon heat exchanger with fins

The effectiveness \( \left( \frac{Q_{act}}{Q_{max}} \right) \) of the heat exchanger can be defined as the ratio of the actual heat transfer rate \( \left( Q_{act} \right) \) for a heat exchanger to the maximum possible heat transfer rate \( \left( Q_{max} \right) \). This can be represented by the following equation:

\[ e = \frac{Q_{act}}{Q_{max}} \]

When:

\[ Q_{act} = m_c C_p c (T_{e,in} - T_{e,avg}) \]
\[ = m_e C_p h (T_{h,avg} - T_{c,in}) \]

As:
From which it follows:

$$\varepsilon = \frac{Q_e}{Q_{\text{max}}} = \frac{Q_e}{Q_{\text{ave}}} = \frac{Q_{\text{ave}}}{Q_{\text{max}}}$$

Where the maximum possible heat transfer rate ($Q_{\text{max}}$) can be represented by the following equation:

$$Q_{\text{max}} = C_e (T_{e,\text{in}} - T_{e,\text{in}})$$

(14)

In case $C_e < C_h$

$$Q_{\text{max}} = C_h (T_{e,\text{in}} - T_{e,\text{in}})$$

(15)

When $C_e = m_e C_{p,e}$ and $C_h = m_h C_{p,h}$

Equation 14 and 15 can be rewritten to the general expression:

$$Q_{\text{ave}} = \frac{Q_{\text{ave}}}{Q_{\text{ave}}} = \frac{Q_{\text{ave}}}{Q_{\text{ave}}}$$

By definition the effectiveness, which is dimensionless, must be in the range $0 \leq \varepsilon \leq 1$.

**Experimental details**

The experimental setup used in this study and the thermocouple locations are shown in fig.4. The specifications of the thermosyphon heat exchanger are given in table 1. The test consists of three main sections: the TPHEX section, the heating loop the cooling section. This was measured using thermocouples (K-Type) with an uncertainty of ±0.1°C at a total of 25 points. The thermocouples were attached to a Data Logger (Agilent Technologies 34970A and the 34970A features 61/2 digits (22bits) of resolution, 0.004% basic DCV accuracy). The device used in the experiment was completely insulated with the glass wool. The amount of heat loss from the evaporator and condenser surfaces was negligible.

The heating loop region is the evaporator section of the TPHEX. This was heated by a voltage regulated heater that controlled the temperature of hot air in the evaporator section at 60/70 and 80 °C. A blower was used to control the heating loop with an inverter (Siemens sinamics g110, output frequency 0 Hz-650 Hz and Cos j ≥ 0.95) to control the speed motor. The air inlet and outlet temperatures of the experimental setup were measured when the system reached a steady state condition.

The cooling loop is in the region of the condenser section of the TPHEX. This caused cooling by refrigeration and the velocity was controlled at 0.5 m/s by use an inverter. The cooling air was allowed to flow through the condenser to cool the TPHEX. The air inlet and outlet temperatures in the condenser zone were measured.

The TPHEX section, for the adiabatic section of the heat exchanger was completely insulated with polyethylene, in fig.5. R134a, ethanol and distilled water were selected as the working fluids with a filling ratio of 50% by total volume of the evaporator section.
Table 1 Specification of thermosyphon heat exchanger and testing condition

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension of thermosyphon heat exchanger (m)</td>
<td>0.2(W)x0.22(L) x 0.5(H)</td>
</tr>
<tr>
<td>Total number of tubes in heat exchanger</td>
<td>13 tube</td>
</tr>
<tr>
<td>Tube outside diameter</td>
<td>20 mm</td>
</tr>
<tr>
<td>Tube thickness</td>
<td>3 mm</td>
</tr>
<tr>
<td>Tube material</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Type and dimensions of fins</td>
<td>Stainless steel annular fn, thickness =2 mm number of fins per tube =16, spacing f =2 cm and radius of fn =0.5 cm staggered, S = 6.3 cm, S = 4 cm</td>
</tr>
<tr>
<td>Thermosyphon arrangement</td>
<td>Staggered, S = 6.3 cm, S = 4 cm</td>
</tr>
<tr>
<td>Working fluid</td>
<td>Distilled Water, Ethanol and R134a</td>
</tr>
<tr>
<td>Filling ratio</td>
<td>50% of total volume evaporator section</td>
</tr>
<tr>
<td>Inlet temperature of hot air</td>
<td>60 70 and 80°C</td>
</tr>
<tr>
<td>Inlet temperature of cool air</td>
<td>25 °C</td>
</tr>
<tr>
<td>Velocity of air</td>
<td>0.5 m/s</td>
</tr>
</tbody>
</table>

Figure 5 Thermosyphon heat exchanger.
Results and discussion

Effect of working fluids on heat transfer rate of thermosyphon heat exchanger

Figure 6 Effect of working fluids on heat transfer rate at different operating temperatures for thermosyphon heat exchanger without fins.

Figure 7 Effect of working fluids on heat transfer rate at different operating temperatures for thermosyphon heat exchanger with fins.

Figure 8 Effect of working fluids on heat transfer rate at an operating temperature of 80 °C for thermosyphon heat exchanger when comparing result with Pipatpaiboon et al. 6.

Figs. 6-7 show the effect of working fluid on heat transfer rates at different operating temperature for the thermosyphon heat exchanger with and without fins (radius of fin is 0.5 cm.). In the experiment, R134a, ethanol and distilled water were selected as the working fluids with a filling ratio of 50% by total volume of the evaporator section. The temperature of hot air in the evaporator section was controlled at 60 70 and 80 °C. The velocity of the cool air in the condenser section was at 0.5 m/s. The experimental results clearly present the effect of the working fluid on the heat transfer rate. Comparing working fluids found that when the working fluid was changed from distilled water to ethanol and to R134a the heat transfer rate increases. In addition, it was found that when the operating temperature increased from 60 70 to 80 °C the thermal efficiency increased under all working fluids. This was due to it increasing the ease of phase change to vapor in the working fluids. In this experiment, R134a showed the maximum heat transfer rate because the boiling point of R134a is lower when compared with distilled water and ethanol. The thermosyphon heat exchangers with fins had heat transfer rates that were higher than the thermosyphon heat exchangers without fins. The fins increased the surface area that enhanced heat transfer.

Pipatpaiboon et al. studied the design, construction and testing of a TPHE in a Thai bio-diesel factory to
reduce the temperature of the bio-diesel after the drying process under actual operating conditions. The thermosyphon was made of 17 steel tubes with an outside diameter of 32 mm and a 1 mm wall thickness. Three working fluids were tested in the thermosyphon: distilled water, methanol and R134a. This experiment found results that were similar, and the heat transfer rate of Pipatpaiboon’s experiment higher this experiment because it is heat exchanger in liquid to liquid which liquid will has specific heat value more than air, see fig. 8.

Effect of working fluids on thermal effectiveness of thermosyphon heat exchanger

Figure 9 Effect of working fluids on thermal effectiveness at different operating temperatures for thermosyphon heat exchanger without fins.

Figure 10 Effect of working fluids on thermal effectiveness at different operating temperatures for thermosyphon heat exchanger with fins.

Figs. 9-10 show the effect of working fluid on thermal effectiveness at different operating temperatures for a thermosyphon heat exchanger with and without fins (radius of fin is 0.5 cm.). The experimental results present the effect of working fluid on thermal effectiveness. When changing the working fluid from distilled water to ethanol and to R134a it was found that the heat transfer rate increases. In addition, it was found that when the operating temperature increased from 60 70 to 80 °C, the thermal efficiency for all working fluid increased. Thus, the thermal effectiveness also increases. In this experiment, R134a showed maximum thermal effectiveness because it had the highest actual heat transfer rate. The thermal effectiveness may be determined from equation (9), which will mean the thermal effectiveness also increases. Comparing the thermosyphon heat exchangers with and without fins found that the TPHEx with fins has a higher heat transfer rate; the thermal effectiveness was also higher than the TPHEx without fins.

When comparing the result with Pipatpaiboon et al. it was found that this result was similar, as shown in fig. 11. When changing the working fluids from distilled water to ethanol and to R134a the thermal effectiveness increases.
Conclusion
The experiments investigated a passive heat transfer enhancement technique with annular fins on the thermosyphon wall and the effect of working fluid on the thermal performance of the TPHEx with annular fins. R134a, ethanol and distilled water were selected as the working fluids. Based on the analysis of the experimental investigations presented in this paper, the following conclusions can be drawn:

1. The working fluid had an effect on heat transfer rate and thermal effectiveness for both thermosyphon heat exchangers, when changing the working fluids from distilled water to ethanol and to R134a, the heat transfer rate and thermal effectiveness increased, at all operating temperatures.

2. The operating temperature had an effect on the heat transfer rate and thermal effectiveness for both thermosyphon heat exchangers using all working fluids.

3. The heat transfer rate and the thermal effectiveness of the thermosyphon heat exchanger with fins under all working fluids and all operating temperatures were higher than the thermosyphon heat exchanger without fins.

Acknowledgment
The authors wish to express thanks to the Energy Policy and Planning Office, Ministry of Energy, Thailand for financial support for this work. Thanks to the Laboratory Heat Pipe Technology, Department of Physics, Faculty of Science and Heat Pipe and Thermal Tools Design Research Unit, Faculty of Engineering, Mahasarakham University.

References


Development of a black galingale dryer using biomass working together with a CLOHP/CV heat exchanger

Pattanapol Meena1*, Songgrot Wongpakdee2, Ardnarong Pholkho3, Siriporn Setwong4

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Abstract
This research was designed to test a black galingale dryer working together with a CLOHP/CV heat exchanger. The dimensions of the drying chamber were 0.6´1.0´1.0 m. The heat exchanger in this study was a closed-loop oscillating heat pipe with check valves (CLOHP/CV) using ethanol and water as the working fluids with a filling ratio of 50% (by total volume of tube). The CLOHP/CV was made of a copper tube with an inner diameter of 2.03 mm. The evaporator, adiabatic and condenser lengths were equal to 200, 100 and 200 mm. The number of turns was 50. The experimental results showed that the moisture content of the black galingale decreased from 143 % (wb) to 2.88% (wb). In addition, the type of working fluid affected the drying time. It was found that the fuel quantity, drying time, heat transfer rate and effectiveness of using ethanol and water as the working fluids were (13.5 kg and 25 kg), (6.30 hr and 10.30 hr), (1851.93 watt and 1078.71 watt) and (0.48 and 0.31) respectively, In conclusion, development of a black galingale dryer using by biomass working together with a heat exchanger was found to be technically suitable for drying black galingale and could reduce energy costs.

Keywords: Closed-loop oscillating heat pipe (CLOHP), check valve (CV), heat exchanger, drying, biomass.

Introduction
Black galingale is a Thai herb used to cure diseases such as dysentery, heart trouble, and diabetes. Black galingale can also cure aches and pains and helps in discharging urine. Moreover, black galingale is a carminative and increases sexual performance. The parts of the black galingale that are used include the leaves, roots and trunk1. Due to its curative abilities, it would be advantageous to keep black galingale for long periods of time so it could be used anytime.

Drying is a dehumidification process of a product using heat transfer. Drying can maintain a product for a long time, which ultimately increases its value. The normal energy used for drying is electrical energy, oil and fuel gas. These energy types are wasteful and expensive. Recently, biomass was used as the energy in a drying process. J. Prasad and V.K. Vijay2 studied a solar-biomass hybrid drier for use with Zingiberofficinale, Curcuma longa l. and Tinosporacordifolia as experimental products. It was found that an initial moisture content of 319.74 %db for their fresh product was dried to a final moisture content of 11.8 %db within 33 hrs. The time for drying with a solar dryer was decreased from 72 - 120 hrs. to 33 - 48 hrs when a solar-biomass hybrid drier was used. M. Mohanrajand P. Chandrasekar3 studied the drying of copra in a forced convection solar drier. It was found that drying copra in the drier reduced its moisture content from about 51.8% to 7.8% and 9.7% in 82h for 1  Assistant professor Heat Pipe Technology Research Laboratory, Department of Physics, Faculty of Science, Mahasarakham University. Email: pattanapol.m@hotmail.com
2  Bachelor degree Heat Pipe Technology Research Laboratory, Department of Physics, Faculty of Science, Mahasarakham University. Email: pattanapol.m@hotmail.com
3  Master degree Heat Pipe Technology Research Laboratory, Department of Physics, Faculty of Science, Mahasarakham University. Email: pattanapol.m@hotmail.com
* Corresponding author : pattanapol.m@hotmail.com
trays located at the bottom and top of the drier, respectively. M.A. Hossain and B.K. Bala studied the drying of hot chili using a solar tunnel drier. It was found that the moisture content of the red chili was reduced from 2.85 to 0.05 kgH₂O kg⁻¹ (db) in 20 h in a solar tunnel drier, and it took 32 h to reduce the moisture content to 0.09 and 0.40 kgH₂Okg⁻¹(db) in improved and conventional sun drying methods, respectively.

A heat pipe is a simple heat exchanger used for heat transfer from a temperature difference between two sources. There are many types of heat pipes. An oscillating heat pipe (OHP) is one type. Normally, an OHP is made from a capillary tube. There are three types of OHPs: closed end oscillating heat pipe (CEOHP), closed-loop oscillating heat pipe (CLOHP) and closed-loop oscillating heat pipe with check valves (CLOHP/CV). The OHP has three sections: evaporator, adiabatic and condenser. The oscillating heat pipe with check valve (CLOHP/CV) is widely accepted as the most efficient heat transfer device for high heat loads. It can transfer the heat by itself using the latent heat of the working fluid in the tubes as stated by Akachi et al. and shown in figure 1.

Figure 1 Type of oscillating heat pipe:
(a) Close-end oscillating heat pipe (CEOHP),
(b) Close-loop oscillating heat pipe (CLOHP) and
(c) Close-loop oscillating heat pipe with Check valves (CLOHP/CV).

Pipatpaiboon et al. studied the effect of inclination angle working fluid and number of check valves on the characteristics of heat transfer in a CLOHP/CV. It was found that the CHOHP/CV equipped with two check valves had the highest heat transfer. In the application of a closed-loop oscillating heat-pipe with check valves (CLOHP/CV), the heat exchanger for the air-preheater is able to use its waste heat in the drying process.
Rittidech et al.\(^7\) studied the heat transfer characteristics of a CLOHP/CV. Rittidech et al.\(^8\) studied the CEOHP air-preheater for energy thrift in the dryer. From the experimental results, it was found that thermal effectiveness increases, and the CEOHP air-preheater achieves energy thrift. Meena et al.\(^9\) studied the application of CLOHP/CV for reducing air humidity in the drying process. It was found that a CLOHP/CV can reduce air humidity during these processes. It has been confirmed that the CLOHP/CV heat exchanger is the most efficient heat transfer device. The heat transfers by itself with the latent heat of the working fluid in the tubes. It also serves as a heat exchanger in the dehumidification process of a product by using heat transfer for dehumidification. This research examines the possibility of drying black galangal using biomass working together with a CLOHP/CV heat exchanger.

**Experimental setup and procedure**

**CLOHP/CV heat exchanger**

A CLOHP/CV was made from a copper capillary tube with an inner diameter of 5 mm. The ratio of the number of check valves to number of turns was 0.2. The working fluids in this case were water and ethanol with a filling ratio of 50% of total volume of the tube. As shown in figure 2, the length of the evaporator, adiabatic and condenser sections were 20, 5 and 10 cm respectively. Moreover, the CLOHP/CV was set up with a biomass tank as shown in figure 3.

**Drying chamber**

The dimensions of the drying chamber were 60 × 100 × 100 cm. The inside of the drying chamber was divided into 4 layers. The distance between each layer was 25 cm and the dimensions of each layer were 53 × 57 cm. The waste hot air from the drying process was released at the top of the drying chamber as shown in figure 4.
Biomass burning chamber

The biomass burning chamber was made from a 30 liter drum as shown in figure 5. The waste hot air from the biomass burning chamber was passed into a 50 liter tank and the CLOHP/CV was set up for heat transfer. A smaller tank was inserted into the 50 liter tank and the clean hot air for the drying process was product in this part.

Figure 5 Biomass burning chamber.

The black galingale dryer using biomass working together with a heat exchanger consist of the CLOHP/CV heat exchanger in two parts; the drying chamber and biomass burning chamber as shown in figure 6.

Data analysis

The data was used to calculate the heat transfer of the test CLOHP/CV using the calorific method. The moisture content of the black galingale was measured at the start and end of each run of the hot air oven method using about 10g samples of finely minced black galingale at 103 °C for 18 h and dried to a constant weight for 4 h at 125 °C. It was found that the initial moisture content was about 143% (wb) to 2.88% (wb). The wet basic moisture content ($M_w$) was calculated by:

$$M_w = \frac{[(w-d)/w] \times 100}{1}$$

Where,

and the effectiveness of the heat exchanger comparing the rate of heat transfer with a heating disposable up of the exchanger of heat can be written as follows:

$$\dot{Q} = mc_p(T_{out} - T_{in})$$

$$\varepsilon = \frac{Q_{act}}{Q_{max}}$$

Where

$$Q_{max} = C_{min}(T_{hi} - T_{co})$$

And

$$Q_{act} = C_c(T_{co} - T_{ci})$$
Results and discussion

The air temperature for the experimental period was 60 °C, and the hot air flow rate was 0.5 m/s. The working fluids were water and ethanol. The black galingale was cut into slices of 2 mm thickness.

Figure 7 shows the relation between the moisture content ratios and drying time with different working fluids. It was found that the black galingale drying time process with the CLOGP/CV heat exchanger and ethanol as working fluid was less than the CLOHP/CV heat exchanger with water as the working fluid. The drying time of the CLOHP/CV heat exchanger with ethanol as the working fluid was 6.30 hr and for the CLOHP/CV heat exchanger with water as the working fluid it was 10.30 hrs.

Figure 6  The black galingale dryer by Biomass work together with heat exchanger.

Figure 7  Relationship between moisture content ratio over drying time.
Figure 8 shows the drying rates over drying time. The drying rate using the CLOHP/CV heat exchanger with ethanol as the working fluid was better than using the CLOHP/CV heat exchanger with water as the working fluid.

![Figure 8](image1.png)

**Figure 8** Relationship between the drying rate and time for drying process.

Fig. 9 shows the relationship between the fuel quantities and drying time. It can be seen that the initial drying used a lot of fuel while trying to heat the ambient air to 60 °C. It was found that the initial fuel quantity for air heating using the CLOHP/CV heat exchanger with ethanol and water as the working fluids were 3 and 2 kilograms respectively. The overall fuel quantities for the drying process using the CLOHP/CV heat exchanger with ethanol and water as the working fluids were 13.5 and 25 kilograms respectively. The drying time using the CLOHP/CV heat exchanger with ethanol as the working fluid (drying time was 6.30 hrs.) was less than the drying time using the CLOHP/CV heat exchanger with water as the working fluid (drying time 10.30 hrs).

![Figure 9](image2.png)

**Figure 9** Relationship between fuel quantities and drying time.

**Effect of working fluid on heat transfer rate**

Figure 10 shows the relationship between the heat transfer rate and the working fluids in the CLOHP/CV. In the CLOHP/CV part 1, it was found that the highest heat transfer rate, when using ethanol as the working fluid in the CLOHP/CV was 1,851.93 watts. In the CLOHP/CV part 2, it was found that the highest heat transfer rate when using ethanol as the working fluid in the CLOHP/CV, was 1,532.84 watt.

![Figure 10](image3.png)

**Figure 10** Relationship between heat transfer rate and working fluids in the CLOHP/CV.
Effect of working fluid on effectiveness

Figure 11 shows the relationship between the effectiveness and working fluids in the CLOHP/CV. In the CLOHP/CV part 1, it was found that the highest effectiveness of 0.48 was when ethanol was used as the working fluid in the CLOHP/CV. In the CLOHP/CV part 2, it was found that the highest effectiveness of 0.32 was when ethanol was used as the working fluid in the CLOHP/CV.

Conclusion

The black galingale dryer using biomass working together with a heat exchanger can save fuel by using a CLOHP/CV as the heat exchanger. The waste hot air from the biomass process was a source of heat for evaporation in the CLOHP/CV. The quality of the fuel for the drying process using the CLOHP/CV heat exchanger with ethanol as the working fluid was better than using the CLOHP/CV heat exchanger with water as the working fluid. Moreover, the drying time using CLOHP/CV heat exchanger with ethanol as the working fluid was less than when using the CLOHP/CV heat exchanger with water as the working fluid.

For the effect of the working fluid on the heat transfer rate and effectiveness, it was found that the CLOHP/CV heat exchanger using ethanol as a working fluid was better than when water was used as the working fluids because the latent heat of the ethanol was the lowest in this experiment. Hence, the moisture content of the black galingale decreased from 143% (db) to 0.28% (db). The fuel quantities, drying time, heat transfer rate and effectiveness, when using ethanol as the working fluid in the CLOHP/CV heat exchanger, were the highest (13.5 kg, 6.30 hrs, 1,851.93 watt and 0.48 respectively).

In conclusion, development of a black galingale dryer using biomass working together with a heat exchanger was found to be technically suitable for the drying of black galingale and achieving energy thrift.

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<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Description</th>
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<tbody>
<tr>
<td>$m$</td>
<td>Mass per unit time</td>
</tr>
<tr>
<td>$C_p$</td>
<td>Specific heat capacity, constant pressure</td>
</tr>
<tr>
<td>$T_{out}$</td>
<td>Outlet temperature at condenser section</td>
</tr>
<tr>
<td>$T_{in}$</td>
<td>Inlet temperature at condenser section</td>
</tr>
<tr>
<td>$E$</td>
<td>Effectiveness</td>
</tr>
<tr>
<td>$Q_{exp}$</td>
<td>Experiment heat transfer rate</td>
</tr>
<tr>
<td>$M_w$</td>
<td>Wet basis moisture content</td>
</tr>
<tr>
<td>$w$</td>
<td>initial weight, kg</td>
</tr>
<tr>
<td>$d$</td>
<td>product weight, kg</td>
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</table>
References


Effect of Inclination Angle on the Heat Transfer Performance of a Closed Loop Oscillating Heat Pipe with Check Valve (CLOHP/CV) and Fins on Tube Wall

Ardnarong Pholkho¹, Teerapat Chompookham², Pattanapol Meena³*
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Abstract
This research aims to study the effect of inclination angle on the heat transfer performance of a Closed-Loop Oscillating Heat-Pipe with Check Valve (CLOHP/CV) with fins on the tube wall. The heat pipe was made from a copper pipe, and the capillary tube had a 5.0 mm inside diameter. There were 24 meandering turns with two check valves. The lengths of the evaporator section and condenser section were 200 mm and the adiabatic section was 100 mm. The working fluid used was water with a filling ratio of 50% of the total volume of the tube. The temperatures for the evaporator section were 60, 70 and 80 °C. Inclination angles were 0, 20, 40, 45, 60, 80 and 90 degrees from the horizontal axis were established. It was found that when the variable temperature increased from 60, 70 to 80 °C heat flux and thermal efficiency increased. In addition, when the inclination angle increased from 0, 20, 40, 45, 60, 80 and 90 degrees heat flux and thermal efficiency increased. Therefore, this research concluded, from the experiment that the heat pipe was a CLOHP/CV. The maximum specific heat flux equaled 1,926.97 W/m² and the maximum thermal effectiveness equaled 0.44, the operating temperature was 80 °C and an angle of inclination to the horizontal axis was 90°

Keywords: Oscillating heat pipe, Check valve, Inclination angles, Heat transfer, Fin

Introduction
The heat pipe is a type of heat transfer equipment that has received much attention. It is a passive device with high performance and thermal conductivity of about 10-100 tons. It can operate even if the difference of temperature between the heat source and the heat sink is small. An oscillating heat pipe (OHP) is one type of heat pipe. It is made from a capillary tube and can be divided into 3 types: closed end oscillating heat pipe (CEOHP): closed-loop oscillating heat pipe (CLOHP) and closed-loop oscillating heat pipe with check valves (CLOHP/CV) fig. 1 An OHP has three sections: evaporator, adiabatic and condenser sections¹-² Rittidech et al.³ presented the CLOHP/CV as the best overall. For the past many years, the CLOHP/CV has been used in a variety of engineering heat transfer applications, such as the cooling of electronic equipment, retaining heat from gasses leaving an engine cooling system, breaking down snow and medical applications, Meena et al.⁴ This study aims to design, construct and test waste heat recovery by closed-loop oscillating heat pipe with check valve from pottery kilns for energy thrift. It has been found that a CLOHO/CV has an application as an air-preheater for reduced relative-humidity in drying systems. Wannapakhe et al.⁵ studied saving the energy from a hot air dryer with a closed-loop oscillating heat pipe (CLOHP/CV) It was found that the hot air dryer with CLOHP/CV can save thermal energy more than a normal hot air dryer. Moreover, if determining savings of electrical energy, the hot air dryer with CLOHP/CV can save more energy than a normal hot air dryer by an average of 28.13%. Heat transfer enhancement techniques have been widely applied to heat exchanger equipment. In the design of heat exchangers heat transfer efficiency must take into account size, shape and proper

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³ Assistant Professor Heat PipeTechnology Research Laboratory. Department of Physics, Faculty of Science, Mahasarakham University. Email: pattanapol.m@hotmail.com
* Corresponding author: pattanapol.m@hotmail.com
use. Currently, developing heat exchangers focuses on two methods: an Active method and a Passive method. Most researchers are often interested in the Passive method because it does not require external power to stimulate the increase of surface area inside or outside the pipe. For several years, many researchers have devoted research to thermal performance.6-9. Wannapakhe et al.10 investigated the effect of aspect ratios (evaporator length to inner diameter of capillary tube), inclination angles, and concentrations of silver nanofluid on the heat transfer rate of a closed-loop oscillating heat pipe with check valves (CLOHP/CV). It was found that the heat transfer rate of the CLOHP/CV using silver nanofluid as a working fluid was better than that of the heat transfer rate when pure water is used because the silver nanofluid increases the heat flux by more than 10%. Nuntaphan et al.11 presents the performance of a wire-on-tube heat exchanger of which the wire is an oscillating heat pipe. The experiments for this heat exchanger were performed in a wind tunnel by exchanging heat between hot water flowing inside the heat exchanger tubes and air stream flowing across the external surface. R123, methanol and acetone were selected as working fluids for the oscillating heat pipe. The results of the models agreed very well with the experimental data with fins often employed to effectively improve the overall performance of the heat pipe12-14. Some general research has reported on the effects of inclination angle on heat transfer performance of closed-loop oscillating heat-pipe with check valve (CLOHP/CV) and with fins at tube wall. In response to the lack of detailed data, this study focuses on determining the actual thermal performance of such a system through experimental investigations.

**Theoretical consideration**

The Oscillating Heat Pipe (OHP), by Akachi et al10, was invented as a new type of heat-pipe made from a capillary tube that has been applied to cool small electronic devices. This new type of heat-pipe is called an oscillating heat-pipe (OHP), and has the same basic operational principle as the oscillating movement of the fluid and phase change phenomena. The first type is a closed-end oscillating heat pipe (CEOHP). In this type, a capillary tube is bent into many meandering turns and closed at both ends. The second type is a closed loop oscillating heat-pipe (CLOHP), in which the capillary tube is connected at both ends to form close-loop. The third type is a closed-loop oscillating heat-pipe with check valves (CLOHP/CV). This type is a closed-loop oscillating heat-pipe, in which both ends of the capillary tube are connected to form a closed-loop. The loop has one or more check valves11, see Fig 1.

![Type of Oscillating Heat Pipes: (a) CEOHP, (b) CLOHP, (c) CLOHP/CV](image-url)
Heat transfer characteristics the CLOHP/CV

Heat transfer characteristics of the Oscillating heat pipe with Check Valve (CLOHP/CV). Determination of heat transfer to the condenser section uses the calorific method calculation by measuring the temperature of the heating fluid at the inlet and outlet of the condenser. The values are calculated using the following equation.

\[ Q = m \cdot C_p \cdot (T_{out} - T_{in}) \]  

(1)

Where \( Q \) is the heat transfer rate (W), \( m \) is the mass flow rate (kg/s), \( C_p \) is the specific heat (J/kg·°C), \( T_{in} \) is the inlet temperature (°C) and \( T_{out} \) is the outlet temperature (°C).

The mass flow rate is given by equation.

\[ m = \rho V A \]  

(2)

Where \( Q \) is the density (kg/m³), \( V \) is the velocity (m/s), \( A \) is the area (m²). The heat transfer rate determined from the equation.

\[ q = \frac{Q}{A_c} = \frac{Q}{\pi D_o L_c N} \]  

(3)

Where \( q \) is the heat flux (W/m²), \( D_o \) is the Outside diameter of the tube (mm), \( L_c \) is the length of condenser section (mm), \( N \) is the number rods of heat pipe condenser section.

Fins efficiency

\( q \) Performance of the fin is the ratio between the heat transfer surface cooling fins, and is obtained from the following equation.

\[ \eta_{fin} = \frac{Q_{fin}}{Q_{max}} \]  

(4)

The heat transfer rate of fin efficiency is given by the following equation.

\[ Q_{max} = A_{fin} \cdot (T_{out} - T_{in}) \]  

(5)

And the heat transfer rate of the fins is given by the following equation.

\[ Q_{fin} = n \cdot \eta_{fin} \cdot h \cdot (T_b - T_a) \]  

(6)

Fin surface area exposed to the fluid is obtained from

\[ A_{fin} = \left[ 2\pi \left( r_o^2 - r_i^2 \right) + 2\pi r_i t \right] \]  

(7)

When \( \eta_{fin} \) is the fins efficiency, \( Q_{fin} \) is the heat transfer Rate at fin surface (W), \( Q_{max} \) is the heat transfer rate at the maximum surface fins (W), \( A_{fin} \) is the fin surface area exposed to fluid.(m²), \( h \) is the Coefficient of heat transfer.(W/m²-K), \( T_b \) and \( T_a \) is the temperature of the pipe surface and ambient temperature, respectively. (°C), \( r_i \) is the internal radial of fins (mm), \( r_o \) is the external radius of fin (mm), \( t \) is the thickness of fin (mm), and \( n \) is the number of fin By Karl, A., Gardner, analyzed the performance of a circular copper fin, then analyzed in the form of graphs for ease of use. As shown in Fig 2.

Figure 2 Performance graphs of circular copper fin Karl A. Gardner.

The y axis is given by the following equation.

\[ y = \frac{r_o}{r_i} \]  

(8)

And the x axis is given by the following equation.

\[ x = L \frac{h}{kt} \]  

(9)

When \( L \) is the length of the tube surface to the fin (mm), \( k \) is the thermal conductivity of the fin material (W/m²-K).
The effectiveness of the CLOHP/CV with fins. The effectiveness (ε) of CLOHP/CV can be defined as the ratio of the actual heat transfer rate ($Q_{act}$) for a CLOHP/CV to the maximum possible heat transfer rate ($Q_{max}$). This can be represented by the following equation:

$$\varepsilon = \frac{Q_{act}}{Q_{max}}$$  \hspace{1cm} (10)

When

$$Q_{act} = m_c C_{p,c}(T_{c,in} - T_{i,in}) = m_c C_{p,c}(T_{c,in} - T_{i,in})$$  \hspace{1cm} (11)

As

$$e_c = m_c C_{p,c}(T_{c,in} - T_{i,in})$$  \hspace{1cm} (12)

$$e_c = m_c C_{p,c}(T_{c,in} - T_{i,in})$$  \hspace{1cm} (13)

From which it follow;

$$\varepsilon = \frac{Q_c}{Q_{max}} = \frac{Q_c}{Q_{max}} = \frac{Q_{ave}}{Q_{max}}$$  \hspace{1cm} (14)

Where the maximum possible heat transfer rate ($Q_{max}$) can be represented by the following equation:

In case $C_c < C_h$

$$Q_{max} = C_h (T_{c,in} - T_{c,in})$$  \hspace{1cm} (15a)

In case $C_c > C_h$

$$Q_{max} = C_h (T_{c,in} - T_{c,in})$$  \hspace{1cm} (15b)

When $C_c = m_c C_{p,c}$ and $C_h = m_h C_{p,h}$

From equation 19a and 20b can be to write the general expression [19]:

$$Q_{max} = C_{min} (T_{i,in} - T_{c})$$

$$Q_{ave} = (Q_{ave} + Q_c) / 2$$  \hspace{1cm} (16)

By definition the effectiveness, which is dimensionless, must be in

Experimental methods

The CLOHP/CV design

An important factor that has to be considered in building a CLOHP/CV is the tube diameter. The maximum inner diameter of the CLOHP/CV can be defined by the equation derived by Maezawa et al. [15]

$$d_{max} \leq 2 \sqrt{\frac{\sigma}{\rho g}}$$  \hspace{1cm} (18)

Where $d_{max}$ [m] is the maximum inner diameter of the capillary tube, $\sigma$ [N/m] is the surface tension of the fluid, $\rho$ [kg/m$^3$] is the liquid density, and $g$ [m/s$^2$] is the gravitational acceleration.

Figure 3 CLOHP/CV using in experiment
Figure 4 Schematic diagram of the experimental setup.

Figure 5 Specification of fin
Table 1 – Specification of the Oscillating heat pipe with check valve (CLOHP/CV).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specification</th>
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<tr>
<td>Capillary tube</td>
<td>Inlet diameter (mm) 5.0</td>
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<tr>
<td></td>
<td>Material Copper</td>
</tr>
<tr>
<td></td>
<td>Number of turn 24</td>
</tr>
<tr>
<td></td>
<td>Thickness (mm) 1.0</td>
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<tr>
<td></td>
<td>Radius of turn (mm) 40</td>
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<td></td>
<td>Length total (mm) 500</td>
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<td></td>
<td>Length of condenser (mm) 200</td>
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<td></td>
<td>Fin pitch (mm) 10</td>
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<td></td>
<td>Diameter (mm) 16</td>
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Table 2 Experimental condition.

<table>
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<tbody>
<tr>
<td>Inlet temperature evaporator section (°C) 60, 70, 80</td>
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<td>Inlet temperature of air (°C) 25</td>
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<td>Working fluid Water</td>
</tr>
<tr>
<td>Velocity of air (m/s) 0.5</td>
</tr>
<tr>
<td>Inclination Angle (degree) 0, 20, 40, 45, 60, 80, 90</td>
</tr>
<tr>
<td>Filling ratio 50 % by volume of total pipe</td>
</tr>
</tbody>
</table>
Specifications of the oscillating heat pipe including a check valve (CLOHP/CV). The check valve is a floating-type valve that consists of a stainless steel ball and a copper tube in which a ball stopper and conical valve seat are provided at the ends of the top and bottom of the check valve case, respectively (Fig. 6). The ball can move freely between the ball stopper and the conical valve seat. The conical valve seat contacts the stainless-steel ball in order to prevent the working fluid flow reversal. The ball stopper allows the working fluid to travel to the condenser section for transferring heat. The CLOHP/CV operation principle relies on three driving forces: surface tension force, gravity force, and oscillating force. These forces are influenced by many parameters. This study selected water as the working fluid because of the latent heat of vaporization equal to 2455 kJ/kg and can be packed very high in copper pipe without corrosion reaction between water and copper pipes resulting in a long period of heat pipe life.

The experimental setup used in this study and the thermocouple locations is shown in Fig. 4. The specifications of oscillating heat pipe including a check valve (CLOHP/CV) are given in Table 1. The test consists of three main sections: the CLOHP/CV section, the heating loop, the cooling section. For experimental purposes the device is completely insulated with glass wool. The amount of heat loss from the evaporator and condenser surface is negligible. The adiabatic section of the heat exchanger is completely insulated with polyethylene. In Figure 3, the experimental procedure in the CLOHP/CV section is repeated for different inclinations of the test section, i.e., (0°, 20°, 40°, 45°, 60°, 80° and 90°) to the horizontal. Measurements were made using thermocouples (K-type) with an uncertainty of ±0.1°C at a total of 25 points. These are attached to thermocouples at a Data Logger (Agilent Technologies 34970A. The 34970A features 61/2 digits (22 bits) of resolution, 0.004% basic DCV accuracy). The heating loop is in the region of the evaporator section of CLOHP/CV. The air inlet and outlet temperature of the experimental setup are measured as the system reaches a steady state condition. The cooling loop is in the region of the condenser section of CLOHP/CV. This cooling is by refrigeration and the velocity is controlled at as 0.5 m/s by an inverter. The cooling air is allowed to flow through the condenser to cool the CLOHP/CV. Air inlet and outlet temperatures in the condenser zone are measured.
Results and discussion

Effect of inclination angles on the heat transfer rate

![Graphs showing the effect of inclination angle on heat transfer rate]

Fig. 7 (a-c) shows the effect of inclination angle and presence or absence of fins (radius of fin is 0.5 cm) on the heat transfer rate of the CLOHP/CV using water as the working fluid. The operating temperatures were 60, 70 and 80°C with an air velocity at the condenser section of 0.5 m/s. It was found that when the inclination angle increased from 0, 20, 40, 45, 60, 80 to 90°, the heat transfer rate also increased. Thus, the inclination angle of the CLOHP/CV has an effect on the heat transfer rate because of a pressure difference brought about by the hydrostatic head of the liquid being positive, negative or zero. This depended on the fluid’s density, acceleration from gravity, tube length and inclination angle of the CLOHP/CV to the horizontal axis. This result is similar to that of Wannapakhe et al. (2009) as shown in Figure 8. The pressure difference may be determined from the following equation:

\[ \Delta P = \rho g L \sin \theta \]  \hspace{1cm} (19)

In which \( \theta \) is positive when the evaporator is lower than the condenser.
Figure 9  Effect of operating temperature and inclination angle on the heat transfer rate of CLOHP/CV.

The results of different working temperatures on the heat transfer rate of the CLOHP/CV are shown in Fig.9. The experimental results clearly present the effect of working temperatures on the heat transfer rate. Comparing the working temperatures found that the heat transfer rates for both CLOHP/CVs increased when the operating temperature increased from 60, 70 to 80°C. This was due to the working fluids being able to simply and quickly undergo a phase change to vapor. The CLOHP/CV with fins had heat transfer rates that were higher than the CLOHP/CV without fins. The fin increases the surface to enhance heat transfer.

Effect of inclination angles on the thermal effectiveness

Figure 10  (a-c) Effect of inclination angles and presence or absence of fins on the thermal effectiveness of a CLOHP/CV at evaporator operating temperatures of 60, 70 and 80°C respectively.
For both CLOHP/DVs, the heat transfer rate and the thermal effectiveness increased as the inclination angle increased because the higher inclination angle had more vapor bubble flow than the lower inclination angle. The operating temperature had an effect on the heat transfer rate and thermal effectiveness for both the CLOHP/CVs because when the operating temperature increased the working fluid boiled there was a latent heat increase.

The heat transfer rate and the thermal effectiveness of the CLOHP/CV with fins at all inclination angles and all temperatures were higher than those of the CLOHP/CV without fins. The fins increased the surface area thereby enhancing heat transfer.

Acknowledgment
The authors wish to express thanks to the Energy Policy and Planning Office, Ministry of Energy, Thailand for the financial support of this work. Thanks to the Laboratory of Heat Pipe Technology, Department of Physics, Faculty of Science and Heat Pipe and Thermal Tools Design Research Unit, Faculty of Engineering, Mahasarakham University.

References


Acaricidal activities of crude extract derived from *Annona squamosa* Linnaeus leaves against cattle tick, *Rhipicephalus microplus* Canestrini (Acari: Ixodidea)

Bounthavy Vongkhamchanh¹*, Paweena Rattanasena², Prapassorn Bussaman³

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Abstract

*Rhipicephalus microplus* Canestrini (Acari: Ixodidea) or cattle tick is considered as harmful and economically important external parasite, and its infestation has affected the cattle milk and meat productions worldwide. Therefore, this study aimed to evaluate the use of crude extract derived from *Annona squamosa* Linnaeus leaves for controlling engorged female *R. microplus* adults. The hexane extract of *A. squamosa* Linn. leaves at the concentrations of 4,000, 8,000, 16,000 and 32,000 ppm was used to immerse female ticks, which then were constantly monitored for their mortality and egg-laying rates for 72 h. The crude leaf extract of *A. squamosa* Linn. was shown to induce tick mortality in a dose-dependent manner with the LC₉₉ value equivalent to 11,157 ppm. The concentration of the extract at 16,000 ppm was found to be the most effective and could reduce the number of ticks for 95.00±5.00% within 48 h and 100% within 72 h. The concentration of 32,000 ppm was shown to completely suppress the oviposition of females (100%), followed by 16,000 ppm (99.71±0.28%), 8,000 ppm (95.93±2.48%), and 4,000 ppm (84.57±6.53%). The effect of storage duration on efficacy of the extracts was examined and the results showed that the extract stored for 1 day could cause significantly high rates of tick mortality (100%) than the extract stored for 90 days (80.00±8.16%). Hence, this revealed that the crude hexane extract of *A. squamosa* Linn. leaves at 16,000 ppm had the highest acaricidal activity against *R. microplus* females, and the long term storage caused the marked reduction on the efficacy of the extract. This data may be helpful for further development of *A. squamosa* Linn. leaf extracts as biological control products against *R. microplus*.

Keywords: *Rhipicephalus microplus*, *Annona squamosa* Linn., crude plant extract, acaricide, biocontrol

Introduction

*Rhipicephalus microplus* (Acari: Ixodidae), known as cattle tick, is considered as one of the blood-sucking arthropods/ectoparasites that are serious threats to a variety of domestic and wild animals throughout the world. Infestation by *R. microplus* may result in severe losses of dairy and meat productions of cattle and goats, especially in the tropical and subtropical regions. In addition, *R. microplus* is also identified as an important vector that transmitting several pathogens to humans and animals, including *Babesia bovis*, *Babesia bigemina* and *Anaplasma marginale*.¹ The chemical acaricides have often been used for controlling infestation by *R. microplus* ticks. However, there are a number of undesirable consequences. Since acaricidal chemicals have non-specific harmful actions to both living creatures and environments, resulting in environmental pollution, contamination in milk and meat products, tick’s resistance, and subsequent increases in cost for controlling measures and productions². Therefore, several countries are developing sustainable, alternative methods for tick control. One is the use of extracts from herbal plants as they have been found to have many advantages,

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including effective acaricidal activities, precise actions against various species of ticks, and also biodegradable properties, which are unlikely to contaminate and damage the environments, humans and animals\textsuperscript{3}.

\textit{Annona squamosa} Linn. (Custard apple) belongs to the Annonaceae family. This plant is native to the West Indies and can be commonly cultivated throughout India and many Asian countries. \textit{A. squamosa} Linn. is deciduous trees with small well-branches and shrubs where bearing edible fruits and has been found to possess a variety of medicinal properties, such as insecticidal, free radical scavenging, hypoglycemic and anti-diabetic activities\textsuperscript{4}. Moreover, several bioactive compounds have been isolated from \textit{A. squamosa} Linn. leaves, barks and fruits, such as \(\beta\)-caryophyllene, \(\alpha\)-pinene, \(\alpha\)-humulene, \(\alpha\)-gurjunene and limonene, which were employed as pesticidal and parasiticidal agents\textsuperscript{5,6}. However, to the best of our knowledge, there is limited information of using the extracts derived from \textit{A. squamosa} Linn. leaves as biological control agents against \textit{R. microplus} ticks.

**Objective**

The aim of this study was to determine the effective concentrations and storage durations of crude hexane extract of \textit{A. squamosa} Linn. leaves for controlling against the engorged female \textit{R. microplus} ticks.

**Materials and Methods**

Preparation of \textit{A. squamosa} Linn. extract

\textit{A. squamosa} Linn. leaves were collected from Pakse district, Champasak province, in the Southern region of Laos PDR. \textit{A. squamosa} Linn. leaves were dried at 40\textdegree C for 72 h, ground into fine powder and sieved through the mesh with 5-mm pore’s size. Hexane was added to the ground material at the ratio of 30\% (w/v) and shaken at 200 rpm for 72 h. Subsequently, the mixture was filtered through Whatman filter paper No. 1 and evaporated at 45\textdegree C by vacuum rotary evaporator. After that, the concentrated crude extract was collected, transferred to glass vial and kept at 4\textdegree C for long term storage\textsuperscript{5}. The crude extract was re-suspended in 2\% (w/v) tween solution (diluted with sterile distilled water) at the appropriate concentrations (4,000-32,000 ppm) before being used for further experiment.

Collection and preparation of engorged female \textit{R. microplus} ticks

The engorged female \textit{R. microplus} ticks were collected in the morning from naturally infested cattle pasture on a local ranch in Laos PDR. The cattle were free from any acaricidal treatments for at least 45 days prior the collection process. The appropriate sites of the cattle for collecting engorged female ticks were perineal area, external ear, udder, scrotum and sternum. Next, the engorged female ticks were washed with sterile water, dried using paper towels, and placed in plastic boxes with the perforated cover to allow ventilation. The body weight of each female adult ticks ranged between 0.1 - 0.25 with the average weight of 0.118 g. These female ticks were kept under laboratory conditions at 27±1.5\textdegree C and 70 – 80\% relative humidity (RH)\textsuperscript{7,8}.

Evaluation of acaricidal and egg laying inhibition activities of \textit{A. squamosa} Linn. extract

The experiment was performed in four replicates using ten female ticks for each replicate (n=10). Female ticks were individually immersed into different concentrations of crude hexane \textit{A. squamosa} Linn. extract, i.e., 4,000, 8,000, 16,000 to 32,000 ppm, for 2 minutes. Female ticks in the control group were treated with 2\% tween solution (diluted in sterile distilled water). Treated ticks were then removed and placed separately in each glass vials layered with moist filter paper. The vials were placed in the incubator at 27±1.5\textdegree C and 70–80\% RH. These female ticks were kept under laboratory conditions at 27±1.5\textdegree C and 70 – 80\% relative humidity (RH)\textsuperscript{7,8}. Index of egg laying (IE) and \% inhibition of egg laying (%IE) were calculated by formulas below\textsuperscript{9}

\[
\text{IE} = \frac{\text{Weight of laid eggs (g)}}{\text{Weight of females (g)}}
\]

\[
\%\text{IE} = \frac{\text{IE control group - IE treated group}}{\text{IE control}} \times 100
\]
Effect of time storage on the efficacy of A. squamosa Linn. extract
The crude hexane extract of A. squamosa Linn. leaves was stored at 4°C in the dark for 1 or 90 days. After that, efficacy of the extract at 16,000 ppm was evaluated on engorged female ticks as described in previous section.

Statistical analysis
The average percentages of mortality and inhibition of egg laying of adult female ticks were analyzed by One-way ANOVA. The experimental treatments were compared using Duncan’s multiple range test. The significant difference between treatments was determined at 95% confidence (P<0.05). The lethal concentration 99% (LC99) was calculated by Probit analysis.

Results
In this study, the different concentrations of A. squamosa Linn. leaf extract were evaluated for their acaricidal properties against engorged, adult female R. microplus ticks. The results showed that leaf extract of A. squamosa Linn. at 16,000 and 32,000 ppm concentrations induced significantly high levels of tick mortality (Table 1), which both resulting in killing 95.00±5.00% of ticks within 48 h and 100% within 72 h (P<0.05). The action of A. squamosa Linn. extract against female ticks was clearly in a dose-dependent manner with calculated LC99 value at 11,157 ppm. No dead ticks were found in the control group (treated with 2% tween solution). In addition, more than 50% of tick mortality was observed as early as 12 and 24 h when applying with A. squamosa Linn. leaf extract at the concentrations of 32,000 and 16,000 ppm, respectively.

Table 1 Mortality of R. microplus after treatments with various concentrations of A. squamosa Linn. leaf hexane extract.

<table>
<thead>
<tr>
<th>Concentration of Annona squamosa Linn. leaf extract</th>
<th>%mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3h</td>
</tr>
<tr>
<td>4,000</td>
<td>0.00±0.00(^{ab})</td>
</tr>
<tr>
<td>8,000</td>
<td>0.00±0.00(^{b})</td>
</tr>
<tr>
<td>16,000</td>
<td>0.00±0.00(^{b})</td>
</tr>
<tr>
<td>32,000</td>
<td>15.00±9.57(^{a})</td>
</tr>
<tr>
<td>Control (2%tween)</td>
<td>0.00±0.00(^{b})</td>
</tr>
<tr>
<td>P-value</td>
<td>0.0509</td>
</tr>
</tbody>
</table>

Note: Different letters in the same column indicate significant differences between the treatments (P<0.05).

Percentages of inhibition of R. microplus egg laying (%IE) after exposure to various concentrations of A. squamosa Linn. leaf hexane extract were shown in Table 2. The results indicated that A. squamosa Linn. leaf extract at the concentration of 8000 ppm could significantly and severely inhibit female oviposition when compared to the control group (P<0.05). The maximum %IE was observed when applying with the A. squamosa Linn. leaf extract at the concentration of 32,000 ppm (100%), followed by 16,000 ppm (99.71±0.28%), 8,000 ppm (95.93±2.48%) and 4,000 ppm (84.57±6.53%). Although the extract at the concentration of 4,000 ppm was shown to induce significantly lower %IE than those of the higher concentrations (P<0.05), it still found to be able to induce more than 80% IE.

The hexane extract of A. squamosa Linn. at 16,000 ppm was clearly shown to be effective against engorged female ticks (Tables 1 and 2). Therefore, this concentration was employed for further evaluation of the effect of storage duration on the efficacy of A. squamosa Linn. leaf extract. The results indicated that long term storage of A. squamosa Linn. leaf extract significantly
affected its efficacy to induce tick's mortality \((P<0.005)\) (Table 3). However, the extract that was kept for 90 days was still capable of killing as high as 75.00±9.57% and 80.00±8.16% of ticks within 48 and 72 h, respectively. The results of inhibition of \(R.\ microplus\) egg laying (%IE) after being exposed to 16,000 ppm of \(A.\ squamosa\) Linn. extract that was stored for 1 or 90 days were shown in Table 4. The results showed that long term storage of the extract at 4 °C did not affect %IE of engorged female ticks. Also, the efficacy of the extract was still as high as 95.53±2.92% after 90 days of storage.

Table 2 Percentages of inhibition of \(R.\ microplus\) egg laying (%IE) after treatments with various concentrations of \(A.\ squamosa\) Linn. leaf extract.

<table>
<thead>
<tr>
<th>Concentration of Annona squamosa Linn. leaf extract</th>
<th>Weight of female ticks (g)</th>
<th>Weight of egg mass of female ticks (g)</th>
<th>Index of egg laying (IE)</th>
<th>Inhibition of egg laying (%IE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,000</td>
<td>0.113±0.01</td>
<td>0.0124±0.01b</td>
<td>0.1034±0.04b</td>
<td>84.57±6.53b</td>
</tr>
<tr>
<td>8,000</td>
<td>0.120±0.02</td>
<td>0.0034±0.01c</td>
<td>0.0272±0.02c</td>
<td>95.93±2.48a</td>
</tr>
<tr>
<td>16,000</td>
<td>0.117±0.01</td>
<td>0.0002±0.01c</td>
<td>0.0019±0.01c</td>
<td>99.71±0.28a</td>
</tr>
<tr>
<td>32,000</td>
<td>0.122±0.01</td>
<td>0.0000±0.00c</td>
<td>0.0000±0.00c</td>
<td>100.00±0.00a</td>
</tr>
<tr>
<td>Control (2%tween)</td>
<td>0.115±0.01</td>
<td>0.0750±0.01a</td>
<td>0.6533±0.03a</td>
<td>0.00±0.00c</td>
</tr>
<tr>
<td>P-value</td>
<td>0.9365</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0285</td>
</tr>
</tbody>
</table>

Note: Different letters in the same column indicate significant differences between the treatments \((P<0.05)\).

Table 3 Mortality of \(R.\ microplus\) after treatments with 16,000 ppm of \(A.\ squamosa\) Linn. leaf extract that was stored for 1 or 90 days.

<table>
<thead>
<tr>
<th>Treatment-storage duration</th>
<th>%mortality</th>
<th>3h</th>
<th>6h</th>
<th>12h</th>
<th>24h</th>
<th>48h</th>
<th>72h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annona squamosa-1 day</td>
<td></td>
<td>0.00±0.00</td>
<td>6.25±6.25a</td>
<td>25.00±0.00ab</td>
<td>100.00±0.00a</td>
<td>100.00±0.00a</td>
<td>80.00±8.16b</td>
</tr>
<tr>
<td>Annona squamosa-90 days</td>
<td></td>
<td>0.00±0.00</td>
<td>0.00±0.00b</td>
<td>0.00±0.00b</td>
<td>0.00±0.00b</td>
<td>0.00±0.00b</td>
<td>0.00±0.00b</td>
</tr>
<tr>
<td>Control (2%tween)</td>
<td></td>
<td>0.00±0.00</td>
<td>0.00±0.00b</td>
<td>0.00±0.00b</td>
<td>0.00±0.00b</td>
<td>0.00±0.00b</td>
<td>0.00±0.00b</td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td>0.0000</td>
<td>0.4055</td>
<td>0.0102</td>
<td>0.0209</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Note: Different letters in the same column indicate significant differences between the treatments \((P<0.05)\).

Table 4 Percentages of inhibition of \(R.\ microplus\) egg laying (%IE) after treatments with 16,000 ppm of \(A.\ squamosa\) Linn. leaf extract that was stored for 1 or 90 days.

<table>
<thead>
<tr>
<th>Treatment-storage duration</th>
<th>Weight of female ticks (g)</th>
<th>Weight of egg mass of female ticks (g)</th>
<th>Index of egg laying (IE)</th>
<th>Inhibition of egg laying (%IE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annona squamosa-1 day</td>
<td>0.108±3.30</td>
<td>0.000±0.00b</td>
<td>0.000±0.00b</td>
<td>100.00±0.00a</td>
</tr>
<tr>
<td>Annona squamosa-90 days</td>
<td>0.124±7.37</td>
<td>0.005±0.01b</td>
<td>0.046±0.03b</td>
<td>95.53±2.92a</td>
</tr>
<tr>
<td>Control (2%tween)</td>
<td>0.122±5.60</td>
<td>0.109±0.01a</td>
<td>1.031±0.10a</td>
<td>0.00±0.00b</td>
</tr>
<tr>
<td>P-value</td>
<td>0.196</td>
<td>0.0001</td>
<td>0.0004</td>
<td>0.1768</td>
</tr>
</tbody>
</table>

Note: Different letters in the same column indicate significant differences between the treatments \((P<0.05)\).
Discussion and Conclusion

The use of natural bioactive compounds to replace chemical pesticides has played an important role in the recent years. Obviously, this is because the adverse consequences of chemical pesticides, especially in the cattle meat and dairy production industries. This study hence focused on using A. squamosa Linn. leaf extract against engorged female R. microplus ticks. A. squamosa Linn. is widely cultivated in Lao PDR and its leaves are rather considered as agricultural waste without any further values. Therefore, application of this agricultural waste may provide great benefits and opportunities to the farmers to use it as cheap, natural and safe agent for controlling R. microplus ticks.

The previous report revealed that A. squamosa Linn. had a variety of bioactive constituents, including 4-((2-nitroethyl)-1-((6-O-β-D-xylopyranosyl-β-D-glucopyranosyl)-oxy) benzene, annonaine, benzyltetrahydro-isoquinoline, borneol, camphene, camphor, car-3-ene, carvone, β-caryophyllene, eugenol, farnesol, geraniol, 16-hentriaconpane, hexacontanol, higenamine, isocorydine, limonene, linalool, linalool acetate, menthone, methylyanthranilate, methylsalicylate, methylheptenone, p-(hydroxybenzyl)-6, 7-(2-hydroxy,4-hydro) isoquinoline, n-octacosanol, á-pinene, ß-pinene, rutin, stigmasterol, ß-sitosterol, thymol and n-triacontanol. Moreover, alkaloid extracts from A. squamosa Linn. at the concentrations of 50 - 200 ppm were shown to have larvicidal, chemosterilant and growth-regulating activities against Anopheles stephensi. Also, sesquiterpenes and monoterpenes, which were considered as major bioactive compounds of Annona species, have been applied as insecticidal agents against the cabbage looper (Trichoplusia ni). Moreover, the acaricidal efficacy of A. squamosa Linn. seed extracts was previously evaluated against R. microplus, and the studies showed that its seed extract at the concentration of 8% could kill up to 70.8% of ticks after 24 h of application and it also severely suppressed the egg production of engorged female ticks. In addition, the crude ethanol extract of A. squamosa Linn. seeds at 10% concentration could kill 87% of R. microplus within 48 h by immersion technique. Furthermore, the adulticidal and larvicidal activities of A. squamosa Linn. leaf extract against Haemaphysalis bispinosa were also assessed and the results showed that application of crude hexane extract of A. squamosa Linn. leaves at 2,500 ppm resulted in as high as 100% mortality of H. bispinosa adults within 24 h and the lethal concentration that killed 50% of H. bispinosa adults (LC50) was determined at 145.39 ppm. The results of this study may suggest that crude hexane extract of A. squamosa Linn. leaves was highly effective at killing engorged female R. microplus ticks and also severely inhibiting their egg laying. Although long term storage (90 days) could reduce its efficacy to induce tick's mortality, its ability to suppress tick's egg laying still remained stable. The future development of A. squamosa Linn. extracts as insecticides should thus consider the methods for preservation of its efficacy for both killing and inhibiting of insect oviposition.

Acknowledgments

We would like to express our sincere gratitude to the Asia-Uninet program and Mahasarakham University for financial support. Thanks to the Department of Biotechnology, Faculty of Technology, Mahasarakham University for providing laboratory facilities.

References


คำแนะนำสำหรับผู้นิพนธ์

วารสารวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยมหาสารคาม กำหนดพิมพ์ปีละ 6 ฉบับ ผู้นิพนธ์ทุกคนสามารถส่งเรื่องมาพิมพ์ได้โดยไม่ต้องเป็นสมาชิก และไม่จำเป็นต้องสมัครสมาชิกวารสารวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยมหาสารคาม แต่การส่งเรื่องพิมพ์ไว้ในวารสารจะต้องมีสาระที่น่าสนใจ หรือคุณค่าใหม่ที่ทันสมัย รวมทั้งเรื่องที่มีประโยชน์ต่อผู้อ่าน และจะต้องมีเรื่องที่ไม่เคยปรากฏในวารสารอื่นมาก่อนและไม่อยู่ระหว่างพิจารณาพิมพ์ในวารสารใด บทความอาจถูกตัดแปลง แก้ไข แปลงรูปแบบ และส่วนหัวท้ายที่ตรงตามระเบียบการพิมพ์หนังสือ ทั้งนี้เพื่อให้วารสารมีคุณภาพในระดับมาตรฐานสากลและนำไปอ้างอิงได้

การเตรียมต้นฉบับ

1. ต้นฉบับพิมพ์เป็นภาษาไทยหรือภาษาอังกฤษก็ได้ แต่จะต้องมีบทคัดย่อทั้งภาษาไทยและภาษาอังกฤษ การใช้ภาษาไทยให้ใช้หลักการใช้คำศัพท์ที่เป็นภาษาอังกฤษตามหลักของราชบัณฑิตยสถานให้สอดคล้องกับการเขียนภาษาอังกฤษในบทความ ยกเว้นกรณีจำเป็น เช่น คำศัพท์ทางวิชาการที่ไม่มีทางแปล หรือคำที่ใช้แล้วทำให้เข้าใจง่ายขึ้น คำศัพท์ภาษาอังกฤษที่เข้าเป็นภาษาไทยให้ใช้หลักการที่เกี่ยวข้องกับ ยกเว้นข้อคริบ การระบุคุณภาพทางวิชาการของผู้เขียนภาษาอังกฤษตามที่กองบรรณาธิการเห็นสมควร

2. ขนาดของต้นฉบับ ใช้กระดาษขนาด A4 (8.5x11 นิ้ว) และพิมพ์ออกกระดาษด้านละ 1 นิ้ว จัดเป็น 2 คอลัมน์ ระยะห่างระหว่างบรรทัดในภาษาที่ใช้เป็น double space ภาษาอังกฤษล้วนให้เป็น single space


4. การพิมพ์ต้นฉบับ ผู้เสนองานจะต้องมีต้นฉบับเป็นไฟล์รูปแบบของผู้นำเสนอต่อไปนี้ ได้แก่ 
   - .doc (MS Word) หรือ .rtf (Rich Text)

5. จำนวนหน้า ความยาวของบทความไม่เกิน 15 หน้า รวมตาราง รูป ภาพ และเอกสารอ้างอิง

6. จำนวนเอกสารอ้างอิงไม่เกิน 20 หน้า

7. รูปแบบการเขียนต้นฉบับ แบ่งเป็น 2 ประเภท ได้แก่ ประเภทบทความรายงานผลวิจัยหรือบทความวิจัย (research article) และบทความทางการทบทวนเอกสารวิจัยที่ผู้อื่นทำเอาไว้ หรือบทความทางวิชาการ หรือบทความทางวิชาการทั่วไป หรือบทความบริบท (review article)

บทความรายงานผลวิจัย ให้เรียงลำดับหัวข้อดังนี้

ชื่อเรื่อง (Title) การตั้ง กระแสวิจัย และสื่อเป็นภาพหลักของงานวิจัย ไม่ให้คายของ เพราะไม่เกิน 100 ตัวอักษร ชื่อเรื่องให้มีภาษาไทยและภาษาอังกฤษ

ชื่อผู้นิพนธ์ (Author(s)) และที่อยู่ ให้ใช้ภาษาไทยและภาษาอังกฤษ และระบุตำแหน่งทางวิชาการ หน่วยงาน หรือสถาบันที่สังกัด และ E-mail address ของผู้นิพนธ์ให้เป็นจริงของหน่วยงาน เพื่ออบรมสร้างสาระการติดต่อได้

บทคัดย่อ (Abstract) เป็นการย่อเนื้อความวิจัยที่สั้นที่สุด ละมุนเนื้อความราวเดิม ความยาวไม่เกิน 250 คำ หรือไม่เกิน 10 บรรทัด และไม่ควรใช้คำย่อ

คำสำคัญ (Keyword) ให้ระบุไว้ท้ายบทคัดย่อขององค์ประกอบละประมาณ 4-5 คำตัว ๆ

บทนำ (Introduction) เป็นส่วนเริ่มต้นของเนื้อหา ที่ถกความเป็นมา เหตุผล และจุดประสงค์ ที่นำไปสู่งานวิจัยนี้ วารสารนี้ให้ความสู่ทางวิชาการที่เกี่ยวข้องจากการตรวจสอบเอกสารประกอบ
วัสดุอุปกรณ์และวิธีการศึกษา (Materials and Methods) ให้ระบุรายละเอียดวัน เดือน ปีที่ทำการทดลอง วัสดุ อุปกรณ์ สิ่งที่นำมาศึกษา จำนวน ลักษณะเฉพาะของตัวอย่างที่ศึกษา อธิบายวิธีการศึกษา แผนการทดลองทางสถิติ วิธีการเก็บข้อมูลการวิเคราะห์และการแปลผล

ผลการศึกษา (Results) รายงานผลที่ค้นพบ ตามลำดับขั้นตอนของการวิจัย อย่างชัดเจนได้ใจความ ถ้าผลใหม่ ซับซ้อนและมีรายละเอียดมากควรใช้คำบรรยาย แต่ถ้ามีตัวเลข หรือ ตัวแปลมาก ควรใช้ตารางหรือแผนภูมิแทน

วิจารณ์และสรุปผล (Discussion and Conclusion) แสดงให้เห็นว่าผลการศึกษาตรงกับวัตถุประสงค์และเปรียบเทียบกับสมมุติฐานของการวิจัยได้หรือไม่ อย่างไร เหตุผลใดจึงเป็นเช่นนั้น และมีที่พื้นฐานอ้างอิงที่เชื่อถือได้มากหรือไม่ อย่างไร อย่างไร จึงเป็นที่พื้นฐานอ้างอิงที่เชื่อถือได้มากหรือไม่

เอกสารอ้างอิง (References) ระบุรายการเอกสารที่นำมาอ้างอิงไว้ท้ายเรื่อง โดยใช้ Vancouver Style ตั้งตัวอย่างข้างล่าง และสามารถอธิบายและเขียนคู่มือเพิ่มเติมได้ที่ www.journal.msu.ac.th
พิทักษ์ พุทธวรชัย, กิตติ บุญเลิศนิรันด์, มณีวรรณ ทะนงศักดิ์, นภา ขันสุภา. การใช้อเอทธีฟอนกระตุ้นสุกของพริก. ใน: เอกสารการประชุมสัมมนาทางวิชาการ สถาบันเทคโนโลยีราชมงคล ครั้งที่ 15. สถาบันวิจัยและพัฒนา สถาบันเทคโนโลยีราชมงคล. กรุงเทพฯ; 2541. หน้า 142-9

4. การอ้างอิงจากพจนานุกรม
รูปแบบ: ชื่อพจนานุกรม. พิมพ์ครั้งที่. เมืองหรือสถานที่พิมพ์. ปีที่พิมพ์. หน้า.

5. การอ้างอิงจากหนังสือพิมพ์
รูปแบบ: ชื่อผู้แต่ง. ชื่อเรื่อง. ชื่อหนังสือพิมพ์ ปี เดือน วัน; Sect.: sohk 15.

6. อ้างอิงจากหนังสืออิเล็กทรอนิกส์
รูปแบบ: ชื่อผู้แต่ง. ชื่อเรื่อง. ชื่อวารสารอิเล็กทรอนิกส์ [หรือ serial online] ปีที่พิมพ์เอกสาร ถ้าจำเป็นระบุเดือนด้วย; Vol no (ฉบับที่): จานวนหน้าจากการสืบค้น. ได้จาก: URL: http://www.edc/gov/neidoc/EID/eid.htm วันที่ เดือน ปีที่ทำการสืบค้น (เขียนเต็ม)

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   - Main Heading: 16 pt. Bold
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   - Footnotes for authors and their affiliations: 12pt.

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