An Approach of Clustering Features for Ranked Nations of E-government 2012

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Abstract: E-government is important for national development. However, the significant features for E-government stages have not been analyzed intelligently. This research proposes a method, clustering features for rankings (CFR), to find stages and features for E-government. The results show that the adult literacy is significant for the beginning stage and the gross enrollment in education for the mature stage. Technically, dominance-based rough set approach is used to generate criteria's evidential weights of nations' rankings and rough set is then used to identify the clustering features composed of dependency rules. The rules comprise the most relevant and important criteria and the ranking intervals as the intelligent knowledge.

Keywords: E-government; clustering features; rankings; dominance-based rough set approach (DRSA); rough set (RS)

1   Introduction

Clustering [1, 2, 3] and Classification [1, 2, 3, 4, 5, 6, 7, 8, 9, 10] of the roughness theory have successfully presented features knowledge (in terms of indiscernbility realations) as intelligent knowledge since 1982. Techniqcally, the roughness classification can partition a given set of objects and the roughness clustering can identify natual grouping of objects. The features can be obtained by choosing either classification or clustering technique. However, neither of them alone, can provide information needed for decision making. For instance, classification only provides the local information restricted by the given set of objects and the natural grouping is short of expert's opinions. A complementary view between classification and clustering evolves an integration to give intelligent features [11, 12]. This research aims to propose an integration method for E-government Development Database of United Nations (UN-EGDD) 2012 [13] in analyzing stages (clustering features composed of continuously ranking intervals). Under the

consideration of rankings these stages signify the development of E-government in terms of dependency rules which are presented in Section 2.3, 3.2 and 4.

E-government seems natural due to the arrival of the information age [14]. It can improve government performance, enhance business efficiency, provide online service to people, and so forth [15, 16]. So far, there is no mathematical model which can quantitatively and naturally identify stages for E-government. According to the characteristics of UN-EGDD, the natural stages could guide the development of E-government [16]. The difficulties of solving the natural stages are summarized below.

● UN-EGDD assumes fixed weights for criteria. This assumption negates the existence of stages. The reason is that stages, at different levels, have different focuses, i.e., weights vary with stages.

● The stages based on rankings are hard to identify. The interval rankings from nation to nation are not easy to define.

1.1   The Objectives

Under considerations of the research background and the problems above, this research aims to identify clustering features with criteria relevance and importance to rankings. The natural clusters will be explained with continuous stages in terms of the dependency rules. The ranking intervals depending on the criteria will imply the features of E-government stages.

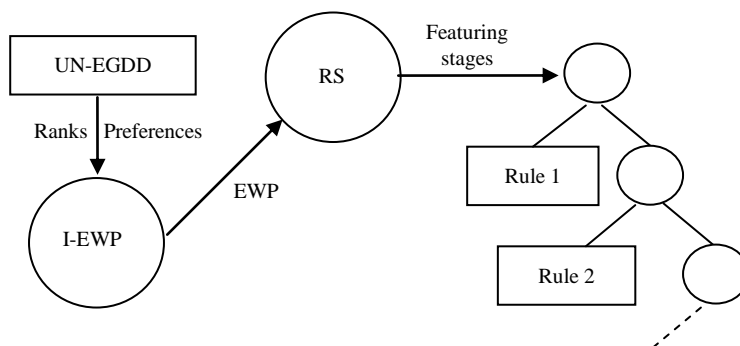## 1.2   The Conceptual Methodology

Figure 1
The conceptual CFR

To achieve the objective and solve the research concerns above, our methodology named clustering features for rankings (CFR) is designed and implemented in two phases. First the classification postoris by I-EWP (induction of preferences based on preferences) for nations' ranks [17]. These postoris are evidential weights based on preferences (EWP). In the second phase, EWP replace the preferences in the information systems to discover clustering features by Rough Sets (RS). The resulted clusters are presented as a hierarchical tree shown in Fig. 1.

1.3   The Organization of This Paper

This paper has two parts. The first is about the implementation of CFR. The second is about applying CFR on UN-EGDD. The remainder of this paper is organized as follows: Section 2 reviews UN-EGDD, I-EWP, and RS. Section 3 presents the propositions for CFR, Section 4 addresses the application results, Section 5 presents discussion on CFR and finally Conclusions provides the concluding remarks to close the paper.

2   Literature Review

This section contains three parts, first is about UN-EGDD, second is about I-EWP to provide criteria's relevance and importance information to rankings, and third is about clustering of RS.

2.1   UN-EGDD

E-government originates in 1993 when US President, William Clinton, announced a six-month review of the federal government, named as National Partnership for Reinventing Government (NPR), and asked Vice President, Al Gore to identify problems and find out solutions for reorganizing the federal bureaucracy, analyzing job performance of federal employees, reviewing each administrative agency and report recommendations to Congress on government reforms [18]. In the autumn of 1993, Vice President Gore presented a report to Clinton and the public about "Reengineering Through Information Technology" [19]. In early 1997 various initiatives of E-government started to enable anyone who wants to transact business with the government electronically [20].

UN-EGDD publication was undertaken by a group of senior E-government researchers and advisors at the United Nations Department of Economic and Social Affairs. The Division for Public Administration and Development Management plays the core to manage the data collection [13]. The criteria of E-government are described in the Table 1 which has preference dataset.

Table 1
Criteria of UN-EGDD

Criteria	ONLINE SERVICES
q_1	Emerging stage with limited and basic information
q_2	Enhanced stage with greater public policy and governance sources of current and archived information, such as policies, laws and regulation, reports, newsletters, and downloadable databases
q_3	Transactional stage allowing two-way interaction between the citizen and his/her government
q_4	Connected stage with integration of G2G, G2C and C2G
	TELECOMMUNICATION INFRASTRUCTURE
q_5	Estimated internet users per 100 inhabitants
q_6	Number of main fixed telephone lines per 100 inhabitants
q_7	Number of mobile subscribers per 100 inhabitants
q_8	Number of fixed internet subscriptions per 100 inhabitants
q_9	Number of fixed broadband facilities per 100 inhabitants
	HUMAN CAPITAL
q_{10}	Adult literacy rate
q_{11}	The combined primary secondary, and tertiary gross enrolment ratio

2.2   I-EWP

The evidential weight proposed by Keynes in 1921 is based on the probability relations to express the rational belief about the importance and relevance between a primary proposition (premise) and a secondary proposition (conclusion) [21, 22] The main idea claims that the doubtful arguments relevant to decision should be considered quantitatively, instead of by logic only. Its application requires considering not only the knowledge of decision makers but also circumstances for induction [23], thus can estimate the evidential relevance like goodness and risk [3, 24]. Recently, the evidential weight is further extended to EWP [17] which is summarized below.

EWP is implemented from the induction rule, $q_{j,t'}^{\geq} \rightarrow Cl_t^{\geq}$, as presented in Property 2. Four properties of [17] are used in this research. Property 1 presents the information system of I-EWP. Property 2 explains the induction rules of I-EWP. Property 3 talks about the induction evidence. Property 4 is about the reliability measures for EWP.

Property 1: The information system of I-EWP

$I-EWP = (U, Q, f, R, Cl_t^{\geq})$, where each object y has a rank assigned by decision makers, $U = \{y \mid y = 1, ..., n\}$, $Q = \{q_1, q_2, ..., q_m\}$, $f : U \times Q \rightarrow R$, R is a

ranking set calculated from preferences, $R \in \{1^{th}, 2^{th}.., n^{th}\}$, $Cl_t^{\geq}$ is a ranking union having nations at least t, t is a rank place like 10th, and $Cl_t^{\geq}$ is a dominance class defined by decision makers.

Property 2: An induction rule of I-EWP

$q_{j,t'}^{\geq} \rightarrow Cl_t^{\geq}$ represents how a criterion q_j supports nations to achieve the top t positions where $q_{j,t'}^{\geq}$, $(q_{j,t'}^{\geq} = \bigcup_{s \geq t'} q_{j,s})$, is also a ranking union containing the top t' positions with respect to q_j. This rule associates the ranking evidence within criterion q_j to the ranking union $Cl_t^{\geq}$. The association is independent to addition or removal of other criteria thus the rules are independent each other. Our design can be conceptualized as in Fig. 2.

Property 3: The induction evidence

Under the induction rule $q_{j,t'}^{\geq} \rightarrow Cl_t^{\geq}$, there are two approximations defined with boundaries $\underline{x}$ and $\overline{x}$ where $\underline{x} \in Cl_t^{\geq}$, $\overline{x} \in Cl_t^{\geq}$, and the rank of $\underline{x}$ is always higher than or equal to that of $\overline{x}$. $\underline{x}$ is assumed as the boundary of the important evidence and $\overline{x}$ as the boundary of the relevant evidence. These two types of evidence are defined as:

Important evidence: $D_P^+(\underline{x})$ located in the area above $\underline{x}$ in Fig. 2

Relevant evidence: $D_P^+(\overline{x})$ located in the area above $\overline{x}$ in Fig. 2

The important evidence belong to the upper part of the relevant evidence in Fig. 2. The approximations based on the induction evidence are defined as:

Important approximation: $\underline{P}'(Cl_t^{\geq}) = D_P^+(\underline{x}) \cap Cl_t^{\geq}$;

Relevant approximation: $\overline{P}'(Cl_t^{\geq}) = D_P^+(\overline{x})$;

Doubtful region: $D_P^+(\overline{x}) - D_P^+(\underline{x})$.

Important approximation contains the important evidence belonging to the ranking interval above, i.e., $Cl_t^{\geq}$. It is same as the lower approximation of DRSA. Relevant approximation contains the evidence above the boundary $\overline{x}$ and requires that $\overline{x}$ belongs to the ranking interval of $Cl_t^{\geq}$. Doubtful region contains the evidence that are relevant but not important. The noise in this area is dissimilar to the important evidence, and is called distinguished noise. Therefore, the noise within approximations is defined as: Undistinguished noise: $D_P^+(\underline{x}) - \underline{P}'(Cl_t^{\geq})$ and Distinguished noises: $D_P^+(\overline{x}) - D_P^+(\underline{x}) - \overline{P}(Cl_t^{\geq})$.

The distinguished noises are objects away from the important evidence, and normally located in the doubtful region. The undistinguished noises mixing with the important evidence within the Important approximation and cannot be separated each other by objective methods. Obviously, the more evidence in $\underline{P}'(Cl_t^{\geq})$ the more important P is; the more noise in $\overline{P}'(Cl_t^{\geq})$ the less relevant P is. Due to the impact of noises, $\underline{x}$ and $\overline{x}$ are non-deterministic priori. Therefore, $\underline{x}$ and $\overline{x}$ are presented as slash lines in Fig. 2. They can be obtained by approximating the optimal classification with the minimum distinguished noises.

Property 4: Measures of EWP

Three measures related to EWP of Fig. 4 are defined below.

● Evidence-accuracy rate (α') [3, 24]

An accuracy rate presents the ratio of 'Important approximation' to 'Relevant approximation,' i.e., the degree of the properly classified evidence relative to the possibly relevant evidence, and is defined as:

$\alpha' = \dfrac{|\underline{P}'(Cl_t^{\geq})|}{|\overline{P}'(Cl_t^{\geq})|}$ where α' for a logical implication represents the degree of

necessary condition of 'Important approximation' in the relevant evidence.

● Evidence-coverage rates (CR') [8, 24]

A coverage rate expresses the ratio of 'Important approximation' relatively belonging to the ranking union, and is defined as:

$CR' = \dfrac{|\underline{P}'(Cl_t^{\geq})|}{|Cl_t^{\geq}|}$ where CR' for a logical implication represents the degree of

sufficient condition that 'Important approximation' influences the ranking union.

● Evidence-certainty rate (Cer$'$) [8]

A certainty rate expresses the ratio of objects in 'Important approximation' relatively belonging to Important evidence:

Cer$' = \dfrac{|\underline{P}'(Cl_t^{\geq})|}{|D_P^+(\underline{x})|}$ where $|\cdot|$ means the number of evidence in a set. Cer$'$

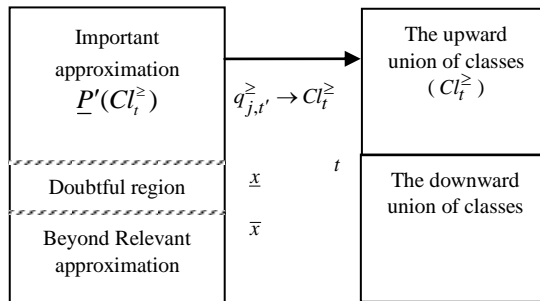represents the degree of reliability of $\underline{P}'(Cl_t^{\geq})$.

Figure 2
Approximations based on the induction evidences

● The values of EWP

The classification rate for $q_{j,t'}^{\geq} \to Cl_t^{\geq}$ needs to consider both, the sufficient and necessary conditions. The product of CR' and α' will be a unique value on an indifference curve, which originates from the product of sufficient and necessary ratios for the indifferent induction rules. The induction measures are independent to addition or removal of other criteria. The product values thus can be used for preference orders. Further, the quality of classification needs address the reliability concern. According to the logical implication, a quality classification can be formulated as:

Quality classification $\Leftrightarrow$ Minimum uncertainty

'Quality classification if and only if minimum uncertainty' can be processed by mathematics to get a unique value on an indifference curve. Therefore, the value of EWP, g_j'', for criterion q_j is the quality classification rate considering the minimum uncertainty, i.e., $g_j'' = \text{Max} \{ \alpha' \times CR' \times Cer' \}$.

2.3 Rough Sets (RS)

Rough sets proposes an approximation space based on equivalence relations. The objects within an equivalence classes have the same characteristics. The criteria dependency represents a measure about the association degree between the partitions based on criteria. The complicate dependency has the association between two set of criteria. The basic dependency [5] related to the clustering features, is described next.

An approximation space presented by a mathematical model is formulated as:

$A = (U, R)$ where U is a set of objects not necessary with preference data and $R \subseteq U \times U$ represents an equivalence relation on U.

The equivalence classes of R are denoted as: $R^* = \{X_1, X_2, ..., X_i, ...\}$ where i is an index for a relation. For any subset $X \subseteq U$ the lower and upper approximation of X is defined as:

$\underline{A}(X) = \bigcup_{X_i \subseteq X} X_i$ and $\overline{A}(X) = \bigcup_{X_i \cap X \neq \varnothing} X_i$ where $\underline{A}(X)$ is the union of all those

elementary sets in A, which are individually contained by X, whereas $\overline{A}(X)$ is the union of all those X_i of which has a non-empty intersection with X.

A knowledge presentation for the dependence relationship between criteria is built as:

$KRS = (U, C, D, V', \rho)$ where C is the set of attributes, D is the set of action attributes, V' represents the value set which does not require preferences within the same attribute, $\rho : U \times (C \cup D) \to V'$ is an information function, $V' = \bigcup_{C \cup D} V_a$, V_a is a domain of a attribute (attribute is same as a criterion in this research due to numerical values only), and $a \in C \cup D$. The dependency measure between two sets of attributes, A and B, based on KRS is presented as:

$\gamma_A(B)$ where $\gamma_A(B) = \dfrac{POS_A(B)}{|U|}$, $0 \leq \gamma_A(B) \leq 1$, $A \subseteq C$, $B \subseteq D$,

$POS_A(B) = \bigcup_{Y_{i'} \in B^*} \underline{A}(Y_{i'})$ where $POS_A(B)$ is the positive region of B^* in A, and $B^* = U / B = \{Y_1, Y_2, ..., Y_{i'}, ...\}$ represent a set of U partitions constructed from equivalence relations based on B.

3   CFR

This section presents definitions of CFR with two phases. First is about replacing preferences with EWP, presented in Definition 1. Second is the clustering features generated by RS, presented in Definition 2 to 6.

3.1   Replacing preferences with EWP

The quality classification rates generated from I-EWP are expressed as $\{g''_{ij}\}$ where i is an index for a nation, $i \in [1, ..., n]$, j is an index for a criterion, $j \in [1, ..., m]$. $\{g''_{ij}\}$ is abbreviated as EWP in this paper. g''_{ij} only performs locally and the natural clusters of EWP cannot be clear at a glance of g''_j only. The reason for the local performance of g''_{ij} is that its effectiveness exists only on a part of

nations. To give a natural clusters on all collections of g''_{ij}, g''_{ij} are used to replace the values corresponding to nations and criteria in Property 1.

Definition 1: Replacement

$$\underset{i\in\{1,...,n\} \text{ and } j\in\{1,...,m\}}{\forall} \left(r_{ij} = g''_{ij}\right)$$

where $r_{ij} \in R$ and $f:U \times Q \to R$ in Property 1

3.2   Generation of Clustering Features

The analysis of clustering features needs to globally consider the topology of dataset. There are three definitions to present the design and implementation. Definition 2 for the information system CFR. The domain values corresponding to nations and criteria are formed by transforming EWP into orders row by row. Users can see which criterion is the most relevant and important to some rank assigned by decision makers. Definition 3 presents how the roughness relations are formed. Definition 4 presents the dependency rules.

Definition 2: The information system of CFR

The information system of CFR, containing n tuples of (r_{i1}, r_{i2} ,…, r_{im}), is defined as $CFR = (U, Q, Cl_t, R', \rho)$ where

$$R' = \begin{cases} 1 & r_{ij} = \max\{r_{i1}, r_{i2}, ..., r_{im}\} \\ 0 & \text{otherwise} \end{cases} \text{ and } \rho : U \times Q \to R'.$$

Definition 3: Approximation space of CFR

The approximation of CFR is defined as $A = (U, \Gamma)$ where $\Gamma = (x_i, x_{i'})$ means x_i and $x_{i'}$ have a relation on a criterion which is of the most significant; $(x_i, x_{i'}) \in \Gamma$ iff $(x_i, r_{ik}) = (x_i, 1)$ and $(x_{i'}, r_{i'k}) = (x_{i'}, 1)$, i and i' are indexes of nations. Therefore, the equivalence class, having the same relevant and important criterion, is formulated as: $A^* = \{X_1, ..., X_k, ...\}$ where k is an index of clusters, $k \le m$, and $A = Q$. The number of clusters equal to or less than the number of criteria in Q makes operation simple and easy.

Definition 4: Ranking intervals

The ranking intervals are defined as $Cl^* = \{Cl_{>L_1}^{\le H_1}, ..., Cl_{>L_k}^{\le H_k}, ...\}$ where $Cl_{>L_k}^{\le H_k} = \{Cl_t \mid L_k < t \le H_k\}$. For the class $Cl_{>L_k}^{\le H_k}$, H_k is the high boundary and L_k is the low boundary. These intervals will map to the equivalence classes of Definition 2. Through the mapping, nations in an interval have the same features

as the corresponding approximation. In our design, Cl^* is an assumption in the beginning. The size of Cl^* counts on the dependency measure and approximation operation next.

Definition 5: Dependency measure for *CFR*

A ranking interval ($Cl_{>L_k}^{\leq H_k}$) depending on an equivalence class (X_k) is presented as a rule $X_k \rightarrow Cl_{>L_k}^{\leq H_k}$. The dependency measure is defined as:

$$\gamma_{\{q_k\}}(Cl_{>L_k}^{\leq H_k}) = \max \left\{ \frac{POS_{\{q_k\}}\left(Cl_{>L_k}^{\leq H_k}\right)}{|U_k|} \right\}$$ where $\{q_k\}$ is a set criteria for the

equivalence class X_k , $X_k = (U_k, \Gamma_k)$, and $\Gamma_k = (x_i, x_{i'})$ means x_i and $x_{i'}$ have a relation on the same criterion q_k . Therefore, nations having the most relevant and important on criterion q_k are grouped together to support the rule, $X_k \rightarrow Cl_{>L_k}^{\leq H_k}$. Under this definition, at most m stages can be available.

Definition 6: Approximation operations

Considering to have a bigger cluster provides a disjunctive operation on approximations, X_k and $X_{k'}$, an is defined to expand the ranking interval. The larger approximation will have more criteria in the relational condition, i.e., A has more criteria in P and fewer partitions in U/P .

$\underline{A}(X_k \cup X_{k'}) = \underline{A}(X_k) \cup \underline{A}(X_{k'})$ if k and k' belong to the same stages

$\underline{A}(X_k) \cap \underline{A}(X_{k'}) = \varnothing$ if k and k' belong to different stages

4   The Application Results

The application results of CFR have three parts in Table 2. The first, shows two clusters. The second, presents the maximum evidential weight of $r_{i1}, r_{i2}, ..., r_{im}$ in EWP column. The third, presents EWP orders of Definition 2 in R' column. The cells having values lower than the maximum weight are presented as empty.

Table 2
EWP orders for E-government stages

| Ranks	Nations	Stage	EWP		R'	
			g_3''	g_{11}''	$r_{i,3}$	$r_{i,11}$
1	Liechtenstein	1		1.00		1
2	Monaco	1		1.00		1
3	Switzerland	1		1.00		1
4	Iceland	1		0.75		1
5	Luxembourg	1		0.80		1
6	Denmark	1		0.67		1
7	Republic of Korea	1		0.77		1
8	Netherlands	1		0.67		1
9	Sweden	1		0.67		1
10	United Kingdom	1		0.69		1
11	France	1		0.84		1
12	Norway	1		0.85		1
13	Germany	1		1.00		1
14	Belgium	1		1.00		1
15	New Zealand	1		0.93		1
16	Andorra	1		0.88		1
17	Finland	1		0.82		1
18	Malta	1		0.78		1
19	Antigua and Barbuda	1		0.77		1
20	Canada	1		0.73		1
21	Austria	1		0.79		1
22	Croatia	1		0.84		1
23	Singapore	2	0.87		1	
24	States	2	0.83		1	
25	Israel	2	0.80		1	
26	San Marino	2	0.85		1	
27	Barbados	2	0.82		1	
28	Italy	2	0.80		1	
29	Estonia	2	0.77		1	
30	Russian Federation	2	0.84		1	
31	Ireland	2	0.83		1	
32	Australia	2	0.81		1	
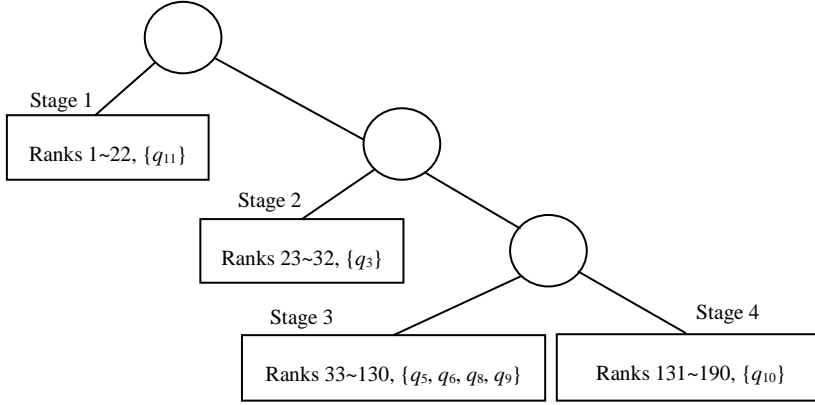
Figure 3
The stages of UN-EGDD

The clustering features are named as stages for illustration in Fig. 3. Their dependency rules are presented below.

Rule 1: If a nation's q_{11} is the most relevant and important then the nation belongs to Sage 1 where the dependency rule as $X_{11} \rightarrow Cl_{>23}^{\leq 1}$,

$$\gamma_{\{q_{11}\}}(Cl_{>L_{23}}^{\leq H_1}) = 1,$$
$$X_{11} = \{\underline{A}(x_i, x_{i'}) \mid (x_i, x_{i'}) \in \Gamma \; iff \; (x_i, r_{i,11}) = (x_{i'}, r_{i',11}), \; r_{i,11} = 1, \; and \; r_{i,'11} = 1\}$$

Rule 2: If a nation's q_3 is the most relevant and important then the nation belongs to Stage 2 where the dependency rule as $X_3 \rightarrow Cl_{>33}^{\leq 23}$,

$$\gamma_{\{q_3\}}(Cl_{>L_{33}}^{\leq H_{23}}) = 1,$$
$$X_3 = \{\underline{A}(x_i, x_{i'}) \mid (x_i, x_{i'}) \in \Gamma \; iff \; (x_i, r_{i,3}) = (x_{i'}, r_{i',3}), \; r_{i,3} = 1, \; and \; r_{i,'3} = 1\}$$

Rule 3: If a nation's q_5, q_6, q_7, q_8, or q_9 is the most relevant and important then the nation belongs to Stage 3, where the dependency rule as

$$X_{5689} \rightarrow Cl_{>130}^{\leq 33}, \; X_{5689} = X_5 \cup X_6 \cup X_8 \cup X_9, \; \gamma_{\{q_5, q_6, q_8, q_9\}}(Cl_{>130}^{\leq 33}) = 0.88,$$
$$X_{5689} = \{\underline{A}(x_i, x_{i'}) \mid (x_i, x_{i'}) \in \Gamma \; iff \; (x_i, r_{i,5}) = (x_{i'}, r_{i',5}), \; r_{i,5} = 1 \; and \; r_{i,'5} = 1,$$
$$(x_i, r_{i,6}) = (x_{i'}, r_{i',6}), \; r_{i,6} = 1 \; and \; r_{i,'6} = 1, \; (x_i, r_{i,8}) = (x_{i'}, r_{i',8}), \; r_{i,8} = 1 \; and \; r_{i,'8} = 1,$$
$$(x_i, r_{i,9}) = (x_{i'}, r_{i',9}), \; r_{i,9} = 1 \; and \; r_{i,'9} = 1\}$$

Rule 4: If a nation's q_{10} is the most relevant and important then the nation belongs to Stage 4 where the dependency rule as $X_{10} \rightarrow Cl_{>L_{491}}^{\leq H_{130}}$,

$$\gamma_{\{q_{10}\}}(Cl_{>L_{491}}^{\leq H_{130}}) = 0.94, \; and$$
$$X_{10} = \{\underline{A}(x_i, x_{i'}) \mid x_i, x_{i'} \in \Gamma \; iff \; (x_i, r_{i,10}) = (x_{i'}, r_{i',10}), r_{i,10} = 1, \; and \; r_{i,'10} = 1\}$$

CFR has two merits. The first, is to integrate classification and clustering together through the characteristics of the information system. One is the characteristic of preferences and the other is EWP. Even DRSA and RS function differently, they can complement each other to discover unknown information. The second, is to simply and easily find the number of clusters. The resulting clusters are featured with the equivalence relations, composed of the most relevant and important characteristic.

5   Discussions

This section has two parts. One is about the technique discussion. The other is a case study for the clustering stages of E-government.

5.1   Technique Discussion

The technique discussion section has four parts. They are goals, methodology, applications and comparison. This research aims to transform the local information from classification to discover a global topology for E-government. The topological clusters map to the ranking intervals thus providing users a global view for E-government stages.

The methodology of CFR takes top relevance and importance as the requirement for the "indiscernability" relationship. EWP contain the characteristics related to a nation's rank. The dependency rules based on EWP thus can present the clustering stages and features, leading to a view for the ranking levels of E-government. The application of CFR on UN-EGDD successfully discovers the topology of E-government has four stages, such as, Adult literacy, Infrastructure development, Online transaction, and expanding e-service through enrollment.

The functions comparison of CFR with DRSA and RS is processed with fair benchmarking, i.e., information system of preferences. The comparison in clustering features and ranks classification are listed in Table 3. The ranks classification is able to separate nations according to the ranking intervals and the clustering features can give natural groups with the dependency rules. The result shows that CFR has both functions of DRSA and RS, and provides an extension beyond DRSA or RS individually.

Table 3
The functions comparison of DRSA, RS, and CFR

	DRSA	RS	CFR
Clustering features	0	1	1
Ranks classification	1	0	1
Total functions	1	1	2

5.2 The Case Study

These dependency rules show that the rankings of UN-EGDD depend on four stages. These stages can be explained by the clustering features such as:

● Stage 1, the educational enrollment plays a critical role to sustain e-government at the top. United Nations E-government Survey 2012 reports a big challenge in development, i.e., low e-service usage. Generally, citizens still use government website much more for information than for transactions. Enrollment, grant application, and so on in education can achieve two merits [25].

  ■ Closing existing gap of e-service availability and usage;

  ■ Significantly moving usage beyond the realm of information to more complex transactions and services such as e-consultation.

  This stage reveals that the expanding usage of e-service can advance the full benefit of E-governments.

● Stage 2, the transactional interactions between government and citizens is the key to fulfilling online service. United Nations E-government Survey 2012 specifies that the sustainable development of the use of Information and Communication Technology (ICT) requires e-participation to contribute the socio-economic uplift of the people. E-government will play a role of proactive facilitator to treat people as active partners, by promoting user uptake, addressing the needs and concerns of the citizenry, especially the vulnerable. Furthermore, greater efficacy and effectiveness in the sustainable development can achieve solving the digital divide [26].

● Stage 3, the telecommunication infrastructure plays the most significant role in developing the fundamentals of E-government. The infrastructure relates to investment, maintenance, needs of cooperative and shared resources, telephone density, Internet penetration, existing speeding of technology change, allowance for convergence, etc [27]. As the evolution of increasingly powerful and user-friendly technologies, E-government can take the advantages, to provide more effective and integral participation thus generate more opportunities of interaction with citizens [28].

● Stage 4, the adult literacy, is the more significant in influencing the least developed nations. United Nations E-government Survey 2012 points out that lack of infrastructure and functional literacy are two difficulties of the least developed nations, such as, some of the African nations. These two factors illustrate low service provision and user uptake for the majority of the populations such as India, Bangladesh, Bhutan, Pakistan and Nepal [29].

Conclusions

This research proposes the CFR method to integrate DRSA and RS. The result shows four clustering features of the E-government stages. Technically, CFR generates evidential weights of criteria for nations' ranks by DRSA then, partitions nations into the equivalence classes by RS. The tree structure of clustering stages shows how UN-EGDD rankings depend on criteria. In the case study, enhancing adult literacy, building telecommunication infrastructures, providing online transactional interactions and expanding usage of e-service through education enrollments are critical points from the birth of E-government to the later mature stages.

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