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A high performance computer system evaluation model with uncertain linguistic information

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ABSTRACT

High performance computing (HPC) is widely used in science and engineering to solve large computation problems. With the development of HPC, the scale of the high performance computers is expanded rapidly. Many new technologies and methods are introduced to improve the performance in the designing of the processor nodes. In this paper, we investigate the multiple attribute decision making problems for evaluating the performance of the computer systems with uncertain linguistic variables. We utilize the uncertain linguistic choquet integral (ULCI) operator to aggregate the uncertain linguistic variables corresponding to each alternative and get the overall value of the alternatives, then rank the alternatives and select the most desirable one (s). Finally, an illustrative example is given.

KEYWORDS

High performance; Performance appraisal; Uncertain linguistic variables; Uncertain linguistic choquet integral (ULCI) operator; Computer system.

INTRODUCTION

High performance computing (HPC) is widely used in science and engineering to solve large computation problems. With the development of HPC, the scale of the high performance computers is expanded rapidly. Many new technologies and methods are introduced to improve the performance in the designing of the processor nodes. The peak performance of computers increases in a continuous and rapid way. But the sustained performance achieved by the real applications does not increase in the same scale as the peak performance does and the gap between them is widening. Performance evaluation of parallel systems, which is one of effective ways to solve this problem, can find the bottleneck of the system and guide the optimization of the system design. As the computer architectures and program structures are becoming much more complex, more and more factors may affect the performance of the programs. Furthermore, these factors interplay with each other in a complex and nonlinear way, which makes the performance evaluation of parallel systems a great challenge. Traditional performance evaluation methods cannot satisfy the need for performance evaluation of these massive parallel systems. Performance model which combines the application signatures and the machine profiles draws the attentions of the research community as well as the industry community[1-6].

The problem of evaluating the performance of the computer systems with uncertain linguistic variables is the multiple attribute decision making problems. The aim of this paper is to investigate the multiple attribute decision making problems for evaluating the evaluating the performance of the computer systems with uncertain linguistic variables. Then, we utilize the uncertain linguistic choquet integral (ULCI) operator to aggregate the uncertain linguistic variables corresponding to each alternative and get the overall value of the alternatives, then rank the alternatives and select the most desirable one (s). The remainder of this paper is set out as follows. In the next section, we introduce some basic concepts related to uncertain linguistic variables. In Section 3 we introduce the multiple attribute decision making problems for evaluating the performance of the computer systems with uncertain linguistic variables. Then, we utilize the uncertain linguistic choquet integral (ULCI) operator to aggregate the uncertain linguistic corresponding to each alternative and get the overall value of the alternatives, then rank the alternatives and select the most desirable one (s) by using the formula of the degree of possibility for the comparison between two uncertain linguistic variables. In Section 4, an illustrative example for evaluating the performance of the computer systems with uncertain linguistic variables is pointed out. In Section 5 we conclude the paper and give some remarks.

PRELIMINARIES

We consider a finite and totally ordered discrete linguistic label set $S=\left\{s_i \middle| i=-t,\cdots,-1,0,1,\cdots,t\right\}$, where t is a positive integer, s_i represents a linguistic variable and satisfy $s_i > s_j$, if $i > j$. For example, S can be defined as[7-8].

$$\begin{aligned} S=\{&s_{-4}=extremely\ poor, s_{-3}=very\ poor, s_{-2}=poor,\\ &s_{-1}=slightly\ poor, s_0=fair, s_1=slightly\ good,\\ &s_2=good, s_3=very\ good, s_4=extremely\ good\} \end{aligned}$$

To preserve all the given information, we extend the discrete term set S to a continuous term set $\bar{S}=\left\{s_a \middle| a\in[-q,q]\right\}$, where $q\left(q>t\right)$ is a sufficiently large positive integer. If $s_a\in S$, then we call s_a the original linguistic term, otherwise, we call s_a the virtual linguistic term. In general, the decision maker uses the original linguistic term to evaluate attributes and alternatives, and the virtual linguistic terms can only appear in calculation[9-12].

Let $\tilde{s}=[s_\alpha, s_\beta]$, $s_\alpha, s_\beta\in S$, s_α and s_β are the lower and the upper limits, respectively, we call $\tilde{s}$ the uncertain linguistic variable. Let $\tilde{S}$ be the set of all the uncertain linguistic variables.

Definition 1[9-12]. Let $\tilde{s}_1=\left[s_{\alpha_1}, s_{\beta_1}\right]$ and $\tilde{s}_2=\left[s_{\alpha_2}, s_{\beta_2}\right]$ be two uncertain linguistic variables, and let $len\left(\tilde{s}_1\right)=\beta_1-\alpha_1, len\left(\tilde{s}_2\right)=\beta_2-\alpha_2$, then the degree of possibility of $\tilde{s}_1\geq\tilde{s}_2$ is defined as

$$p\left(\tilde{s}_1\geq\tilde{s}_2\right)=\frac{\max\left(0, len\left(\tilde{s}_1\right)+len\left(\tilde{s}_2\right)-\max\left(\beta_2-\alpha_1,0\right)\right)}{len\left(\tilde{s}_1\right)+len\left(\tilde{s}_2\right)} \qquad \textbf{(1)}$$

From Definition 1, we can easily get the following results easily:

(1) $0 \le p\left(\tilde{s}_1 \ge \tilde{s}_2\right) \le 1, 0 \le p\left(\tilde{s}_2 \ge \tilde{s}_1\right) \le 1$;

(2) $p\left(\tilde{s}_1 \ge \tilde{s}_2\right) + p\left(\tilde{s}_2 \ge \tilde{s}_1\right) = 1$. Especially, $p\left(\tilde{s}_1 \ge \tilde{s}_1\right) = p\left(\tilde{s}_2 \ge \tilde{s}_2\right) = 0.5$.

In the following Xu[13] shall propose an uncertain linguistic weighted geometric mean (ULWGM).

Definition 2. Let $\mathrm{ULWGM}: \tilde{S}^n \to \tilde{S}$, if

$$\mathrm{ULWGM}_\omega\left(\tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_n\right) = \left(\tilde{s}_1\right)^{\omega_1} \otimes \left(\tilde{s}_2\right)^{\omega_2} \otimes \cdots \otimes \left(\tilde{s}_n\right)^{\omega_n} \quad \textbf{(2)}$$

where $\omega = \left(\omega_1, \omega_2, \cdots, \omega_n\right)$ is the exponential weighting vector of uncertain linguistic variables $\tilde{s}_i \left(\tilde{s}_i \in \tilde{S}, i = 1, 2, \cdots, n\right)$ with $\omega_i \in [0,1]$, $\sum_{i=1}^{n} \omega_i = 1$, then the function ULWGM is called the uncertain linguistic weighted geometric mean (ULWGM) operator of dimension n. Especially, if $\omega = \left(1/n, 1/n, \cdots, 1/n\right)$, then the ULWGM operator is reduced to the ULGM operator.

The ULWGM operator has the following properties[18].

Theorem 1 (Commutativity).

$ULWGM_\omega\left(\tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_n\right) = ULWGM_\omega\left(\tilde{s}_1^*, \tilde{s}_2^*, \cdots, \tilde{s}_n^*\right)$ where $\left(\tilde{s}_1^*, \tilde{s}_2^*, \cdots, \tilde{s}_n^*\right)$ is any permutation of $\left(\tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_n\right)$.

Theorem 2. (Idempotency) If $\tilde{s}_j = \tilde{s}$ for all j, then

$$ULWGM_\omega\left(\tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_n\right) = \tilde{s}$$

Theorem 3. (Monotonicity) If $\tilde{s}_j \le \tilde{s}_j^*$ for all j, then

$$ULWGM_\omega\left(\tilde{s}_1, \tilde{s}_2, \cdots, \tilde{s}_n\right) \le ULWGM_\omega\left(\tilde{s}_1^*, \tilde{s}_2^*, \cdots, \tilde{s}_n^*\right)$$

A HIGH PERFORMANCE COMPUTER SYSTEM EVALUATION MODEL WITH UNCERTAIN LINGUISTIC INFORMATION

The following assumptions or notations are used to represent the multiple attribute decision making problems for evaluating the performance of the computer systems with uncertain linguistic variables. Let $A = \left\{A_1, A_2, \cdots, A_m\right\}$ be a discrete set of alternatives. Let $G = \left\{G_1, G_2, \cdots, G_n\right\}$ be a set of attributes. The information about attribute weights is completely known. Let $\omega = \left(\omega_1, \omega_2, \cdots, \omega_n\right)$ be the weight vector of attributes, where $\omega_j \ge 0$, $j = 1, 2, \cdots, n$. S Suppose that $\tilde{R} = \left(\tilde{r}_{ij}\right)_{m \times n}$ is decision matrix, where $\tilde{r}_{ij} \in \tilde{S}$ is an uncertain linguistic variable, given by the decision maker for the alternative $A_i \in A$ with respect to the attribute $G_j \in G$.

In the following, we apply the ULCI operator to multiple attribute decision making for evaluating the performance of the computer systems with uncertain linguistic variables.

Step 1. Determine the fuzzy measure of attribute of $G_j \left(j = 1, 2, \cdots, n\right)$ and attribute sets of G. There are a few methods for the determination of the fuzzy measure. For example, linear methods, quadratic methods, heuristic-based methods and genetic algorithms and so on are available in the literature.

Step 2. Utilize the ULCI operator

$$\tilde{r}_i = \mathrm{ULCI}_\mu\left(\tilde{r}_{i1}, \tilde{r}_{i2}, \cdots, \tilde{r}_{in}\right), i = 1, 2, \cdots, m \quad \textbf{(3)}$$

to derive the overall preference values $\tilde{r}_i \left(i = 1, 2, \cdots, m\right)$ of the alternative A_i.

Step 3. To rank these collective overall preference values $\tilde{r}_i\left(i=1,2,\cdots,m\right)$, we first compare each $\tilde{r}_i$ with all the $\tilde{r}_j\left(j=1,2,\cdots,m\right)$ by using Eq. (1).

Step 4. Rank all the alternatives $A_i\left(i=1,2,\cdots,m\right)$ and select the best one (s) in accordance with the collective overall preference values $\tilde{r}_i\left(i=1,2,\cdots,m\right)$.

Step 5. End.

NUMERICAL EXAMPLE

Currently, network-based computer technology makes a great push towards the development and wide application of cluster system. High-performance workstations or PC connected in a certain structure by high-speed network into cluster, then scheduled, so as to get the similar functions of large machine and parallel machine with a very small amount of cost. The software system used to manage these workstations and PC are the targeted Cluster Management System in this thesis, and job scheduling technology is one of the key technologies of cluster management system. New-generation Cluster Management System's study and application technology is regarded as the mainstream study approach in the field of high-performance computer over the past few years. Many civilly or commercially used software and related products have been promoted. This section presents a numerical example for evaluating the performance of the computer systems with uncertain linguistic variables to illustrate the method proposed in this paper. There are five prospect computer systems $A_i\left(i=1,2,3,4,5\right)$ for four attributes $G_j\left(j=1,2,3,4\right)$. The four attributes include manufacturer $\left(G_1\right)$, processor type $\left(G_2\right)$, processor speed $\left(G_3\right)$ and systems $\left(G_4\right)$ respectively. The five possible computer systems $A_i\left(i=1,2,\cdots,5\right)$ are to be evaluated using the linguistic term set S by the decision maker under the above four attributes, as listed in the following matrix.

$$\tilde{R}=\begin{matrix} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{matrix}\begin{matrix} \begin{matrix} G_1 & \quad G_2 & \quad G_3 & \quad G_4 \end{matrix} \\ \begin{pmatrix} [s_2,s_3] & [s_3,s_4] & [s_2,s_3] & [s_0,s_1] \\ [s_3,s_4] & [s_2,s_3] & [s_1,s_3] & [s_{-2},s_1] \\ [s_1,s_2] & [s_0,s_1] & [s_{-3},s_{-2}] & [s_2,s_3] \\ [s_{-1},s_1] & [s_{-2},s_{-1}] & [s_{-2},s_0] & [s_3,s_4] \\ [s_{-2},s_0] & [s_1,s_2] & [s_2,s_3] & [s_1,s_2] \end{pmatrix} \end{matrix}$$

In the following, we apply the ULCI operator to multiple attribute decision making for evaluating the performance of the computer systems with uncertain linguistic variables. Then, we utilize the uncertain linguistic approach developed to get the most desirable high performance computer systems.

Step 1. Suppose the fuzzy measure of attribute of $G_j\left(j=1,2,\cdots,n\right)$ and attribute sets of G as follows:

$$\begin{aligned}
&\mu\left(G_1\right)=0.25,\mu\left(G_2\right)=0.30,\mu\left(G_3\right)=0.35,\mu\left(G_4\right)=0.25,\mu\left(G_1,G_2\right)=0.75,\\
&\mu\left(G_1,G_3\right)=0.65,\mu\left(G_1,G_4\right)=0.60,\mu\left(G_2,G_3\right)=0.55,\mu\left(G_2,G_4\right)=0.55,\\
&\mu\left(G_3,G_4\right)=0.45,\mu\left(G_1,G_2,G_3\right)=0.70,\mu\left(G_1,G_2,G_4\right)=0.80,\\
&\mu\left(G_1,G_3,G_4\right)=0.85,\mu\left(G_2,G_3,G_4\right)=0.75,\mu\left(G_1,G_2,G_3,G_4\right)=1.00
\end{aligned}$$

Step 2. Utilize the decision information given in matrix $\tilde{R}$, and the ULCI operator, we obtain the overall preference values $\tilde{r}_i$ of the computer systems $A_i\left(i=1,2,\cdots,5\right)$.

$$\begin{aligned}
&\tilde{r}_1=\left[s_{1.24},s_{2.15}\right],\tilde{r}_2=\left[s_{0.34},s_{0.98}\right],\tilde{r}_3=\left[s_{0.75},s_{1.45}\right]\\
&\tilde{r}_4=\left[s_{-1.08},s_{1.34}\right],\tilde{r}_5=\left[s_{0.76},s_{1.56}\right]
\end{aligned}$$

Step 3. Rank these preference degree $\tilde{r}_i\left(i=1,2,3,4,5\right)$, we first compare each $\tilde{r}_i$ with all the $\tilde{r}_j\left(j=1,2,3,4,5\right)$ by using Eq. (1), and then develop a complementary matrix:

$$P=\begin{bmatrix} 0.500 & 0.200 & 0.250 & 0.015 & 0.098 \\ 0.800 & 0.500 & 0.280 & 0.152 & 0.602 \\ 0.750 & 0.720 & 0.500 & 0.343 & 0.740 \\ 0.850 & 0.657 & 0.603 & 0.500 & 0.980 \\ 0.912 & 0.398 & 0.260 & 0.020 & 0.500 \end{bmatrix}$$

Summing all the elements in each line of matrix P , we have

$$p_1 = 3.678,\ p_2 = 2.316,\ p_3 = 5.658,\ p_4 = 4.175,\ p_5 = 2.560.$$

Then we rank the preference degree $\tilde{r}_i\left(i=1,2,3,4,5\right)$ in descending order in accordance with the values of $p_i\left(i=1,2,\cdots,5\right)$: $\tilde{r}_3 \succ \tilde{r}_4 \succ \tilde{r}_1 \succ \tilde{r}_5 \succ \tilde{r}_2$.

Step 4. Rank all the computer systems $A_i\left(i=1,2,\cdots,5\right)$ in accordance with the preference degree $\tilde{r}_i\left(i=1,2,\cdots,5\right)$: $A_3 \succ A_4 \succ A_1 \succ A_5 \succ A_2$, and thus the most desirable computer system is A_3.

CONCLUSION

The field of High-performance computing has experienced extensive changes and remarkable development. High-performance computing has been widely used by many compute-intensive applications involving energy, biology, meteorology, Geology and scientific research. High-performance computer is an outstanding symbol of Comprehensive national strength in the field of science and technology. It is also play an important role in modern society. On the other hand, the power consumptions of high-performance computing system are already tremendous. It poses a serious challenge to the development of high performance systems. With the continued development of semiconductor technology and significantly improvement of chip integration, microprocessor's performance and power density are both increasing sharply. At the same time, the scale of these systems becomes larger and larger, and the density of chipsets integration increases drastically because of the greater demands on performance. High power consumption will lead to high heat and consume more cooling costs, and greatly limiting the development and application of high-performance computers. The problem of evaluating the performance of the computer systems with uncertain linguistic variables is the multiple attribute decision making problems. The aim of this paper is to investigate the multiple attribute decision making problems for evaluating the evaluating the performance of the computer systems with uncertain linguistic variables. Then, we utilize the uncertain linguistic choquet integral (ULCI) operator to aggregate the uncertain linguistic variables corresponding to each alternative and get the overall value of the alternatives, then rank the alternatives and select the most desirable one (s).

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