Modified Clustering Algorithm for Energy Efficiency Utilizing Fuzzy Logic in WSN (MCF)

Tuba Firdaus[1], Meenakshi Yadav[2]

Dept. of Computer Sc. & Engg, MMMUT Gorakhpur, U.P., India, Dept. of Computer Sc. & Engg, MMMUT Gorakhpur, U.P., India

tubafirdaus@gmail.com; cycuspinus@gmail.com

Abstract

A number of research have taken place in the field of Wireless Sensor Networks (WSN) as there is continuous need of advancement in the field of wireless communication, digital technology and micro-electro-mechanical systems(MEMS) . So the need of growth of low cost, low power, multifunctional sensor nodes have been required. A Wireless Sensor Network is a collection of sensor nodes that have the capability of sensing any environmental phenomenon, processing that information and then sending that data to the base station. A single sensor node is not capable of capturing desired information from a particular region so a collection of nodes are arranged to get accurate and sufficient result. This collection of sensor nodes along with a base station will collaboratively form a network that is known as Wireless Sensor Network.

As limited energy is one of the most important constraint of WSN so it must be assured that it is utilized in most efficient way. Clustering is best approach to remove redundant data transmission to base station. Each cluster has a cluster head that is responsible for transmitting data to base station for that cluster members. Cluster head (CH) collect the data from all members of its cluster and perform aggregation on these data to remove redundancy then send it to base station. So appropriate CH election is very important for improving efficiency.

In this thesis we have presented a clustering approach that has taken a heterogeneous environment and uses fuzzy logic to elect CHs more efficiently. We have combined two parameters Distance and Residual Energy and apply fuzzy rules on that to find the priority of a node for being a CH. Simulation shows that using fuzzy logic in SEP (Stability Election Protocol) will improve the energy efficiency by providing better load distribution and utilizing the benefits of heterogeneity of network. We have shown our analysis on two parameters- Number of dead nodes and average energy of nodes

Keywords

Sensor Nodes; Clustering; Energy Efficiency; Fuzzy Logic; Residual Energy Distance

INTRODUCTION

Wireless Sensor Networks [1][2] is an emerging technology in the field of communication. Wireless sensor nodes provide real observed data from the different environmental conditions and provide data for monitoring and controlling the systems.

In Wireless Sensor Network sensor nodes are most important which are responsible for gathering sensory information, processing it and then forwarding that information to other nodes [3][4] Wireless distributed sensor and actor network consists of randomly deployed wireless sensors nodes in densely or sparsely manner and a base station. Wireless Sensor Network uses the sensor nodes for sensing the environmental entities like humidity, noise level etc. periodically or on demand and propagates these sensed data to the base station. These sensor nodes are equipped on an on board processor. Each sensor node consists of transceiver with an antenna, processing unit (processor and storage), and sensors for sensing the desired features, detecting events, sensing location of event ID

2324-7037/16/01 024-11

doi: 10.12783/ijcsa.2016.0502.01

and controlling actuators locally[5]. Sensors have analog to digital converter and some optional parts like location finding system, mobilizer and actuator.

The prime idea about such kind of WSN is anytime and anywhere computing paradigm with sensing, computing, communication etc. elements i.e.

Wireless Senor Network = Sensing(Measuring) + Computing+ Communication Element + Controlling features.

Energy consumption for transmitting l-bit data [6] over a distance d in WSNs can be easily understood by following formula:-

$$E = \begin{cases} \text{Eelec} * \text{l} + \text{Efs} * \text{d}^2 & \text{d} < d0 \\ \text{Eelec} * \text{l} + \text{Emp} * \text{d}^4 & \text{d} => d0 \end{cases} \quad (1)$$

Where d_0 is threshold value, we use free space (E_{fs}) model if receiver and transmitter lies between distance d_0 i.e. we consider direct communication between sensor node and base station else we use multipath fading (E_{mp}) model i.e. we consider energy dissipation due to presence of multiple path for propagation and reflections of another nodes in network. Once the network is deployed, nodes continue sensing the information and the battery power decreases exponentially. Sensor node uses exterior power source which has restricted energy .So to increase the lifetime of overall network it is required that each nodes utilize their power in most efficient way.

Clustering [7] provide one of the best ways to achieve better utilization of energy of sensory nodes. As given in Fig [1] the entire network is divided into certain number of clusters and for each cluster we select a leader called as CH whose job is to aggregate overall cluster information and then forwarding it to base station. Users can access network information from base station via internet which is center of network [8]. As each CH is located at different distances from base station they cause imbalance in energy consumption. Imbalance energy consumption creates network partitions and which causes some nodes to die soon due to hot-spot problem.

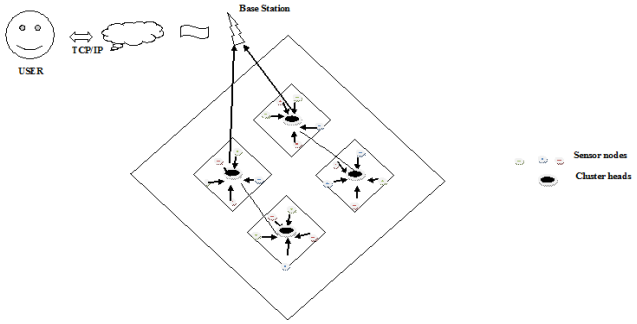

FIGURE 1 CLUSTERING IN WIRELESS SENSOR NETWORK

But our desired network should be in such a way that most of the nodes die together so that it can be replaced together. Other desirable characteristics of this network are fault tolerance, stabilized network topology, and reliability etc. By using clustering energy efficient routing can be performed for inter or intra communication in WSNs.

BENEFITS OF CLUSTERING:

a) Decreases the size of routing table by restricting the route arrangement in a cluster.
b) Consumption of less energy in communication
c) Enhance lifetime of particular sensor
d) Do not require fixed infrastructure

In past decades many approaches of clustering has been proposed and main focus of each approach is to improve energy efficiency. Clustering approaches can be classified by considering overall network topology or operational objectives or desired number of generated clusters etc.

Fuzzy logic: Fuzzy logic is basically many valued logic where variables can be any number between 0 and 1 unlike Boolean logic where values of variables can only be 0 or 1. Fuzzy logic is useful to handle the concept of partial truth where it is not necessary that value is either true or false there is a possibility of being partially true. Such concepts can easily be handled by fuzzy logic and in WSN fuzzy logic can be used to find the probability of being CH y considering many parameters where a node need not fall in any one category it may partially belong to two or more categories. Complete fuzzification method is explained in fig[2].

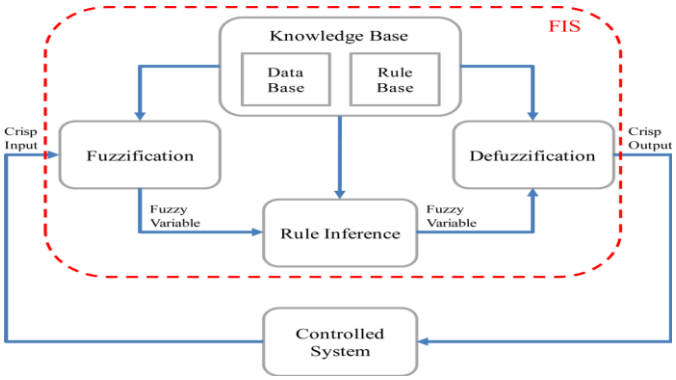

FIGURE 2 FUZZIFICATION AND DEFUZZIFICATION PROCESS

In section II various clustering algorithms proposed for WSN has been explained. In section III a comparative analysis of each algorithms have been done based on different parameters. In section IV we conclude current clustering technologies and give some future research options.

RELATED WORK

LEACH (Low Energy Adaptive Clustering Hierarchy) The first effort in the area of hierarchal clustering the sensor nodes in WSNs is given in LEACH presented by Hein Zelman [9] which uses TDMA-based MAC protocol. Main idea behind LEACH is to move the cluster head over whole network for better load distribution. In LEACH data fusion is also performed to reduce data transmission load. Cluster head selection for each group is totally based on probability.

In LEACH whole operation is divided into rounds and in every round the algorithm execute two phases first is setup phase and second is steady state phase. In setup phase each node calculates its probability by generating a random number within the range of 0 and 1. If a nodes random number is less than a threshold the node is selected as CH and send CH-ADV message to all other nodes. The nodes that have value higher than threshold are not selected as CH and it send join message to the nearest CH. LEACH protocol ensures that each node will become CH once in 1/P rounds, where p is the required number of cluster heads in the network.

All messages in LEACH use CSMA (Carrier Sense Multiple Access) for transmitting data either from node to CH or from CH or base station. LEACH has the chief priority because of its capability of providing load distribution, energy efficient solution and scalability. But LEACH protocol has some critical issues as it is totally based on probability. Residual energy of a node is not considered so node having low energy can be selected as CH. It is also possible that elected CHs are very close to each other which cause congestion in particular areas. LEACH uses single hop communication that's why it is not very useful in large networks.

PEGASIS (Power-Efficient Gathering in Sensor Information System) is a Chain-based protocol given by Lindsey et al. [10] which is an advancement of the LEACH protocol. It focused on data gathering and gives the idea that energy saving can also be achieved without forming clusters. In this algorithm a chain is established from farthest node to nearest node to the base station. Each node sense data merge it with its own data and create a packet of same size then it will forward the data to its nearest neighbor. Finally the node nearest to the base station will send that processed data to the base station.

PEGASIS performs better than LEACH as it eliminates the requirement of forming dynamic clusters and also it provide better load balancing as fusion is done at each node rather than creating overhead at a single node which tends to that all nodes will die nearly at the same time. But PEGASIS has some limitations as it requires prior knowledge of network topology which is quite impractical in large distributed systems and also if a single node dies it will break the whole network which will reduce reliability.

M-LEACH (Multi-hop LEACH) LEACH is not very feasible when the network diameter is very large as it uses single hop to communicate with base station which causes high energy dissipation but Multi hop LEACH proposed by Aslam et al. [11] uses multi hop path for communicating with base station that reduces energy consumption at cluster heads. M-LEACH is made to use in heterogeneous environment where sensor nodes are of different capacity level. Except the communication method between base station and cluster heads rest of the protocol is same as LEACH. Like LEACH this algorithm is divided into rounds and each round has two phases. In setup phase appropriate nodes elect itself as cluster heads and other nodes join nearest cluster head.

In steady state phase nodes in every cluster send data to their CHs, cluster heads aggregate that data and then forward it to base station either directly or using other intermediate cluster head. In multi hop leach two types of communication takes place first intra-cluster communication and second is inter-cluster communication. In first type of communication nodes communicates with cluster heads and cluster head forward cluster data to the base station using single hop communication. In second type of communication when base station and CHs are at large distance, CHs finds best path that requires minimum hop-count between first cluster head and base station. Multi-hop LEACH performs better than LEACH in large distributed system as energy dissipation for communication with base station is reduced by transmitting through minimum cost path.

TEEN (Threshold Sensitive Energy Efficient Sensor Network Protocol) given by Manjeshwarand et al. [12] is an event driven approach in which data to the base station is send only if some event occurs. TEEN uses two types of threshold namely soft and hard. When a node sensed soft threshold that may be because of some change in attribute or no change it switches to transmitter without having any report for cluster head. When node achieves hard threshold it switches to transmitter and forward the data to the cluster head. In TEEN hierarchy of cluster head is formed which reduces number of transmissions to the base station. TEEN is good to use in applications which are time-concerned. But it has some flaws too as node respond only if they achieve the threshold but if a node dies the user will not be aware of it and forced to wait to get response of that node. So TEEN is not good to use in applications that require periodic update.

APTEEN (Adaptive Threshold Sensitive Energy Efficient Sensor Network) given by the authors of TEEN Manjeshwar et al. [13] is an algorithm that provides improvement over LEACH and TEEN. APTEEN combines both periodic approach of LEACH and event driven approach of TEEN to provide solutions to the problem occurring in TEEN. In this algorithm CHs are elected by base station. As soon as CHs are selected these CHs broadcast a message to its members that contains four parameters- thresholds, schedules, count time and attributes. Based on this information nodes sends its sensed data to the base station only if it is satisfying hard threshold. Nodes that have not forwarded data for pre-specified time as informed by CHs will immediately sense the environment and then forward the data to the CHs. These four parameters make this algorithm very flexible as we can get our requirement by adjusting these parameters. APTEEN is good for the applications that require periodic update but it increases the complexity as it imposes additional threshold function and count time.

SEP (A Stable Election Protocol for clustered heterogeneous wireless sensor networks):Proposed by Georgios Smaragdakis et. al.[14] is an algorithm that utilizes the heterogeneity of network and make CHs among the nodes which are equipped with some extra power. LEACH protocol does not consider the heterogeneity of nodes that is energy of nodes are different initially so energy consumption cannot be optimized in the case where heterogeneity exists. So in this paper author proposed an approach where heterogeneity of node is considered and based on that nodes are divide into two parts namely- Normal nodes and advanced nodes. Normal nodes have lesser energy as compared to advanced nodes. Advanced nodes will more often get selected as CH as compared to normal nodes and all the nodes will generate random number to calculate threshold value. Author presents comparison with

LEACH protocol considering the factor First Node Dies (FND) which is improved over LEACH as normal nodes will die soon due to lesser energy and in last only advanced nodes will be left in network.

PROPOSED WORK

In this chapter, we propose an algorithm for cluster-head election in wireless sensor networks that is designed for heterogeneous network. We also provide a comparative analysis of our proposed approach with SEP which is one of the best protocols in the field of clustering for heterogeneous network.

Our algorithm is implemented in a heterogeneous environment where all nodes will not initially have same amount of energy. There are two characteristics parameters of heterogeneity i.e. namely the fraction of advanced nodes (m) and the additional energy factor between advanced and normal nodes (α) i.e. advanced nodes will have more energy than normal nodes by a factor of α. Like SEP our algorithm attempts to maintain the constraint of well-balanced energy consumption [14]. Advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fairness constraint on energy consumption. Initially each node can become a cluster head with a probability P_{opt} i.e. our protocol guarantees that every one of them will become a cluster head exactly once in every $\frac{1}{Popt}$ rounds. Suppose that each normal node will have energy E_0 and advanced nodes will have energy $Eo \cdot (1+\alpha)$. Then the total energy of this heterogeneous WSN will be equal to:

$$n \cdot (1 - m) \cdot Eo + n \cdot m \cdot Eo \cdot (1 + \alpha) = n \cdot Eo \cdot (1 + \alpha \cdot m) \quad (2)$$

Where n is the total number of nodes and m is the fraction of advanced nodes. So fraction of normal nodes can be obtained by n*(1-m).each normal node will become CH once in $\frac{1}{Popt}$ rounds while each advanced node becomes a cluster head exactly $1 + \alpha$ times in every $\frac{1}{Popt}$ rounds.

The algorithm will be divided into rounds and in these rounds CHs will be elected by using the threshold value and the priority value. Threshold will be calculated by the following formula:

$$Th = \frac{Popt}{1 - Popt(r.mod\frac{1}{Popt})} \quad (3)$$

Where r is the current round number and P_{opt} is different for normal nodes and advanced nodes and this can be calculated by following formula:

$$P_{nrm} = \frac{Popt}{1 + \alpha.m} \quad (4)$$

$$P_{adv} = \frac{Popt}{1 + \alpha.m}(1 + \alpha) \quad (5)$$

The motivation behind our protocol is that using important and effective parameters for selection of CHs will lead to provide energy efficient protocol. For selecting a CH we will combine several factors to find the probability of each node being CH. In this protocol we will prove that using fuzzy logic can reduce gathering data and calculation overheads. Thus, the lifetime of the sensor network can be extended. Our clustering algorithm is aimed to overcome the significant limitation of SEP as it is pure probabilistic approach.

Cluster-heads produced by SEP may be located at the edges of network and may be possible that CHs are too close to each other[14]. To overcome shortcomings of SEP we propose a protocol that uses three parameters to elect a CH. Like SEP in our protocol there are two types of nodes in the network i.e. advanced nodes and normal nodes.

In our proposed work we are implementing fuzzy logic with SEP (Stable Election Protocol). Our algorithm will use two parameters- Distance and Residual energy for calculating the chance value of a node for being CH for that particular round.

Distance to base station will be calculated by using the mathematical formula of distance between two points.

$$d_{toBS} = \sqrt{(x - Xb)^2 + (y - Yb)^2} \quad (6)$$

where x is X coordinate of node and y is Y coordinate of node and X_b is X coordinate of base station and Y_b is Y coordinate of base station.

Residual energy of nodes will be calculated by the formula given in equation (1) by replacing the variables with the values. Now a set of fuzzy if-then rules will be defined to find the optimal P value that will be used for threshold calculation in further rounds. Rules that we are using in our simulation are given below:

TABLE 1. FUZZY IF-THEN MAPPING RULES FOR PRIORITY

Distance	ResEnergy	Priority
close	low	low
close	low	average
close	medium	low
mid	medium	average
mid	high	Low
mid	high	Average
far	low	High
far	medium	High
far	high	High

The membership function we use for the distance variable ad residual energy is Gaussian membership function and for output variable priority we use triangular membership function. The numeric values corresponding to each membership functions is taken as follows-

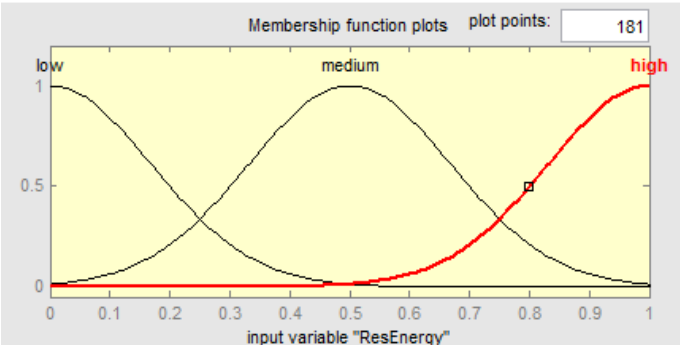

FIGURE 3 MEMBERSHIP FUNCTION FOR INPUT RESIDUAL ENERGY

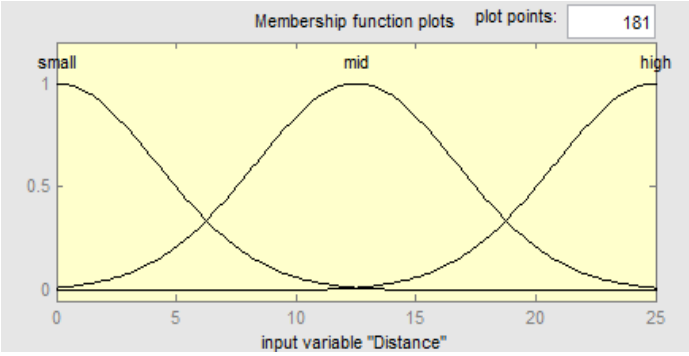

FIGURE 4 MEMBERSHIP FUNCTION FOR INPUT DISTANCE

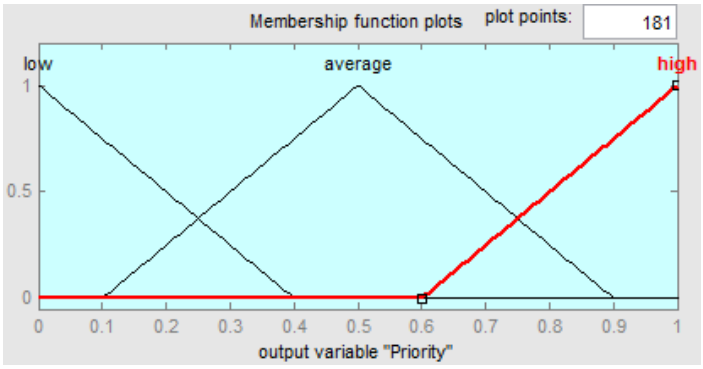

FIGURE 5 MEMBERSHIP FUNCTION FOR OUTPUT PRIORITY

ALGORITHM

1: START
2: Initialize parameters
n ← number of nodes
m ← fraction of advanced nodes
α ← additional energy factor between advanced and normal nodes
P_{opt}← Optimal value of cluster-heads
3: Define E0, d0, Etx, Erx, Efs, EDA energies.
4: countCH = 0
5: r = 0
6: ResEnergy for normal nodes = E0
ResEnergy for advanced nodes = E0(1 + α)
7: for round = 0 to rmax
8: Calculate threshold (Th) using equation 3, 4 and 5.
9: μ ←rand(0,1)
10: if(μ < = Th)
11: $r = \sqrt{(A/(\pi * n * P_{opt}))}$
12: Calculate amount of energy dissipated by using equation 1
13: ResEnergy = ResEnergy – Energy Dissipated
14: Calculate distance parameter of nodes by using equation 6
15: Calculate Priority using fuzzy if-then rules
16: if(Priority > = adj_priority)
17: countCH = countCH + 1
18: endif
19: endif
20: endfor
21:END

SIMULATION RESULT

In this chapter, we present the results of the experiments that we have done to evaluate our algorithm. We compare our clustering algorithm MCF with SEP algorithm. We have implemented a wireless sensor network clustering simulator to evaluate our algorithm. We have run several experiments on this tool to evaluate our algorithm. We

have executed our algorithm for 1000 rounds and take 200 nodes in our network. Experimental results have shown that our algorithm performs better than SEP protocol on two parameters- Average energy and Number of Dead nodes. We have calculated the average of energy and number of dead nodes in each 250 rounds.

TABLE 2. SIMULATION PARAMETERS

PARAMETERS	VALUES
Network size	100×100
Base Station Location	(100, 50)
Number of Sensor nodes	200
Initial Energy	E = 0.1 joule
Data Packet Size	4000 bits
Transmit/Receive Energy	E_{elec} = 50nJ/bit
E_{mp}	0.0013 pJ/bit/m^4
E_{fs}	10 pJ/bit/m^2

In our simulation initial energy of a normal node is set to E0 = 0.4 Joules, m=0.2 i.e. 20% of the nodes are advanced and α = 3 i.e. advanced nodes have 30% more energy than normal nodes.

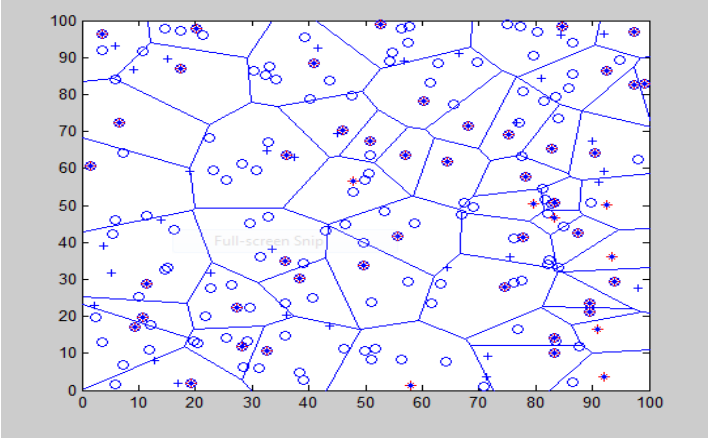

FIGURE 6 AN INSTANCE OF THE CLUSTERED NETWORK

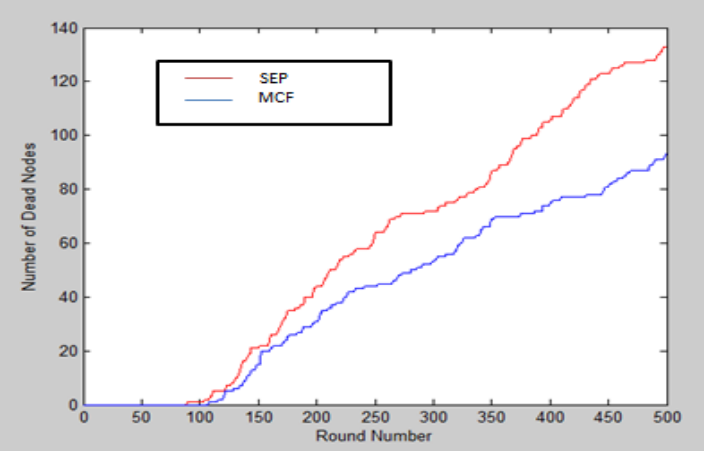

FIGURE 7 DISTRIBUTION OF NUMBER OF DEAD NODES AFTER 500 ROUNDS

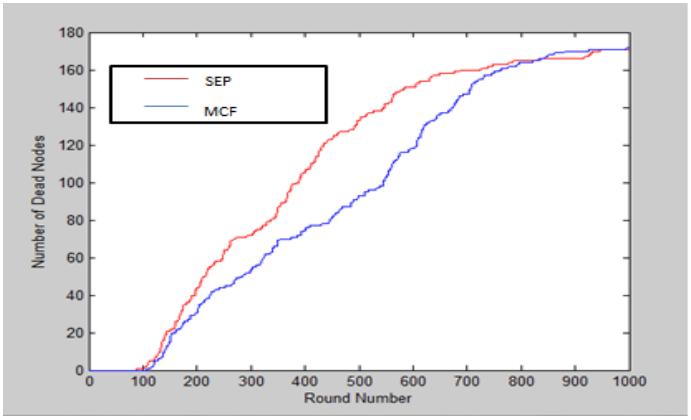

FIGURE 8 DISTRIBUTION OF NUMBER OF DEAD NODES AFTER 1000 ROUNDS

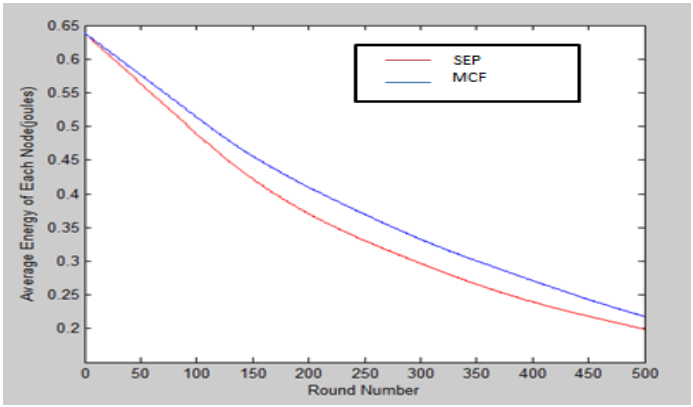

FIGURE 9 DISTRIBUTION OF AVERAGE ENERGY OF NODES AFTER 500 ROUNDS

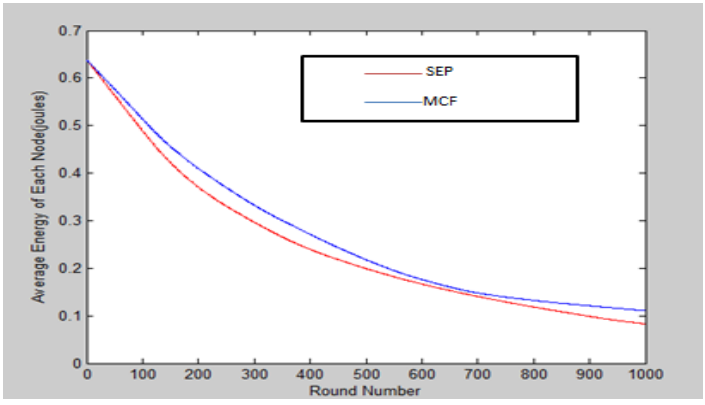

FIGURE 10 DISTRIBUTION OF AVERAGE ENERGY OF NODES AFTER 1000 ROUNDS

CONCLUSION AND FUTURE WORK

Conclusion

In this thesis we have proposed a heterogeneous clustering algorithm that uses fuzzy logic to combine two parameters i.e. distance and residual energy. Here we have observed various hierarchal clustering algorithms considering in which conditions these algorithms are suitable to use and where it is not providing efficient result. In wireless sensor network limited energy is a crucial issue. Many researchers have been done to give different

approaches of reducing energy consumption in various networking environment. Clustering is one of these approaches that achieve better energy utilization by dividing the whole network into various clusters. Hierarchal clustering involves re-clustering of nodes in various time interval which improves reliability of nodes . Re-clustering let the base station aware of nodes capacity and provide more reliable network by informing dead and low energy nodes. We have taken heterogeneous environment where some nodes called advanced nodes are equipped with some extra energy so that we can get better distribution of nodes after some rounds when nodes started dying. We have implemented fuzzy logic along with the heterogeneous clustering protocol and get better distribution of nodes and compare the algorithm considering two parameters average energy and number of dead nodes.

Future Work

From this thesis it has been concluded that implementing fuzzy logic for clustering is a good way to use effective parameters for the selection of CHs. Heterogeneity of nodes most cogently exist in the network so it is better to use heterogeneous network for your work to deal with the energy efficiency problem. Power utilization of sensor nodes can further be optimized using other important parameters for cluster head selection. Another parameters that can be used in fuzzy logic are node centrality, node concentration, communication cost etc. Using these parameters will optimize the energy efficiency in clustering.

REFERENCES

[1] I.F. Akyildiz et al., Wireless sensor networks: a survey, Computer Networks 38 (2002) 393–422.

[2] G. Gupta, M. Younis, Load-balanced clustering in wireless sensor networks, in: Proceedings of the International Conference on Communication (ICC 2003), Anchorage, Alaska, May 2003.

[3] D. Culler, D. Estrin, M. Srivastava, "Overview of Sensor Networks", IEEE Computer, USA, vol 37, pp. 41-49, August 2004.

[4] S. Ghiasi, A. Srivastava, X. Yang, M. Sarrafzadeh, Optimal energy aware clustering in sensor networks,Sensors Magazine MDPI 1 (1) (2004) 258–269

[5] SIan F. Akyildiz & Mehment Can Varun, Handbook of Wireless Sensor Network.

[6] Wendi Rabiner Heinzelman, Anantha Chandrakasan, and Hari Balakrishnan "*Energy-Efficient Communication Protocol forWireless Microsensor Networks*", Proceedings of the 33rd Hawaii InternationalConference on System Sciences - 2000Information Technology, 8-10 March 2014, Khulna, Bangladesh

[7] Ameer Ahmed Abbasi a,*, Mohamed Younis, A survey on clustering algorithms for wireless sensor networks, Computer Communications 30 (2007) 2826–2841.

[8] Dissertation, Hang Zhou, Zhe Jiang and Mo Xiaoyan, "Study and Design on Cluster Routing Protocols of Wireless Sensor Networks", 2006.

[9] HeinzelmanW. B., Chandrakasan A. P., Balakrishnan H., "An applicationspecific protocol architecture for wireless microsensor networks," IEEE Trans on Wireless Communications, Vol. 1, No. 4, 2002, pp. 660-670,

[10] S. Lindsey, C. Raghavendra, and K. M. Shivalingam,"Data Gathering Algorithms in Sensor Networks Using Energy Metrics" ,*IEEE Transactions on Parallel and Distributed Systems, Vol. 13, no.9, pp. 924-935, 2002.*

[11] Rajashree.V.Biradar, Dr.S.R. Sawant, Dr. R. R. Mudholkar , Dr. V.C .Patil "Multihop Routing In Self-Organizing Wireless Sensor Networks" IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 1, January 2011.

[12] A. Manjeshwar and D. P. Agarwal, "TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks" in *Proceedings of 15th International Parallel and Distributed Processing Symposium*, pp. 2009-2015.

[13] Arati Manjeshwar and Dharma P. Agrawal, APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks, Proceedings of the International Parallel and Distributed Processing Symposium (IPDPSí02) 1530-2075/02 $17.00 © 2002 IEEE .

[14] Georgios Smaragdakis, Ibrahim Matta, Azer Bestavros, "SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks, ITR ANI-0205294, EIA- 0202067, ANI-0095988, and ANI-9986397.

[15] Hakan Bagci and Adnan Yazici, Senior Member, IEEE, "An Energy Aware Fuzzy Unequal Clustering Algorithm for wireless Sensor Networks," Fuzzy Systems (FUZZ), 2010 IEEE InternationalConference on Digital Object Identifier: 10.1109/FUZZY.2010.5584580 Publication Year: 2010, Page(s): 1 – 8.

A Metadesign Approach in Ontology Construction

Support for Social and Technical Sub-system

Mesnan Silalahi

Center for S&T Development Studies, Indonesian Institute of Sciences,

Jl. Gatot Subroto no. 10. Jakarta Selatan, Indonesia

mesnans@yahoo.com

Abstract

This paper describes the ontology construction using a metadesign approach. The approach will constitutes key concepts such as: supporting human-problem interaction, underdesigning for emergent behavior, enabling legitimate peripheral participation, sharing control, promoting mutual learning and support, rewarding and recognizing contributions, and fostering reflective communities. The approach supports for flexibility and extensibility in the process and the used tools. The development of semantic web applications was part of the tools support to follow the metadesign framework. The central actor along the phases are the domain experts who also were respondencts in the survey. Based on the resultant ontology and the survey of the participatory domain-experts in a case-study, this approach proved to effectively build the ontology.

Keywords

Ontology; Ontology Engineering; Metadesign; Semantic Web Application

Introduction

The engineering of ontology has become a complex activity, whereby the social process plays a profound role along with the technicalities. But the methodology to support this social process in ontology engineering still lag behind. We propose a methodology that takes a socio-technical approach which recognized the ontology construction also as a social process. The methodology thus requires the creation of a socio-technical environment in the ontology construction process. The social process runs parallel with the technical process along with the ontology engineering process. The methodology describes the phases of the ontology building process whereby the central actors are the domain experts [2]. The approach adopts the metadesign framework in creating a socio-technical environment along the construction process of the ontology [12]. The approach will include creating an environment for learning, share knowledge and building argumentation. A metadesign approach which creates socio-technical environments will empower domain experts to engage actively in the continuous development of an ontology as designers rather than being restricted to the use of an existing ontology. In this case a socio-technical environment is a balanced collaborative work environment between the online and the physical presence. We setup and develop web based tools to create a socio-technical work environment where the domain experts can access relevant knowledge to generate and discuss ideas and to develop concepts and formalize it into ontology. The tools are introduced and trained to domain experts to empower them in the ontology construction process. At the end phases, the demonstration of a semantic web application needs to be conducted in order to show a clear picture of the semantic web technology and in doing so to demonstrate the usefulness of the ontology. By this way, it encourages the participatory domain experts in the process and build an opportunity and awareness of the long term goal.

As a proof of concept we conducted a case study of the development of Indonesian medicinal plants (TOAI) ontology. The investigation involved ten domain experts whereby all of them have no knowledge on ontology engineering and the tools. The participants were chosen to closely resemble domain experts who may perform

2324-7037/16/01 035-9

doi: 10.12783/ijcsa.2016.0502.02

ontology modelling tasks and who have been given hands-on training using an ontology editor before doing some conceptualization. They also will be the participants of the Focus Group Discussion (FGD).

This paper also describes part of the implementation and evaluation phase of the ontology engineering processes whereby the validation of the ontology follows a metadesign point of view with functionality embedded in an web semantic application which is developed for ontology validation by domain experts.

Related Works and Motivation

Building an ontology is a technical engineering work that is also an activity that is laden with social process. Several studies have attempted to accommodate this social aspect by building an environment that facilitates collaboration among stakeholders. Reference [10] proposed a methodology called HCOME to fully support the knowledge worker on day to day activities to actively involved in an ontology life cycle. This methodology is centred on a human side whereby the developed tool supports an eclectic way to ontology development by providing a personal and a shared space for the knowledge workers involved. Reference [18] developed a tool called OntoEdit which is an ontology engineering environment that combines ontology development methodology with capabilities for collaboration and inferencing. They identified the need to clearly define the ontology life-cycle and to support the ontology engineering process with tools from feasibility analysis and identification of goals, to requirements specification, implementation, evaluation and maintenance of ontologies [17]. Reference [8] examined aspects of a wiki-based tool support which makes it possible to introduce a crowd sourcing in ontology engineering. Reference [3] developed a tool aimed for domain experts in constructing ontologies using a user-friendly tool based on controlled natural languages to guide the authoring of a conceptual ontology into a logical ontology in OWL. This will also support the domain experts to be designers in the ontology building. The tool is tailored to follow the Kanga methodology [11] that includes the activites such as: (a) identifying the scope, purpose and other requirements of the ontology; (b) gathering sources of knowledge (e.g. documents and external ontologies); (c) defining lists of concepts, relationships and instances supplied with natural language descriptions; (d) formalizing core concepts and their relations in structured English sentences; (e) generating the OWL ontology.

A Metadesign Approach in the Ontology Construction

Engineering an ontology is more and more recognized as a social and evolving process, involving geographically dispersed people with different knowledge and expertise, such as knowledge engineers, ontology engineers and domain experts. Most of the methodology for ontology engineering consists of a life cycle with a series of stages, in which the designer decides how to model a domain ontology to suit the needs and the requirements. Or the knowledge engineer drives the ontology authoring process, whereby the domain experts may become secondary to the process of knowledge modeling because the domain experts have no understanding of the languages and tools used to construct the ontology. Meanwhile, most existing ontology construction tools are designed to be used by specialists with appropriate knowledge engineering skills but who may lack the necessary domain expertise to create the relevant ontologies [8]. Mostly the domain experts are asked to provide relevant knowledge sources, or restricted only in a knowledge elicitation process to identify concepts, whereafter an ontology engineer encodes the ontology. This approach may have a negative impact on the quality of the resultant ontology, such as incorrect or incomplete knowledge constructs [3][4]. For these reasons we introduce a metadesign approach in the construction of the ontology which aims to give more support and tools for the domain expert to become a designer in the ontology building. The approach will folow metadesign key concepts as guidelined in [6] such as: supporting human-problem interaction, underdesign for emergent behavior, enabling legitimate peripheral participation, share control, promoting mutual learning and support, rewarding and recognizing contributions, and fostering reflective communities.

The underlying concept of metadesign is embedded into the methodology that will constitute: (1) how a system and its environment should be designed by domain experts, and (2) how to empower the domain experts involved in the process to become a designer. It proposes to extend the system life-cycle model from the development stage

to the maintenance and evolution stage. Changes and system evolution could be practically performed by efforts of the domain experts. Metadesign is aiming to plan, evaluate and incorporate at some extent the possible changes at design time in order to ease their implementation at use time [8]. The latter deals with design processes and models enabling involvement of the domain experts into the design process and to become a designer and be able to perform changes in the ontology life-cycle. Although domain experts who participated in our study had minimal training in the tools, we expect that domain experts would be able to author a simple model, such as taxonomy, into the ontologies without some formal training. The tools provided is aimed for the creation of solution spaces instead of specific solutions; which usually takes place in a traditional software development. At the final phase, the output of the process, namely the ontology, needs to be evaluated according to the requirements specification. To this end we build a functionality which lists the competency questions in a web form. This functionality can be used to edit and to execute the SPARQL scripts for evaluation. Typically this phase serves as a proof for the usefulness of the developed ontology and involves the engineering team as well as the domain experts. Ideally the domain experts could do the evaluation of the ontology independently by learning some skill in SPARQL.

Processes

The phases within the ontology engineering follows the methods in the framework of metadesign. In order to ensure that the ontology is a product of a consensus within the participant, a socio-tecchnical environment is pursued in the workplace. This will include the consideration of the social aspects in the methods, techniques and tools that will adapt to the need of the participants of the design team. To this end, in the first place, we use a scenario based approach in conducting the activities.

1) Scenario 1

In the first scenario we conducted interviews with the domain experts who have been identified and selected for elaborating and capturing the context and scope of the problems of the domain which is this case the genetic resources and traditional knowledge in Indonesia, particularly in the domain of native Indonesian medicinal plants. After that, data collection was carried out from a variety of sources and with a variety of formats as well as the collection of documents related to medicinal plants such as books, journals, terminology, nomenclatures and standards, as well as standard operating procedures, use cases and best practices. Then we conducted brainstorming with the domain experts who gathered together in a focused group discussion to start building some mutual agreement. Prior to the FGD, a seed domain ontology is built which is expected to be the focus and attention as well as a trigger for the development of concepts and ideas and a sharpening the scope. In this scenario a feedback from the domain experts are expected to significantly improve the quality of the seeds ontology. A work environment within the FGD is equiped with the web base data repository within a web portal, and a visualization tool to comprehend the built concepts. There is an introductory session given to the domain problem and tools. All the feedback given will be entered into a model, by the ontology engineer, as source materials for the next session. At the end of the session a communication model for the next steps is pursed to agree upon, which take the needs and personal preferences of the participants into consideration. We will adapt the needed settings of the tools to suit the new requirements for the work evironment.

2) Scenario 2

In this scenario is conducted after having a kick-off meeting whereby the participant is knowledgeable of the ontology and the ontology engineering process. The domain experts were independently asked to identify and build concepts in the domain of their expertise related to the domain of the ontology. In this case, they have previously been given hands-on training using a a web based ontology editor that is setup and can be accessed online at any time and in any place. For this task we also provided a concise manual using the editor, so they can use it at their comfort. Training using the ontology editor were given at their workplace. By using that tool each individual was expected to have the time to review and seek the necessary documents before developing a concept in the ontology and put arguments on it. It is possible to have a web based discussion with other domain experts on building argumentation on the concepts. This scenario also provides direct interaction between ontology engineers and domain experts and eventually will foster consensus in the creation of a truly shared ontology.

3) Scenario 3

In this scenario the domain experts were asked to provide feedbacks and inputs as well as critics to a semantic web application built using data that has been converted into RDF format. This activity is conducted in the FGD session. Converting data into RDF follows the model that has been developed in the ontology. In this application there are functionalities to evaluate ontology formally using the competency questions in a web form which is designed to be able to create, edit and execute SPARQL scripts. By this way, we create a work environment for the domain experts to design by themselves new requirements and to design an evaluation form of the new requirements. In In In this scenario, there is a session to show the RDF dataset in various forms. By showing a real-world example of the developed models in an application with prototypical datas, we expect the domain experts have more comprehension of all the abstract models in the construction of the ontology. By showing the usefulness of ontology, that are built in a few examples of applications such as semantic search and linked data application, will provide a strong motivation by the domain experts for more specific ontology building purposes. In this scenario, the FGD session is also pursued to the concensus of the ontology.

Tools

In the initial phases a web portal was developed using Scratchpads framework [16] which is based on Drupal [5] as a knowledge repository of all relevant sources related the domain of the ontology which is the Indonesian Genetic Resources and Traditional Knowledge (IGRTK) in particular Indonesian medicinal plants (e.g. reusable ontologies, thesauri, nomenclatures, standards, use cases and best practices). We use Drupal as a meta-design environment because it can be adapted to suit various settings to cope with emergent socio-technical issues in an ongoing manner. Extension to future needs can be adapted in the web portal as the used CMS software is built on modules which provides deep capabilities and endless flexibility on the web [5]. Within the web portal as shown in Fig.1, functionalities were built to give comments, to have discussion on a topic, and to write a blog page.

FIG.1 INFORMATION DETAIL OF A MEDICINAL PLANT IN THE IGRTK WEB PORTAL

The ontology is formally built using WebProtege [21] as shown in Fig.2, which is a web-based ontology editor for collaborative work based on Java. The main purpose of the use of this application is to provide support for online ontology development, so that it is easy for everyone to participate and contribute in a collaborative ontology development project as there is no boundary of time and place. Other capabilities of this application is the ability to provide support in a collaborative work in developing concepts such as making annotations and comments in the elements of the ontology. WebProtege supports the annotation for each components of ontology whereby the domain experts can put arguments; By this way we setup a tool to capture the participant's input to the design process so that they will take the responsibility for what they are inputting.

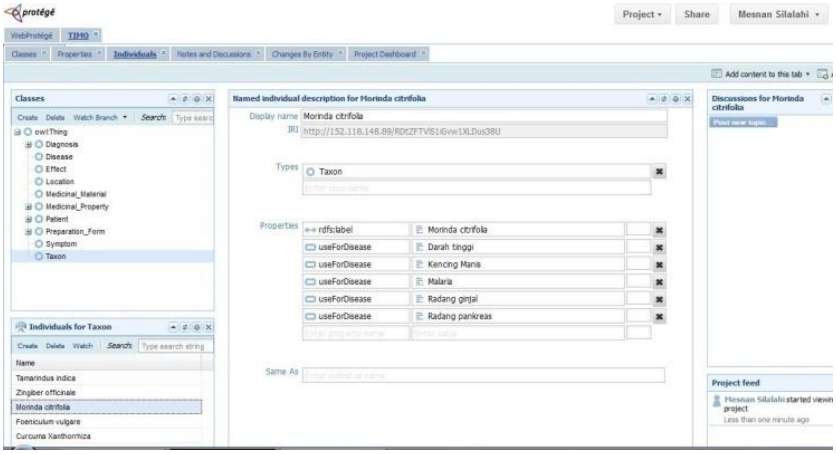

FIG.2 WEBPROTEGE AS A WEB BASED TOOL FOR DOMAIN EXPERT TO CONSTRUCT ONTOLOGY

The data that has been identified and collected is converted into RDF format. These data will be used in a semantic search application that is built in Java with interfaces using JSP and its APIs using Corese. The architecture of the Corese based platform is adapted from [14]. The development of the semantic web application is based on Sewese. Sewese is a web interface in JSP which is based on Corese. A customized semantic web application can be built easily using Sewese because of the availability of an API called SemTag in the Corese development environment as well as the availability of JSTL as template for display in JSP. Corese is compatible with SPARQL.1.1 specifications which is a recommendation of the W3C Working Group [19]. This specification also defines the syntax and semantics of SPARQL 1.1 federated query extension for executing queries distributed over different SPARQL endpoints [20]. This query extension would be needed in order to be able to show the capability of the semantic web in integrating distributed data resources.

The web semantic application for the Indonesian medicinal plants can be used to validate, evaluate, as well as to show the usefulness of the ontology. The competency questions (CQs) as shown in Fig.3 were embedded in a web application, which later can be evaluated (edited) by viewing the SPARQL scripts and executed to display results.

FIG.3 A FORM PAGE TO EDIT AND EXECUTE SPARQL SCRIPT AS VALIDATION OF THE ONTOLOGY USING COMPETENCY QUESTIONS.

The development of semantic web applications of Indonesian medicinal plants has the goal to be able to show the usefulness and the capabilities of the ontology. These are shown by building a semantic web application that demonstrates the ability of a semantic search, a linked data application and a decision support system. In general, key factors in the approach are such as: the availability of a demonstrable usefulness that can be shown to the stakeholders particularly the domain experts and the availability of a supporting work environment that is effective in building the ontology and towards a consensus. This semantic web application is built with functionalities such as: management of selected query, list of competency questions, dislay of semantic data description of a medicinal plant species as shown in Fig.4, drilldown of concepts schema and property of the

ontology.

Detil Tanaman Obat Zingiber officinale Rosc.		
http://152.118.148.89 /toai#Zingiber_officinale_Rosc.	http://152.118.148.89 /toai/toai.owl#MedicinalUse	melegakan perut.
http://152.118.148.89 /toai#Zingiber_officinale_Rosc.	http://152.118.148.89 /toai/toai.owl#MedicinalUse	menawarkan racun
http://152.118.148.89 /toai#Zingiber_officinale_Rosc.	http://152.118.148.89 /toai/toai.owl#MedicinalUse	rematik
http://152.118.148.89 /toai#Zingiber_officinale_Rosc.	http://152.118.148.89 /toai/toai.owl#MedicinalUse	Membantu pengobatan batuk
http://152.118.148.89 /toai#Zingiber_officinale_Rosc.	http://152.118.148.89 /toai/toai.owl#hasMedicinalMaterial	http://152.118.148.89 /toai/MedicinalMaterial#flavonoid
http://152.118.148.89 /toai#Zingiber_officinale_Rosc.	http://152.118.148.89 /toai/toai.owl#hasMedicinalMaterial	http://152.118.148.89 /toai/MedicinalMaterial#polifenol
http://152.118.148.89 /toai#Zingiber_officinale_Rosc.	http://152.118.148.89 /toai/toai.owl#hasMedicinalMaterial	http://152.118.148.89 /toai/MedicinalMaterial#Minyakatsiri
http://152.118.148.89 /toai#Zingiber_officinale_Rosc.	http://rs.tdwg.org/dwc/terms/Species	Zingiber officinale
http://152.118.148.89 /toai#Zingiber_officinale_Rosc.	http://rs.tdwg.org/dwc/terms/Synonym	Zingiber minus Rumph.
LocalName Zingiber officinale Rosc.		
http://152.118.148.89 /toai/LocalName#Zingiber_officinale_Rosc.	http://152.118.148.89/toai/toai.owl#Aceh	Halia
http://152.118.148.89 /toai/LocalName#Zingiber_officinale_Rosc.	http://152.118.148.89/toai/toai.owl#Bali	Cipakan
http://152.118.148.89 /toai/LocalName#Zingiber_officinale_Rosc.	http://152.118.148.89/toai/toai.owl#Baree	Kuni
http://152.118.148.89 /toai/LocalName#Zingiber_officinale_Rosc.	http://152.118.148.89/toai/toai.owl#Batak	Bahing
http://152.118.148.89 /toai/LocalName#Zingiber_officinale_Rosc.	http://152.118.148.89/toai/toai.owl#Bugis	Pese
http://152.118.148.89 /toai/LocalName#Zingiber_officinale_Rosc.	http://152.118.148.89/toai/toai.owl#Buol	Yuyo
http://152.118.148.89 /toai/LocalName#Zingiber_officinale_Rosc.	http://152.118.148.89/toai/toai.owl#Dayak	hai
http://152.118.148.89 /toai/LocalName#Zingiber_officinale_Rosc.	http://152.118.148.89/toai/toai.owl#Gayo	Bening

FIGURE 4. INFORMATION DETAIL OF A MEDICINAL PLANT IN A SEMANTIC WEB APPLICATION

Some of the functionality that is built into the semantic web applications of Indonesian medicinal plants are as follows: functionality for data search and a list of medicinal plants associated with these diseases, functionality for data search list of the symptoms of the disease and medicinal plants that can be used as remediation, functionality for data search of Indonesian medicinal plants in the local language of the ethnic groups in Indonesia, functionality for ontology validation, by displaying a list and description of the query result competency question and its functionality to list classes and properties of the ontology, functionality to provide recommended medicinal plants that can be used from the search input symptoms and the type of patients who will be using. The TOAI ontology is constructed consisting of five aspects: taxonomy, medicinal plants cultivation, pharmacology, healthcare-various recipes of Indonesian traditional herbs and the conservation of endangered native Indonesian medicinal plants. Taxonomy including data of the local name by region or ethnic group whose numbers are very large in Indonesia.

Results and Discussion

The existence of tools for convenient participation in the process and the support for use can not fully guarantee that the ontology can be effectively constructed. So limited contribution of the domain experts to the resultant ontology is acceptable because of factors such as the urgency of the work. Our experiment showed the inability of the domain experts to create complex axioms into the ontology due to minimal training in the languages and the tools. However, with the various means, socially and technically, used to achieve the desired goal, the approach fosters the contributions of the various parties which is necessary for the development and sustainability of the ontology. To this end, we conducted face-to-face events such as kickoff-meeting, FGDs, interviews, hands-on training and to provide a workbench with manuals. We encourage the participatory design by explaining the benefit and the remedies to current problems where eventually we prove it with the establishment of the semantic web application where they can see the data in the new forms. Another benefit of this establishment is to build a user-friendly view of the built artifacts so that it becomes easy to comprehend, while building a sense of purpose. By this way a consensus building of the ontology can proceed effectively.

Work Initiation and Seed Model

Kickoff meeting is an event created to introduce a face-to-face meeting organized for the socialization and personal interaction among the participants so that they can get closer to each other and are familiar with the communication preferences of each other as well as to improve mutual understanding of the rules and procedures proposed among participants. Through socialization of norms, in which the identity and the bond between the team members is built, will enable team members to communicate effectively and to perform [13]. The planning phase proved very important in metadesign approach because of preconditions that must be created and prepared carefully as recommended in a socio-technical system engineering [1] which is also confirmed from a survey. Kick-off meeting becomes important because in this event a shared commitment and agreement on procedures and mechanisms of work is also proposed in building ontology. Therefore, the presence of all participants in this first meeting is very important in the next processes of building the ontology. In this meeting a presentation is given about the identified domain problem and the working draft that became the basis and the beginning process of doing the analysis. The core work is to present a seed model that has been prepared. Seeds of this model are supposed to guarantee the quality besides as a way to build initial mutual understanding and to trigger creative ideas. Seeds is a representation of the underdesign work [7] which will require feedbacks from the participants. This seed model represents the basic structure of the ontology to be built according to the standards, but also provides space and options for the development of models in accordance with the conditions and needs. Our experiment showed that beginning the session from scratch can be intimidating, as the participants don't know where to start and at a loss about how to proceed. Indeed, it is much harder when one has to come up with something new from scratch. As we expected, during the kick-off it will be difficult for users to come up with design ideas and criteria related to the tools although we have an accessible online seed model built using WebProtege. Using this web tool the model can only be seen as a folder-structured like visualization because our tool doesn't support the visualization functionality for the ontology. To this end, we prepare a seed model in a printed graphical form distributed to the participants just before the meeting. The participants were observing and listening to the proposed ideas but they can only ask the difference with the current systems, and have no clues to come up with ideas and solutions and to share their own knowledge with the group. Eventually one of the participant came up with the idea that there should be a graphical tool to build concepts and the relations in the web portal. The next FGD sessions that we conducted has an effect of reciprocal acceleration of creativity [22] after people are introduced to the tools and given hands-on training. We demonstrate the seeds for the participants while showing how to use WebProtege which inspires them to other possibilities. Participants could take the seeds further by developing, refining and appropriating them.

Socio-technical Workbench

Our metadesign approach in ontology engineering uses web tools based on open-source software such as the Drupal platform. This platform has the flexibility and ability for extention of new functionality beyond the existing core modules. This web-based content management system is used to build an ontology engineering workbench with the ability to accommodate socio-technical aspects whereby creating and editing the formal ontology can be done by integrating it with a more powerful tool like WebProtege. Efforts to integrate these tools in a Drupal-based workbench has been done with some of the progress that needs to be improved further. One important functionality, which is from the participant's feedback, is to build concept maps tool with visualization capabilities. Concept maps similar to mind maps or topic maps are a popular tool to represent relationships between different ideas by visually connecting links through arrows, lines, and labels. Using Drupal with this interactive functionality equiped with a simple feature to give comments will create a brainstorming like work environment with a different tool. We try using the available features to achieve what we wanted . A visualization tool facilitates participants to reach a common understanding by interacting with the concretely available tools and materials. It will enhance collaborative creativity by supporting participants in creating and sharing design ideas. Visibility is crucial in externalizing ideas, reasoning about ideas or discussing them. It also supports users in coming up with new ideas, since participants have the opportunity of listening and seeing other participants' ideas [22]. The development of semantic web applications of Indonesian medicinal plants has the goal of showing the benefits that can be derived from the capabilities of an ontology. These benefits are demonstrated by building semantic web

applications that demonstrate capabilities in semantic search, the development of linked data application or the development of a recommending system.

General Effectiveness of the Approach

Based on the results of a survey on participants, the preference for kick-off meeting is the highest, followed by FGD activities, workshops, training, and the last is the activity to work independently through an online system using WebProtege. Work remotely which does not require physical presence is an option with the lowest preference value compared to other interactive work mode. These results show the preference of participants for the activity that requires physical presence in the process. Most participants saw the process through physical presence as an effective process in building ontology. In this case this physical preference is equiped with web based tools which records all results for later works whereby the participants can contribute without border of place and time.

ACKNOWLEDGMENT

I thank the Faculty of Computer Science, University of Indonesia and the Ministry of Education of Republic of Indonesia for supporting this research within the scheme of BOPTN 2014.

REFERENCES

[1] Clegg, Chris W. "Sociotechnical principles for system design." Applied ergonomics 31.5 (2000): 463-477.

[2] Dana Indra Sensuse, Mesnan Silalahi, Indra Budi. Towards a Socio-technical Ontology Engineering Methodology. International Journal of Computer Science and Application, 2014, 3(3), 111-117. doi: 10.14355/ijcsa.2014.0303.02.

[3] Denaux, Ronald, et al. "Supporting domain experts to construct conceptual ontologies: A holistic approach." Web Semantics: Science, Services and Agents on the World Wide Web 9.2 (2011): 113-127.

[4] Dimitrova, Vania, et al. Involving domain experts in authoring OWL ontologies. Springer Berlin Heidelberg, 2008.

[5] Drupal | A CMS platform for great digital experiences, https://drupal.com/

[6] Fischer, Gerhard and Thomas Herrmann. "Socio-Technical Systems: A Meta-Design Perspective." IJSKD 3.1 (2011): 1-33. Web. 29 Sep. 2013.

[7] Fischer, Gerhard, and Jonathan Ostwald. "Seeding, evolutionary growth, and reseeding: Enriching participatory design with informed participation." Proceedings of the Participatory Design Conference, PDC. Vol. 2. 2002.

[8] Fischer, Gerhard, et al. "Meta-design: a manifesto for end-user development." Communications of the ACM 47.9 (2004): 33-37.

[9] Funk, Adam, et al. "Clone: Controlled language for ontology editing." The Semantic Web. Springer Berlin Heidelberg, 2007. 142-155.

[10] Kotis, Konstantinos, and George A. Vouros. "Human-centered ontology engineering: The HCOME methodology." Knowledge and Information Systems 10.1 (2006): 109-131.

[11] Kovacs, K., Dolbear, C., Hart, G., Goodwin, J., & Mizen, H. (2006). A methodology for building conceptual domain ontologies. Ordnance Survey Research Labs Techn. Report IRI-0002.

[12] Mesnan Silalahi, Dana Indra Sensuse, Indra Budi, On Supporting a Metadesign Approach in Socio-technical Ontology Engineering, ICCSIE 2014 : XII International Conference on Computer Science and Information Engineering, Sydney, Australia

[13] Oshri, Ilan, Julia Kotlarsky, and Leslie Willcocks. "Missing links: building critical social ties for global collaborative teamwork." Communications of the ACM 51.4 (2008): 76-81.

[14] Priscille Durville and Fabien Gandon, (n.d). SeWeSe: Semantic Web Server, Retrieved from http://www-sop.inria.fr/acacia/personnel/Fabien.Gandon/research/www_2007_dev_track/

[15] Bridging the Gep between Semantic Web and Web 2 (2007): 127-138.

[16] Smith, Vincent S., et al. "Scratchpads: a data-publishing framework to build, share and manage information on the diversity of life." BMC bioinformatics 10.Suppl 14 (2009): S6.

[17] Sure Y (2002) A Tool-supported Methodology for Ontology-based Knowledge Management.ISMIS 2002, Methodologies for Intelligent Systems

[18] Sure, York, et al. OntoEdit: Collaborative ontology development for the semantic web. Springer Berlin Heidelberg, 2002.

[19] W3C, Best Practices for Publishing Linked Data - W3C Working Group Note 09 January 2014, http://www.w3.org/TR/ld-bp.

[20] W3C, SPARQL 1.1 Federated Query, W3C Recommendation 21 March 2013, http://www.w3.org/TR/sparql11-federated-query.

[21] WebProtege, http://webprotege.stanford.edu/

[22] Zhu, Li, and Thomas Herrmann. "A Meta-design Approach to Interactive Spaces." (2010).

Mesnan Silalahi born in Medan, Indonesia in 1967 and received his M.Sc in materials science from TU Delft, Netherland in 1994 and Magister in information technology from University of Indonesia in 2007. He received his Ph.D in computer science from University of Indonesia in 2016.

He works as a researcher at the Indonesian Institute of Sciences. His research interest includes ontology engineering, semantic web, e-government system, and scientometrics. He has been involved as consultant in various funded projects by JICA and ADB located in Indonesia mostly based in Jakarta. The ranges of job title is from an information system specialist to a web specialist. He also work as honorer lecturer at some universities teaching courses on management information system and internet programming.

.