Towards Developing Agent-Based KMS In Managing Knowledge of Green SD For Community of Practice

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***Abstract*—Green Software Development (GSD) is about adopting green practices in Software Development Life Cycle towards developing environmentally-friendly software products. GSD is knowledge-intensive project, which is heavily depending on sharing of green practices in Community of Practice (CoP) to develop greener software products. As knowledge sharing is an important activity in Knowledge Management (KM), this is how the power of KM comes in to support GSD. However, there is a lack of KM application in managing green knowledge of GSD. To address the research gap, this paper suggests an implementation of agent technology together with KM application in helping CoP to share knowledge of GSD. Based on Literature Review, a conceptual architecture of agent-based KM System (KMS) is proposed, with the aim of studying on how multi-agent system and KMS are working together efficiently to enhance knowledge sharing in GSD environment.**

***Index Terms*—Knowledge Management; Green Software Development; Agent Technology; Community of Practice.**

I. INTRODUCTION

Green software development (GSD) is about to apply green practices (the green knowledge) in Software Development Life Cycle (SDLC) [1]. Software developers can adopt the green practices to develop environmentally-friendly software products. The final aim of GSD is to produce greener software products in order to deliver positive effects on environmental problems [2,3].

Green and sustainable projects are heavily depending on discovery and dissemination of knowledge and experience among knowledge workers [4]. GSD is one of the green projects. This is how the power of Knowledge Management (KM) comes in to this concern. Several researchers studied about GSD and the green practices [5,6,7,8]. However, no one study about how to manage and share the green practices of GSD to other software developers efficiently. The green practices that are discovered in GSD are important green knowledge. Hence, a research gap is found: there is a lack of KM application in managing the green knowledge of GSD efficiently.

Besides, KM needs mechanism to respond to the fast-changing world. Nowadays, management of fast-growing knowledge becomes difficult which is leading to more time is needed in managing knowledge and therefore resulting in lower productivity [9]. Agent technology especially in related to multi-agent system (MAS) can play its roles together with KM System (KMS) in helping the Community of Practice (CoP) to organize, coordinate and share the knowledge efficiently [10,11].

Agent technology is applied in KM because the characteristics of software agent in learning based on the previous experience in responding to the dynamic environment autonomously. Agent has the capability of knowledge-based reasoning. The characteristic of agent technology can make sure that knowledge will grow and improve continuously [9].

Therefore, this research makes use of characteristics of agent technology. This research addresses the following question: How to apply agent technology in KMS to share the green knowledge efficiently among CoP in GSD?

Contribution of this research is to propose an Agent-based KMS in managing green knowledge of GSD for members of CoP. The members of CoP include IT practitioners, IT experts, software developers and researchers in IT field. They will share their experience and knowledge about the green practices with each other. In the long run, environmental sustainability can be achieved.

II. LITERATURE REVIEW

A. Green Software Development (GSD)

GSD and Green Software are two different terms. The main aim of GSD is about applying green practices in SDLC to produce greener software products, which includes any types of application software and system software products [1,2,3]. On the other hand, Green Software is about the intention of developing specific software applications to help the environment [1,5]. Examples of Green Software are Power Consumption Monitor and Sustainability Indicator Reporting Software.

This research will only focus on GSD. GSD includes seven phases: 1) Requirement, 2) Design, 3) Implementation, 4) Testing, 5) Installation, 6) Maintenance, and 7) Retirement [12]. Awareness of environmental issues and green practices should be promoted at the beginning of the software development [13].

Green practices are defined as clusters of knowledge about green activities and policies that address the common environmental issues [14]. Hence, the green practices are important green knowledge that can help to produce greener software products. Examples of environmental issues that have been addressed are realization of energy efficiency in field of computing and optimal use of computing resources.

B. Community of Practice (CoP)

CoP is a group of people who has a shared purpose or learning goal to deepen their expertise and knowledge in a specific field by interacting with each other on an on-going basic [15] . CoP has low level of institutionalization because the members of CoP do not necessary work for the same organization [16]. However, they have high level of connectivity and mutual engagement by holding a tight social network with each other [17].

C. Agent and Multi-Agent System (MAS)

Agent is an independent, autonomous and intelligent software program [18]. Agent makes decision autonomously by reacting to the dynamic environment, without human direct intervention. Hence, the agent needs to be designed with a clear perspective in order to achieve the users' goals [19].

Moreover, among agents, they will communicate, cooperate, coordinate and negotiate with each other to fulfill designed goals [18]. A number of agents work together in a system is called as MAS. MAS is a collection of heterogeneous agents which each of them have their own problem solver [20]. Different activities will be carried out by different agents. In MAS, output of one agent can be input of another agent. Hence, all agents in MAS have partially control over a share environment.

D. Agent Technology in KMS

KM environment is heterogeneous and dynamic. In the environment, collaboration is necessary to be fulfilled in the process of capturing, managing and sharing of knowledge to make sure that the knowledge will be distributed to and used by the correct personnel [20]. Hence, agent technology can be applied in KM. Agent has the characteristics of handling collaborative distributed environment, by enhancing coordination efficiency in KM process. A number of agents can collaborate and cooperate with each other in helping to manage knowledge autonomously [21]. Therefore, the right knowledge can be available to the right practitioners at the right time.

In KM field, there are several agent-based KMS were created. For example, Faeni (2015) introduced a type of agent-based KMS with the following features:

- Intelligent information agents: To decrease work and information burden;
- Filtering agents: To search and filter different sources of information and guide users to different knowledge; and
- Story-telling agents and pedagogical agents: To enhance the learning process.

Moreover, Antonini (2014) introduced a web-based and agent-based Social KMS. Objective of the system is to help the local residents in determining, generating and distributing information about their neighborhood. There are three characteristics of the system:

- To find related information among the large quantity of public portals;
- To assess reliability and quality of the information captured; and
- To provide users with an easy, direct and reliable feedback mechanisms.

On the other hand, Abdullah (2008) introduced an agent-based KMS to research management unit in higher learning institution. The system used Lotus Notes as a platform to enhance collaboration among members of CoP in research management unit.

The above examples of agent-based KMS show that all the agents support each other to perform various tasks in order to achieve the main goal. Software agent approach can break difficult and complex tasks into smaller sub-tasks. Therefore, each sub-task is handled by different agent and each agent has its own most suitable reasoning method to solve the specific problem without increasing the overall execution time.

Research of Faeni (2015) proved that institutions with agent-based KMS can increase job performance and decrease time to completion in knowledge-intensive job tasks. Besides, personnel of the institution can achieve better quality of work and better delegation in job performance.

Aradea, Suwardi and Surendro (2014) presented the overview of implementation of MAS to KMS. The authors summarized functionalities that agent-based KMS can provide:

- Learn, adapt and grow in the fast-moving collaborative environment;
- Match supply and demand of knowledge;
- Negotiate and receive knowledge;
- Notify if new knowledge is available;
- Recommend knowledge to fulfill users' request;
- Search, acquire, evaluate, integrate and record knowledge from various sources;
- Share and reuse knowledge;
- Update existing knowledge and delete obsolete knowledge; and
- Verify reliability and quality of knowledge.

Furthermore, Kamble (2013) summarized advantages of applying agent technology in KMS:

- Fault-tolerance can be reached by distributing responsibility to separate agents;
- Increase robustness of system;
- Minimize time overhead for knowledge serving through agent-to-agent communication;
- Problem solving competency can be enhanced;
- Scalability can be reached by adding other agent to the multi-agent system; and
- Tasks can be done simultaneously by assigning different jobs to separate agents.

III. Research Methodology

This research proposes an agent-based KMS for implementing multi-agent concept in KM process in order to utilize the green knowledge in GSD. There are involving steps as shown in Figure 1 before designing the conceptual architecture of agent-based KMS.

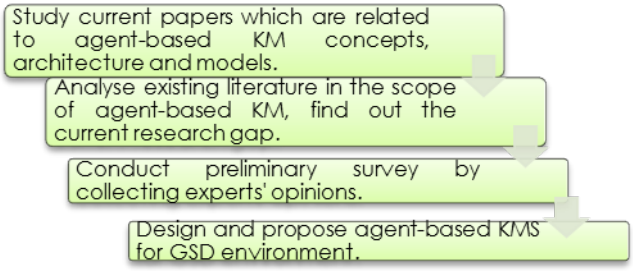

Figure 1: Research Methodology

To propose the agent-based KMS, existing papers on applying agent-based KMS to different fields have been analyzed. The increasing attention on the topic of agent-based KMS was started from year 2012. Table I shows the citation of literatures on agent-based KMS from year 2012. However, since this paper is finished on September 2015, hence it is incorrect to say that there is lesser attention on agent-based KMS on year 2015.

Table 1
Existing Literature on Agent-based KMS

Year	Source	Focus
2015	[18]	Agent-based KM for higher education
	[22]	Impact of web-2.0/3.0 for agent usability in KM
	[19]	Agent-based KM for urban social space
	[4]	Collaborative agent-based knowledge discovery
2014	[20]	Multi-agent KM
	[23]	Multi-agent KM
	[24]	Multi-agent KM for education
	[21]	Multi-agent KM for e-health
	[25]	Agent roles in personal KM process
2013	[26]	Agent-based KM for Marketing-Mix Decision Making
	[27]	Multi-agent enterprise KM system (EKMS)
	[9]	Multi-agent enterprise KM system (EKMS)
	[28]	Multi-agent KM for R&D Enterprises
	[29]	Agent-based KM for academic research
	[30]	Agent-based KM for Collaborative Software Maintenance
	[31]	Agent-based KM for education
	[32]	Multi-agent enterprise KM system (EKMS)
2012	[33]	Multi-agent enterprise KM system (EKMS)
	[34]	Multi-agent KM
	[35]	Multi-agent KM
	[36]	Multi-agent KM for BI
	[37]	Multi-agent on Personal KM
	[38]	Multi-agent Ontology-based KM

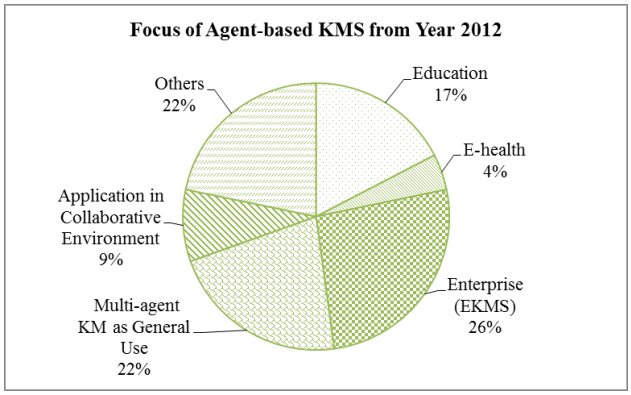

Figure 2: Focus of Agent -based KMS from Year 2012

According to Figure 2, agent technology on Enterprise KMS (EKMS) received the highest attention from researchers. The reason is about complexity of the EKMS. Hence, intelligent software agent technology is applied in KMS to divide big task into smaller sub-tasks. Therefore, different agents with suitable reasoning techniques can carry out sub-tasks simultaneously. Overall execution time can be decreased.

The second highest focus of agent-based KMS was about researches on multi-agent KMS as general use. Examples of the researches were architecture and communication language of multi-agent KMS. The researchers discussed them as general use, which means that did not implementing them to a specific application in the real world. Based on the Figure 2, research gap can be seen obviously: There is a lack of research paper about implementing agent-based KMS in GSD field.

Based on the agent-based KMS by Abdullah (2008), a preliminary survey is carried out to investigate whether the four agents that introduced by the researcher can be adapted for implementing in GSD field.

Opinion from a total of six experts towards importance of the agents are been collected. The experts are: an associate professor, who is an expert in KM and software engineering; a professor, who is an expert in KM and information system management; two senior lecturers, one of them is an expert in KM and electronic commerce, and another senior lecturer is an expert in KM and mobile information systems; and two senior programmers, who work in private sector of software companies for more than 5 years. All of the experts are knowledgeable in KM and software development field.

It should be stated that the survey is an expert evaluation exercise rather than a full-sized and complete industrial survey. From the scale of 1 to 5, where 5 is the most important, the experts are been asked to rate the important of every agent. Then, the result is collected by having simple addition of the responses over the full range of the scale. The result towards the perceived importance of each agent is shown in Figure 3.

Figure 3: Perceived Importance of Agents

Based on the result, notification agent is the most important agent in the system. Individual can be passive in searching knowledge. Therefore, it is useful while the notification agent can be triggered in notifying knowledge seekers about activities of incoming new knowledge and editing on existing knowledge. The second higher importance is profile agent because it can define users' preferences, which is useful to collaborate with notification agent in figuring out preferences of the members of CoP in certain specific knowledge type of GSD. All agents can be adapted for implementing in GSD field.

IV. Proposed Conceptual Architecture

This paper proposes a conceptual architecture of agent-based KMS as shown in Figure 4, which is adapted from the agent-based KMS by Abdullah (2008). Objective of the proposed conceptual architecture is to enhance collaboration among the members of CoP in sharing green knowledge efficiently in the GSD environment.

The members of CoP include IT practitioners, software developers, IT experts and researchers in IT field. By applying the agent-based KMS in the domain of GSD, the green knowledge that discovered by experts and researchers can be identified, collected, stored and disseminated efficiently to the practitioners and software developers who need the green knowledge in developing environmentally-friendly software products.

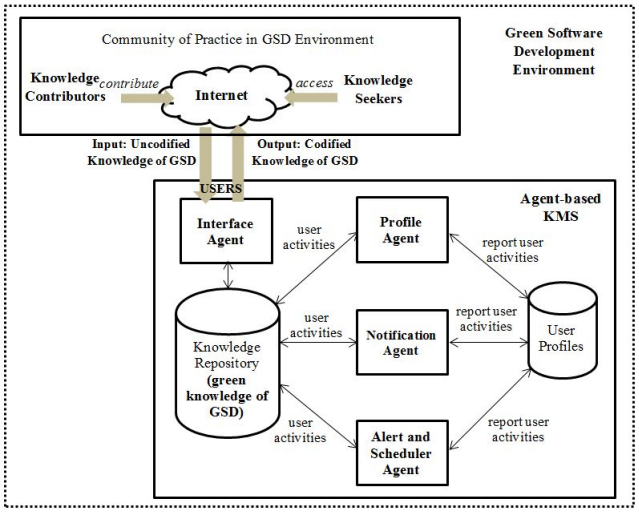

Figure 4: Proposed Agent-based KMS

As shown in Figure 4, knowledge contributors (experts and researchers) can contribute their knowledge as input to the system through Internet browsers. They demonstrate their willingness of sharing green knowledge by creating new knowledge or editing existing knowledge to the system.

Then, knowledge seekers will access to the system to search for certain green knowledge. Knowledge seekers are the software developers and IT practitioners who involve in the process of developing environmentally-friendly software products. Knowledge codification process is carried out, by converting tacit knowledge of knowledge contributors to explicit knowledge. Now, the explicit knowledge is available for the knowledge seekers to access.

Users are the members of CoP who access to the system through the Internet browser. There are five software agents and two repositories are included in the proposed agent-based KMS. Table 2 shows the components and their capabilities.

When user logs in, the Interface Agent provides options to the user for selection of the type of knowledge that he wants to contribute or access. Then, the user can access to the database and search for green knowledge, for example green practices that can be applied in design phase of GSD.

While user accesses the Knowledge Repository, Profile Agent will be triggered to record user's profile, type of document that the user contributes of accesses, and number of times in accessing the particular document. All the information about users will be report back to the User Profile and be stored in the repository of User Profile.

The proposed agent-based KMS can increase productivity of software developers. The reason is capabilities of the system in promoting and facilitating distribution of green knowledge among members of CoP. For example, software developers can acquire the green knowledge from the system and then utilize them into the process of developing environmentally-friendly software products. Hence, by having the proposed system, software products can be developed in a more sustainable manner. It is a vital step towards achieving a sustainable world, without compromising the ability of the future generation to meet their needs.

Table 2
Components and Functions of Agent-based KMS

Component	Function
Knowledge Repository	• Stores all the related data, which is the knowledge about the green practices of GSD, which are contributed by the knowledge contributors.
Users Profile	• Stores and maintains users' personal data, preferences and history. • All the agents will report users' activities back to the User Profile so that it can access and evaluate users' behaviours.
Interface Agent	• Acts as a bridge between knowledge seekers and contributors. • To be triggered in displaying information to the seekers and contributors. • Gives options to the users for selection of the type of knowledge.
Profile Agent	• Works for acquiring user profiles to define users' preferences by recording number of times that user accesses or reads certain document. • To be triggered in recording knowledge distribution to the members of CoP.
Notification Agent	• Works for acquiring user profiles to define users' preferences. • Then it will associate the users with similar categorisation of the knowledge. • Gives updates of the current discoveries in software development field to the concerned members of CoP. • To be triggered in notifying members of CoP about incoming new knowledge or editing on existing knowledge.
Alert Agent	• To be triggered based on the date given in reminding members of CoP about an event that will happen.
Scheduler Agent	• Works for managing records in database in terms of lifetime of the records. • For example, records that exceed expiry date will be deleted.

V. The Way Forward of Advantages

The main purpose of the proposed agent-based KMS is to enhance collaboration among the members of CoP in sharing green knowledge in GSD environment. The proposed conceptual architecture is expected to provide the following advantages:

- Autonomous Function: Automatic computation can be carried out while the agents are triggered by certain actions in the environment.
- Fault-tolerance: Tasks can be done concurrently by assigning different jobs to separate agents. Therefore fault-tolerance can be attained by distributing responsibilities to separate agents.
- Quality Assurance: Robustness of the system and also the quality of services that deliver to the members of CoP can be achieved.
- Scalability: Since all the agents act separately, hence scalability can be reached by adding other agent to the multi-agent system.
- Simplicity: The proposed architecture is simple in nature. The roles and flows of difference agents can be understand easily.
- Time Saving: Time overhead for knowledge serving can be minimized through smooth agent-to-agent communication.

VI. CONCLUSION AND FUTURE WORK

This paper proposes a conceptual architecture of agent-based KMS for GSD environment. The final objective is to apply agent technology in KM process in order to utilize the green knowledge of GSD among members of CoP. Hence, all the members of CoP can share green knowledge with each other and apply the green knowledge in developing environmentally-friendly software products. Environmental sustainability in software development can be achieved in the long run. The future work of this research will be focused on having analysis for the verification of the proposed conceptual architecture, and then developing a prototype to fulfill the primary objective of promoting green knowledge in GSD environment efficiently.

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