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The 18th APIEMS

Proceedings

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organized by :

Industrial Engineering Study Program
Faculty of Industrial Technology
Bandung Institute of Technology

co-organizer :

The Indonesian Association of Industrial Engineering Higher Education Institution

Universitas Atma Jaya, Yogyakarta

Sepuluh Nopember Institute of Technology, Surabaya

www.apiems2017.org

18th APIEMS 2017

Table of Contents

Program Book

MESSAGE FROM THE APIEMS PRESIDENT

On behalf of the Asia Pacific Industrial Engineering and Management Society, I would like to welcome the participants to APIEMS 2017 Conference. Started in 1998, APIEMS has grown to become a major conference for industrial engineering and management systems in the Asia Pacific region with participants from all over the world.

I would like to thank to Conference Chair, Prof. Andi Cakravastia from Bandung Institute of Technology, as well as Conference Co-Chairs, Prof. Abdul Hakim Halim from Bandung Institute of Technology and Prof. Nyoman Pujawan from Institut Teknologi Sepuluh Nopember, Indonesia, who have made this conference a successful one.

I wish you have fruitful discussions at the conference and enjoy your stay at this beautiful ancient city of Yogyakarta.

Chi-Hyuck Jun
President, APIEMS
Professor, Industrial & Management Engineering
POSTECH, S. Korea

MESSAGE FROM RECTOR
OF BANDUNG INSTITUTE OF TECHNOLOGY

It is an honor for Bandung Intitute of Technology (ITB) in collaboration with Institut Teknologi Sepuluh Nopember-Surabaya, and Atma Jaya University-Yogyakarta to host the 18th APIEMS 2017 in Yogyakarta. The city that is very important to history of our country, Indonesia.

ITB is going to celebrate its 100 years of delivering engineering higher education in Indonesia. We thank APIEMS for holding this conference in Indonesia and being part of our important milestone.

ITB pioneered industrial engineering higher education in Indonesia almost half century ago. Today, there are more than 250 industrial engineering programs in our country. We hope that by holding APIEMS in Indonesia, it will accelerate further development and role of industrial engineering in Indonesia.

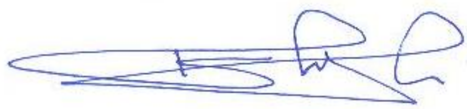
We sincerely express our gratitude to Ministry of Industry Republic of Indonesia, the Indonesian Association of Industrial Engineering Higher Education Institution, APIEMS, Keynote Speakers: Professor. D.N.P. (Pra) Murthy, Professor Emeritus of The University of Queensland, Professor Alexandre Dolgui, The Editor-in-Chief of the International Journal of Production Research, and all participants of the 18th APIEMS 2017 for their great support that make this conference possible.

Today, we are witnessing another revolution of industrial development. The internet of things era has lead the change on consumer behavior, innovate production system technology, and transform global supply chain. All of these may reshape our future.

On behalf of Bandung Institute of Technology, I encourage all participants of the 18th APIEMS 2017 to work together and contribute into future development of Industrial Engineering and Management System in Asia Pacific Region and create our better society.

We wish all participants to have a fruitful conference, expand our academic network, and enjoy the historical & cultural city of Yogyakarta.

Bandung, December 2017



Prof. Dr. Ir. Kadarsah Suryadi, DEA.
Rector of Bandung Institute of Technology

MESSAGE FROM THE GENERAL CHAIR

Welcome to the 18th APIEMS 2017 in Yogyakarta – Indonesia, an enchanted cultural city in Indonesia. It is our great privilege, Bandung Institute of Technology (ITB) collaborate with Institut Teknologi Sepuluh Nopember-Surabaya, and Atma Jaya University-Yogyakarta, to organize APIEMS in Indonesia.

By hosting the 18th APIEMS 2017 in Indonesia, we hope to contribute to the development of research and academic collaborative activities throughout Asia Pacific network in the field of Industrial Engineering and Management Systems. From the perspective of our country, we are very keen to promote development of Industrial Engineering and Management in Indonesia. We would like to continue the longstanding history of APIEMS as an important forum for exchanging ideas and information about latest development in industrial engineering and management system among professionals from Asia-Pacific countries.

The organizing committee would like to express our deep appreciation to Ministry of Industry Republic of Indonesia, Keynote Speakers: Professor. D.N.P. (Pra) Murthy, Professor Emeritus of The University of Queensland, Professor Alexandre Dolgui, The Editor-in-Chief of the International Journal of Production Research, APIEMS Fellows and Board Members, all of the Reviewers and Jury, all of the Contributors and Participants for their excellent contribution and support to the 18th APIEMS 2017. We thank to the Indonesian Association of Industrial Engineering Higher Education Institution, Bandung Institute of Technology, Institute Technology Sepuluh Nopember-Surabaya, and Atma Jaya University-Yogyakarta for the collaborative support to host the 18th APIEMS 2017.

We hope all participants of the 18th APIEMS 2017 to enjoy the conference and the cultural city of Yogyakarta.

Bandung, December 2017

Dr. Andi Cakravastia
Chair of 18th APIEMS 2017

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Day 1: December 3 (Sunday)	
Registration Bogey's Teras Bogey's Teras, Hyatt Hotel 16:00 - 19:00	
	Welcome Party 17:00 - 19:00 Bogey's Teras, Hyatt Hotel
Day 2: December 4 (Monday)	
Registration Bogey's Teras Bogey's Teras, Hyatt Hotel 07:00 - 17:00	Fellow Meeting (Arjuna Room, Hyatt Hotel) 7:00 - 17:00
	Opening Ceremony (Ballroom) 9:00 - 10:00
	Coffee Break
	Keynote Speech : D.N.P. (Pra) Murthy; Alexandre Dolgui (Ballroom) 10:20 - 12:00
	Lunch (Kemangi Bistro, Hyatt Hotel) 12:00 - 13:20
	Parallel Sessions: 13:20 - 15:00
	Coffee Break
	Parallel Sessions: 15:20 - 16:40
	APIEMS Board Meeting (Bale Raos Meeting Room) 16:00 - 18:00
Board Dinner (Bale Raos Restaurant) 18:00 - 20:00	Dinner (Prambanan Temple) 18:00 - 20:00
Day 3: December 5 (Tuesday)	
Registration Bogey's Teras Bogey's Teras, Hyatt Hotel 07:00 - 17:00	Parallel Sessions: 8:20 - 10:00
	Coffee Break
	Parallel Sessions: 10:20 - 12:00
	Lunch (Kemangi Bistro, Hyatt Hotel) 12:00 - 13:20
	Parallel Sessions: 13:20 - 15:00
	Coffee Break
	Parallel Sessions: 15:20 - 17:20
	Banquet (Poolside, Hyatt Hotel) 18:00 - 20:00
Day 4: December 6 (Wednesday)	
Registration Bogey's Teras Bogey's Teras, Hyatt Hotel 07:00 - 10:00	Parallel Sessions: 8:20 - 10:00
	Coffee Break
	Parallel Sessions: 10:20 - 12:00
	Lunch (Kemangi Bistro, Hyatt Hotel) 12:00 - 13:20

Sunday, December 3 2017						
16:00 - 19:00	**Registration (Bogey's Teras, Hyatt Hotel)**					
17:00 - 19:00	**Welcome Party (Bogey's Teras, Hyatt Hotel)**					
Monday, December 4 2017						
7:00 - 17:00	**Registration (Bogey's Teras, Hyatt Hotel)**					
7.00 - 9:00	**Fellow Meeting (Arjuna Room, Hyatt Hotel)**					
9:00 - 10:00	**Opening Ceremony (Ballroom)**					
10:00 - 10:20	**Coffee Break 1 (Ballroom)**					
10:20 - 12:00	**Keynote Speech : D.N.P. (Pra) Murthy; Alexandre Dolgui (Ballroom)**					
12:00 - 13:20	**Lunch (Kemangi Bistro, Hyatt Hotel)**					
13:20 - 15:00	**Parallel Session 3**					
	A1	**B1**	**C1**	**D1**	**E1**	**F1**
Room	**Bromo 1**	**Bromo 2**	**Bromo 3**	**Merapi 1**	**Merapi 2**	**Merapi 3**
Session name	PPC 1	PPC 2	OR 1	Logistics & SCM 1	Logistics & SCM 2	Quality 1
Paper ID	289	52	161	278	239	48
	206	345	155	311	363	332
	140	284	89	110	62	362
	2	305	10	203	39	58
	88	274	165	212	187	57
15:00 - 15:20	**Coffee Break 2**					
15:20 - 16:50	**Parallel Session 4**					
	A2	**B2**	**C2**	**D2**	**E2**	**F2**
Room	**Bromo 1**	**Bromo 2**	**Bromo 3**	**Merapi 1**	**Merapi 2**	**Merapi 3**
Session name	OR & Optimization 1	OR & Optimization 2	OR & Optimization 3 & Product Design 1	Maintenance 1	Modelling 1	Sustainability 1
Paper ID	246	11	18	112	195	134
	306	172	38	91	7	267
	173	8	317	302	233	268
	136	323	127	35	204	132
16:00 - 18:00	**APIEMS Board Meeting (Bale Raos Meeting Room)**					
18:00 - 20:00	**Dinner (Prambanan Temple)**					
18:00 - 20:00	**Board Dinner (Bale Raos Restaurant**					
Tuesday, December 5 2017						
7:00 - 17:00	**Registration (Bogey's Teras, Hyatt Hotel)**					
8:20 - 10:00	**Parallel Session 1**					
	A3	**B3**	**C3**	**D3**	**E3**	**F3**
Room	**Bromo 1**	**Bromo 2**	**Bromo 3**	**Merapi 1**	**Merapi 2**	**Merapi 3**
Session name	Product Design 1	Logistics & SCM 3	Maintenance 2	Information System 1	Optimization 2	Eng Economy 1

Paper ID	198	245	235	51	26	138
	254	307	70	174	73	215
	263	63	276	163	210	93
	190	28	211	171	354	180
	357	179	104	196	145	9
	271	337	154	24	23	4
10:00 - 10:20	**Coffee Break 1**					
10:20 - 12:00	**Parallel Session 2**					
	A4	**B4**	**C4**	**D4**	**E4**	**F4**
Room	**Bromo 1**	**Bromo 2**	**Bromo 3**	**Merapi 1**	**Merapi 2**	**Merapi 3**
Session name	Logistics & SCM 4	Logistics & SCM 5	Logistics & SCM 6	Information System 2	Technology Mgmt 1	Eng Economy 2
Paper ID	234	17	86	66	60	160
	99	19	318	71	170	12
	153	217	209	141	199	122
	96	247	192	325	283	14
	188	107	72	42	269	353
12:00 - 13:20	**Lunch (Kemangi Bistro, Hyatt Hotel)**					
13:20 - 15:00	**Parallel Session 3**					
	A5	**B5**	**C5**	**D5**	**E5**	**F5**
	Bromo 1	**Bromo 2**	**Bromo 3**	**Merapi 1**	**Merapi 2**	**Merapi 3**
Session name	Modelling 2	Optimization 1	Quality 3	Information System 3	Logistics, SCM & Service System	Ergonomics 1
Paper ID	205	6	77	164	84	279
	207	285	300	124	83	162
	208	295	277	15	266	261
	175	280	97	227	111	75
	49	65	87	238	130	159
15:00 - 15:20	**Coffee Break 2**					
15:20 - 16:50	**Parallel Session 4**					
	A6	**B6**	**C6**	**D6**	**E6**	**F6**
Room	**Bromo 1**	**Bromo 2**	**Bromo 3**	**Merapi 1**	**Merapi 2**	**Merapi 3**
Session name	Maintenance 2 & Optimization 2	Quality 2	IE Education 1	IE Education 2	Ergonomics 2	Sustainability 2
Paper ID	34	30	202	270	40	355
	55	344	340	214	324	264
	223	27	114	129	333	32
	158	51	125	128	50	167
	150	350	230	94	44	46
	241	312	194	92	146	
18:00 - 20:00	**Banquet (Poolside, Hyatt Hotel)**					

Wednesday, December 6 2017						
7:00 - 10:00	**Registration (Bogey's Teras, Hyatt Hotel)**					
8:20 - 10:00	**Parallel Session 1**					
	A7	**B7**	**C7**	**D7**	**E7**	**F7**
Room	**Bromo 1**	**Bromo 2**	**Bromo 3**	**Merapi 1**	**Merapi 2**	**Merapi 3**
Session name	Ergonomics 3	Ergonomics 4	Logistics & SCM 7	Service System 1	Service System 2	Eng Economy 1
Paper ID	85	81	296	281	351	105
	258	76	342	358	142	68
	320	126	329	334	298	67
	80	232	216	297	133	143
	189	31		90	213	256
	224	22		43	116	286
						113
10:00 - 10:20	**Coffee Break 1**					
10:20 - 12:00	**Parallel Session 2**					
	A8	**B8**	**C8**	**D8**	**E8**	**F8**
Session name	**Bromo 1**	**Bromo 2**	**Bromo 3**	**Merapi 1**	**Merapi 2**	**Merapi 3**
Paper ID	PPC 3	Ergonomics 5	Technology Mgmt 2	Other	Special Session 2	Others
	242	117	47	349	Special Paper 1	
	249	20	328	137	Special Paper 2	
	253	21	37	121	Special Paper 3	
	265			248	Special Paper 4	
	243			359	343	
12:00 - 13:20	Lunch (Kemangi Bistro, Hyatt Hotel)					

FLOOR PLAN : Hyatt Regency

1. Hyatt Regency Yogyakarta Entrance (Concierge & Golden Bird Area)
2. Lobby Court
3. Ballroom Corridor
4. Ballroom Restroom
5. Ballroom
6. Lobby Reception
7. Merbabu Room
8. Arjuna Room
9. Regency Lounge
10. Kemangi Bistro Restaurant
11. Merapi Garden
12. Bogey’s Teras

A Particle Swarm Optimization-based Clustering for Non-Metric Data

Ririn Diar Astanti†, The Jin Ai
Department of Industrial Engineering
Universitas Atma Jaya Yogyakarta, Yogyakarta, Indonesia
Tel: (+62) 274-487711, Email: ririn@mail.uajy.ac.id, jinai@mail.uajy.ac.id

Voratas Kachitvichyanukul
Department of Industrial and Manufacturing Engineering
Asian Institute of Technology, Pathumtani, Thailand
Tel: (+66) 2-5245683, Email: voratas@ait.asia

Abstract. Advance development of information technology enables an organization to get their transaction data easily or it is called as a big data era. The data they have are meaningless unless there is an effort to mine those data to be valuable information that can be used for the managerial level to make a decision. One of the methods to mine the data is clustering technique. To the best of author knowledge there are many researches have been found dealing with clustering metrics for metric data however there is limited research dealing with clustering technique for non-metric data. This paper proposes Particle Swarm Optimization (PSO)-based clustering for non-metric data.

Keywords: big data, clustering, non-metric, particle swarm optimization

1. INTRODUCTION

Advanced development of information technology has change the company run its business. For example a technology such as Point of Sale (POS) terminal is nowadays implemented in many modern retails. Those technologies enable the company to record their transaction data in example, using POS enable a retail to get detail data about customer purchase. Another example is that using optical scanning and bar code enable the company to record the inventory product easily. Therefore, nowadays industry is facing of what it is called as Big Data era.

The ability of each organization to gain many data is meaningless if the data cannot be processed to become information that is useful for the managerial to make decision. Therefore the challenge in this big data era is how we can retrieve, process and analyze in a large volume of data or it called as data mining technique (DMT) (Liao et al., 2012; Weiss & Indurkhya, 1998). Turban et al. (2007) defines data mining as "*the process that uses statistical, mathematical, artificial intelligence and machine-learning technique to extract and identify useful information and subsequently gain knowledge from large databases*" Other researcher such as Liao et al. (2012) also stated that "*data mining have formed a branch of applied artificial intelligence (AI)*". Similar definition regarding data mining have been proposed by several researchers such as Berson et al. (2000), Lejeune (2001), Ahmed (2004) and Berry and Linoff (2004).

According to Liao et al. (2012), they are several major kinds of data mining methods. One of them is clustering. According to Dong and Qi (2009) and Jain et al. (1999), clustering is an exploratory data technique that is very useful such as for data mining and pattern classification. Different with discriminant analysis, clustering technique is a grouping technique for unlabeled data.

Clustering technique can be classified into 2 techniques. They are hierarchical and non-hierarchical technique (Jain et al. (1999). Particle Swarm Optimization is proposed by Kennedy and Eberhart (1995). Since from the earliest development of Particle Swarm Optimization, one of the common application of this optimization algorithm is on data clustering, especially clustering for metric data, i.e. Van Der Merwe & Engelbrecht (2003), Chen & Ye (2004). After that, enormous researches are conducted on the topic of PSO on clustering. These researches recently have been reviewed by Rana et al. (2011), Alam et al. (2014), and Esmin et al. (2015).

Based on the review papers, there are three important issues related to the application of PSO on data clustering. First, it is well known that many variants of PSO are exists in the literature and most of them have been applied on data clustering, for example: cooperative PSO (Zhang et al., 2016), niching PSO (Ma et al., 2015), Second, various

† :Corresponding Author

clustering applications are exists being solved by PSO, for example: feature selection (Lane et al., 2013), data streams clustering (Fong et al., 2016), text document clustering (Abualigah et al., 2017), medical images processing (Vishnuvarthanan, 2017). Third, the PSO is commonly being combined or hybridized with other techniques when it is applied on data clustering. Several techniques that are commonly used are K-means (Niu et al., 2017), Nelder Mead (López García et al., 2014), and GRASP (Marinakis et al., 2008).

As data can be divided into metric and non-metric data, therefore a proper method for data mining dedicated to each data type is needed. In the particular application of PSO on data clustering, however, majority of focus is on the metric data. Therefore, there is a room for exploring in the area of PSO application on non-metric data.

2. HOMOGENEITY AND HETEROGENEITY DEFINITIONS

Let consider a clustering problem with all non-metric data. Number of objects considered in the clustering is *N* with *V* classifier variables. The number of cluster created by the algorithm is *K*. The objective is to create *K* number of clusters, in which the homogeneity of each cluster is maximize and the heterogeneity among cluster is also maximize. In order to convert this problem into optimization problem, we need to define homogeneity and heterogeneity into quantitative terms.

Let us consider cluster *k*, which consists of N_k objects. Homogeneity among objects in this cluster, can be identified by the similarity of each classifier variable across objects. In here, we define the similarity of variable *v* in this cluster as

$$S_{k,v} = \begin{cases} 1, & \text{if} \quad x_{k,1,v} = x_{k,2,v} = \cdots = x_{k,N_k,v} \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

where

$x_{k,i,v}$: the value of classifier variable *v* in the object *i* of cluster *k*

After the similarity of all variables are obtained, the homogeneity of cluster *k* can be defined as:

$$G_k = \frac{1}{V}\sum_{v=1}^{V} S_{k,v} \tag{2}$$

For whole clusters, the homogeneity measurement can be defined as:

$$\bar{G} = \frac{1}{K}\sum_{k=1}^{K} G_k \tag{3}$$

In order to express heterogeneity into quantitative term, we define the difference of variable *v* between cluster *j* and cluster *k* as

$$D_{(j,k),v} = \begin{cases} 0, & \text{if} \quad S_{j,v} = S_{k,v} = 1 \text{ and } x_{j,1,v} = x_{k,1,v} \\ 1, & \text{otherwise} \end{cases} \tag{4}$$

After the difference of all variables are obtained, the heterogeneity between cluster *j* and *k* can be defined as:

$$H_{(j,k)} = \frac{1}{V}\sum_{v=1}^{V} D_{(j,k),v} \tag{5}$$

For whole clusters, the heterogeneity measurement can be defined as:

$$\bar{H} = \left(\sum_{j=1}^{K}\sum_{k=j+1}^{K} H_{j,k}\right) \Bigg/ \sum_{k=1}^{K-1} k \tag{6}$$

Therefore, the clustering problem can be stated as optimization problem of maximizing weighted total homogeneity and heterogeneity measurement:

$$Z = w_g \bar{G} + w_h \bar{H} \tag{7}$$

where

w_g : weight of homogeneity measurement

w_h : weight of heterogeneity measurement

It is noted that $w_g + w_h = 1$.

3. DECODING METHOD

The most important issues before implementing PSO to any optimization problem are defining the solution representation, i.e. how the problem is being represented in the PSO, and decoding method, i.e. the relationship between solution in the domain of the PSO and the solution of the optimization problem. In this paper, a solution representation of non-metric clustering problem with *N* objects to form *K* clusters is particle with *N* dimension, in which each particle dimension is encoded as a real number within range [0, *K*].

It is noted that each particle dimension is representing each object, i.e. dimension *d* is representing object *d*. The position value of dimension *d* is indicating the cluster number that includes object *d*. The conversion of position value into cluster number is following this equation

$$X_h = \lceil \theta_{lh} \rceil \tag{8}$$

where

X_h : cluster number of object *h*

θ_{lh} : position value of a particle *l* in the dimension *h*

Following illustration is provided to give example how the particle position is being decoded into clusters. Given the particle position is [0.67; 0.42; 1.76; 0.87; 1.45], conversion using equation (8) is lead to cluster number [1; 1; 2; 1; 2]. Therefore, the cluster 1 consists of object 1, 2, 4 and cluster 2 consists of object 3,4.

4. THE PROPOSED PSO ALGORITHM

A PSO variant called GLNPSO (Pongchairerks and Kachitvichyanukul, 2005) is applied here, in order to solve the clustering problem with all non-metric data. The algorithm is presented below. Two problem specific steps are inserted into the GLNPSO Algorithm, which became step 2 and step 3 of the algorithm.

In order to give overall information about the algorithm, the algorithm is rewritten here although this algorithm is similar to the application to other problem, i.e. vehicle routing problem (Ai and Kachitvichyanukul, 2009). Only step 2 and step 3 of the algorithm are different.

Particle's position is converted to cluster in the step 2 (See Section 3) and the performance of cluster, which is weighted total homogeneity and heterogeneity measurement (See Section 2), is calculated in the step 3. In this framework, the particles are initialized in step 1. The iteration of particles movement is described by steps 2-8, in which the particles' fitness value are evaluated in steps 2-3, their cognitive and social information are updated in steps 4-7, and their positions are updated in step 8. Step 9 is the controlling step to repeat or stop the iteration.

Notation

τ	:	Iteration index; $\tau = 1 \ldots T$
l	:	Particle index, $l = 1 \ldots L$
h	:	Dimension index, $h = 1 \ldots H$
u	:	Uniform random number in the interval $[0,1]$
$w(\tau)$	:	Inertia weight in the τ^{th} iteration
$\omega_{lh}(\tau)$	:	Velocity of the l^{th} particle at the h^{th} dimension in the τ^{th} iteration
$\theta_{lh}(\tau)$	:	Position of the l^{th} particle at the h^{th} dimension in the τ^{th} iteration
ψ_{lh}	:	Personal best position (pbest) of the l^{th} particle at the h^{th} dimension
ψ_{gh}	:	Global best position (gbest) at the h^{th} dimension
ψ_{lh}^{L}	:	Local best position (lbest) of the l^{th} particle at the h^{th} dimension
ψ_{lh}^{N}	:	Near neighbor best position (nbest) of the l^{th} particle at the h^{th} dimension
c_p	:	Personal best position acceleration constant
c_g	:	Global best position acceleration constant
c_l	:	Local best position acceleration constant
c_n	:	Near neighbor best position acceleration constant
$\theta^{\max}$	:	Maximum position value
$\theta^{\min}$	:	Minimum position value
Θ_l	:	Vector position of the l^{th} particle, $\left[\theta_{l1} \quad \theta_{l2} \quad \cdots \quad \theta_{lH}\right]$
Ω_l	:	Vector velocity of the l^{th} particle, $\left[\omega_{l1} \quad \omega_{l2} \quad \cdots \quad \omega_{lH}\right]$
Ψ_l	:	Vector personal best position of the l^{th} particle, $\left[\psi_{l1} \quad \psi_{l2} \quad \cdots \quad \psi_{lH}\right]$
Ψ_g	:	Vector global best position, $\left[\psi_{g1} \quad \psi_{g2} \quad \cdots \quad \psi_{gH}\right]$
Ψ_l^L	:	Vector local best position of the l^{th} particle, $\left[\psi_{l1}^{L} \quad \psi_{l2}^{L} \quad \cdots \quad \psi_{lD}^{L}\right]$
R_l		The l^{th} set of vehicle route
$Z(\Theta_l)$	:	Fitness value of Θ_l
FDR	:	Fitness-distance-ratio

PSO Algorithm

1. Initialize L particles as a swarm, generate the l^{th} particle with random position Θ_l in the range $\left[\theta^{\min}, \theta^{\max}\right]$, velocity $\Omega_l = 0$ and personal best $\Psi_l = \Theta_l$ for $l = 1 \ldots L$. Set iteration $\tau = 1$.
2. For $l = 1 \ldots L$, decode $\Theta_l(\tau)$ to a set of clusters R_l.
3. For $l = 1 \ldots L$, compute the performance measurement of R_l, and set this as the fitness value of Θ_l, represented by $Z(\Theta_l)$.
4. Update pbest: For $l = 1 \ldots L$, update $\Psi_l = \Theta_l$, if $Z(\Theta_l) < Z(\Psi_l)$.
5. Update gbest: For $l = 1 \ldots L$, update $\Psi_g = \Psi_l$, if $Z(\Psi_l) < Z(\Psi_g)$.
6. Update lbest: For $l = 1 \ldots L$, among all pbest from K neighbors of the l^{th} particle, set the personal best which obtains the least fitness value to be Ψ_l^L.

7. Generate nbest: For $l=1\ldots L$, and $h=1\ldots H$, set $\psi_{lh}^{N}=\psi_{oh}$ that maximizing fitness-distance-ratio (FDR) for $o=1\ldots H$. Where FDR is defined as

$$FDR=\frac{Z(\Theta_l)-Z(\Psi_o)}{|\theta_{lh}-\psi_{oh}|} \quad \text{which } l\neq o \tag{9}$$

8. Update the velocity and the position of each l^{th} particle:

$$w(\tau)=w(T)+\frac{\tau-T}{1-T}\left[w(1)-w(T)\right] \tag{10}$$

$$\begin{aligned}\omega_{lh}(\tau+1)&=c_p u\left(\psi_{lh}-\theta_{lh}(\tau)\right)+c_g u\left(\psi_{gh}-\theta_{lh}(\tau)\right)\\&+c_l u\left(\psi_{lh}^{L}-\theta_{lh}(\tau)\right)+c_n u\left(\psi_{lh}^{N}-\theta_{lh}(\tau)\right)\\&+w(\tau)\omega_{lh}(\tau)\end{aligned} \tag{11}$$

$$\theta_{lh}(\tau+1)=\theta_{lh}(\tau)+\omega_{lh}(\tau+1) \tag{12}$$

If $\theta_{lh}(\tau+1)>\theta^{\max}$, then

$$\theta_{lh}(\tau+1)=\theta_{lh}(\tau+1)-\theta^{\max} \tag{13}$$

$$\omega_{lh}(\tau+1)=0 \tag{14}$$

If $\theta_{lh}(\tau+1)<\theta^{\min}$, then

$$\theta_{lh}(\tau+1)=\theta^{\min}+\left[\theta^{\min}-\theta_{lh}(\tau+1)\right]$$

$$\omega_{lh}(\tau+1)=0$$

9. If the stopping criterion is met, i.e. $\tau=T$, stop. Otherwise, $\tau=\tau+1$ and return to step 2.

CONCLUDING REMARKS

Two important elements of the PSO implementation for solving clustering problem with non-metric data are proposed in this paper, which are the solution representation and the decoding method. In addition, the performance of formed clusters is defined in term of homogeneity and heterogeneity measurements. Using these proposed definitions, the PSO algorithm is ready to be implemented as a computer program to solve the intended non-metric clustering problem.

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