A Platform for Enterprise-Wide Healthcare Knowledge Management

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ABSTRACT

The importance of effective information and knowledge management in enterprises has spurred the development of numerous information and knowledge management software. Whilst emphasis is placed on effective document management, the essence of knowledge management is diluted as the focus is presently on managing uninterpreted data and information in document-type formats. To address this issue of the lack of true knowledge management in enterprises, especially in healthcare enterprises, we propose a Platform for Enterprise-Wide Healthcare Knowledge Management (KM-Platform). This platform is made up of two suites of applications and services, i.e. the Intelligent Agent-Based Knowledge Management Application Suite and the Strategic Visualisation, Planning and Coalition Formation Service Suite.

Keywords

Knowledge Management, Visualisation, Data Mining, Planning, Coalition Formation

1.0 INTRODUCTION

A lot of emphasis has been placed in the importance of effective information and knowledge management in enterprises. This has spurred the development of numerous information and knowledge management software and solutions such as Worksite by iManage, Quantum by Entopia, Tacit by Tacit Knowledge Systems, Livelink by Open Text and FingerTips by AmberSoft just to name a few.

Whilst a lot of emphasis is placed on effective document management, the essence of knowledge management is diluted as the focus is presently on managing uninterpreted chunks of data and information in document-type formats. This results in knowledge that is hidden in the data and text to go unnoticed and unidentified, leading to the lack of knowledge sharing and reuse.

To address this issue of the lack of effective and true knowledge management in enterprises, especially in healthcare enterprises, due to the lack of such features in many knowledge management software, we present a proposed Platform for Enterprise-Wide Healthcare Knowledge Management (KM-Platform), that aims to reinforce the efforts of the Malaysian Government towards realising a K-economy.

In order to achieve this goal, this platform capitalises on existing generic and layered architectures in order to develop an enterprise-wide knowledge management platform consisting a suite of intelligent knowledge management tools. These knowledge management tools are strategically positioned as intelligent *applications* (or *processors*) and *services* that, respectively, (a) addresses specific knowledge management processes, and (b) facilitates the delivery of knowledge-driven visualisation, planning and coalition formation for enterprise-wide strategic purposes. The services that will be developed will focus on the domain of healthcare where there is an abundant source of experience and knowledge to be tapped.

The KM-Platform addresses key areas of knowledge management and builds on the fundamental framework of knowledge management processes, i.e. knowledge creation, identification, acquisition, organisation, sharing, adaptation and utilisation (see Figure 1). These processes would yield knowledge sources that can be effectively used for a host of enterprise-wide services, particularly in healthcare, for strategic visualisation, planning and coalition formation.

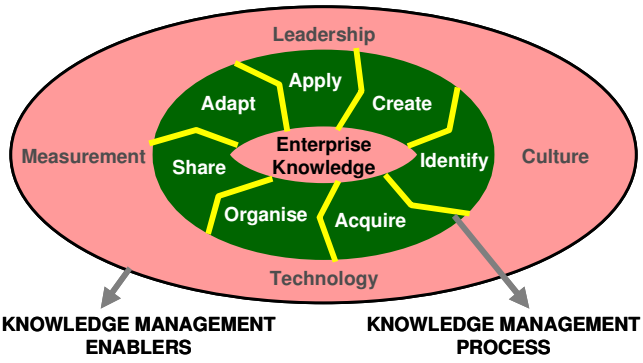

Figure 1: Knowledge Management Framework (O'Dell and Grayson, 1997)

2.0 THE KM-PLATFORM: AN OVERVIEW

The proposed KM-Platform consists of two main groups of applications and services:

1. *Intelligent Agent-Based Knowledge Management Application Suite*: This application suite addresses six

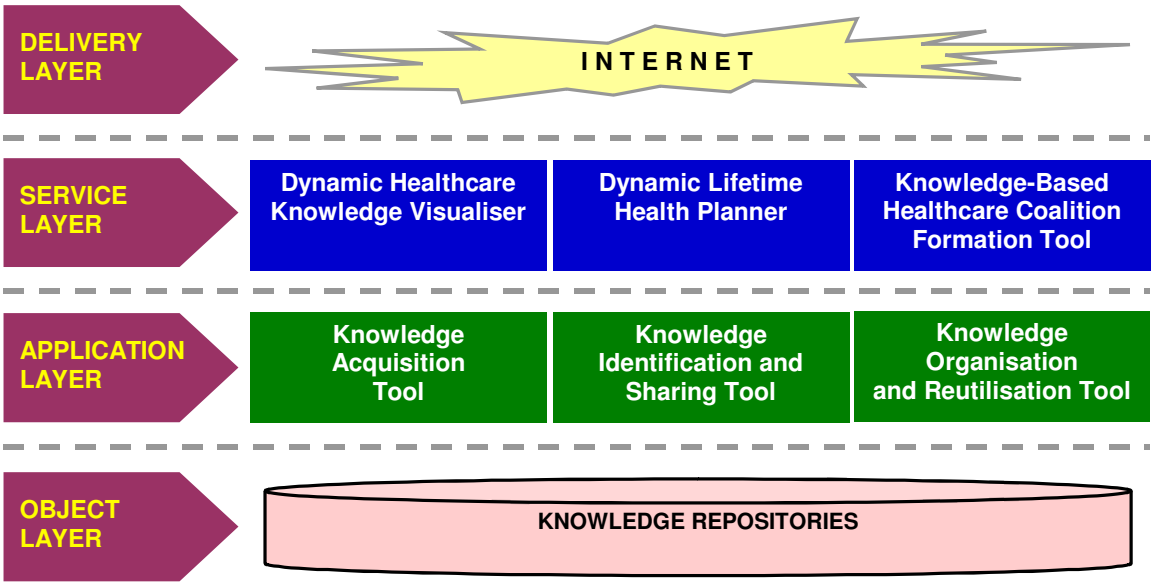

Figure 2: The KM-Platform four-layer architecture

key knowledge management processes, i.e. knowledge acquisition, identification, sharing, organisation and reutilisation. It consists of the following components:

- *Knowledge Acquisition Tool*: This component is responsible for acquiring knowledge from healthcare experts, a fundamental task in any knowledge-based system.
- *Knowledge Identification and Sharing Tool*: This component facilitates the identification of knowledge by individuals who require health-related knowledge and the sharing of knowledge by healthcare experts via the interaction of intelligent agents.
- *Knowledge Organisation and Reutilisation Tool*: Upon establishing suitable repositories of knowledge via the knowledge acquisition and knowledge sharing tools, this component facilitates the organisation, categorisation and reformatting of knowledge so as to allow effective reutilisation of healthcare knowledge for other purposes or situations.

2. *Strategic Visualisation, Planning and Coalition Formation Service Suite*: This service suite complements the functionalities of the application suite where it facilitates decision making and strategic planning in healthcare enterprises. It consists of the following components:

- Dynamic Healthcare Knowledge Visualiser: This component allows effective viewing or browsing of healthcare knowledge that has been mined from the repositories.
- Dynamic Lifetime Health Planner: This component combines generic plans available for healthcare enterprise and individuals and customises them according to current enterprise and personal health needs.
- Knowledge-Based Healthcare Coalition Formation Tool: This component utilises plans, schedules and resources to form optimum teams to carry out tasks within the healthcare enterprise.

These application and service components can be laid out in a four-layered architecture (see Figure 2).

3.0 INTELLIGENT AGENT-BASED KNOWLEDGE MANAGEMENT APPLICATION SUITE

The realisation of a Malaysian K-economy requires that enterprise-wide knowledge be tapped and utilised effectively and efficiently as a form of knowledge capital for the generation of wealth and competitive advantage. This calls for the proper management of enterprise knowledge and thus, this is the main aim of the Intelligent Agent-Based Knowledge Management Application Suite. As mentioned earlier, knowledge management involves the creation, identification, acquisition, organisation, sharing, adaptation and application of enterprise knowledge. As straightforward as it may seem, the task of orchestrating knowledge management processes is not easy as it requires a paradigm shift in terms of enterprise culture and management.

It is envisaged that this application suite will not only lead to the building of a Malaysian K-economy on a macro level but also form a community of healthcare enterprise memories at a micro level. This is where healthcare enterprises are not only able to create and manage decision-quality knowledge but also to effectively internalise and crystallise knowledge to be used for effective decision-making and strategic planning via the service suite that will be discussed in detail later.

We now describe in detail, the individual components of the Intelligent Agent-Based Knowledge Management Application Suite.

3.1 Knowledge Acquisition Tool

The Knowledge Acquisition Tool consists of three main components: an e-mail server, an application server and the knowledge repository (Cheah and Lim, 2003).

The e-mail server supports the basic functions of sending and receiving e-mails from various e-mail clients used by healthcare experts. This server would employ alternative protocols for handling e-mails and messages unlike traditional e-mail protocols that popularly utilise POP and SMTP protocols. The main sub-components of the e-mail server are as follows:

- *Intelligent E-Mail Manager*: This component handles all incoming e-mail transactions and decides on the next course of action based on who the sender or recipients are, the e-mail subject or even the e-mail size.
- *Mailet*: This mailet component receives instructions from the Intelligent E-Mail Manager. Possible actions include the creation of discussion groups for a particular healthcare issue/problem or the forwarding of e-mails to the intended group of recipients.
- *E-mail Formatter*: This component works in tandem with the Mailet to perform intelligent parsing functions to capture relevant message content (e.g. sender, recipient, date, time, etc.) as well as to reformat e-mails before they are forwarded to recipients or before it is stored in the repository.

The second component is the web-enabled application server which consists of the following sub-components:

- *Service Manager*: This component receives service requests from users. This can be in the form of registration requests, etc.
- *Evaluation Engine*: This engine allows a recipient to evaluate an e-mail's content (this may be a reply to a query/problem) in terms of its quality (i.e. usefulness, relevance, accuracy, etc.). The evaluation details are stored together with the e-mail concerned and would facilitate searches for quality answers from the e-mail content.

The final component is the e-mail repository. It is the main storage mechanism for all e-mails and discussion threads handled by the system. It includes the storage of evaluation details and the details of senders and recipients.

The Knowledge Acquisition Tool would manifest itself in the form of the KM-Mail (Knowledge-Management E-Mail) system that integrates the various components into a seamless knowledge acquisition tool. Figure 3 illustrates the KM-Mail architecture.

3.2 Knowledge Identification and Sharing Tool

The Knowledge Identification and Sharing Tool consists of three main components: an intelligent agent-based knowledge management framework, an agent-based knowledge identification agent and an agent-based knowledge sharing agent.

The intelligent agent-based knowledge management framework provides the basic and generic architecture of all the intelligent agent sub-component of the project (Lacher and Koch, 2000). Each intelligent would then be defined further to address different tasks assigned to it.

The knowledge identification agent follows protocols that facilitate healthcare non-experts to go about looking for

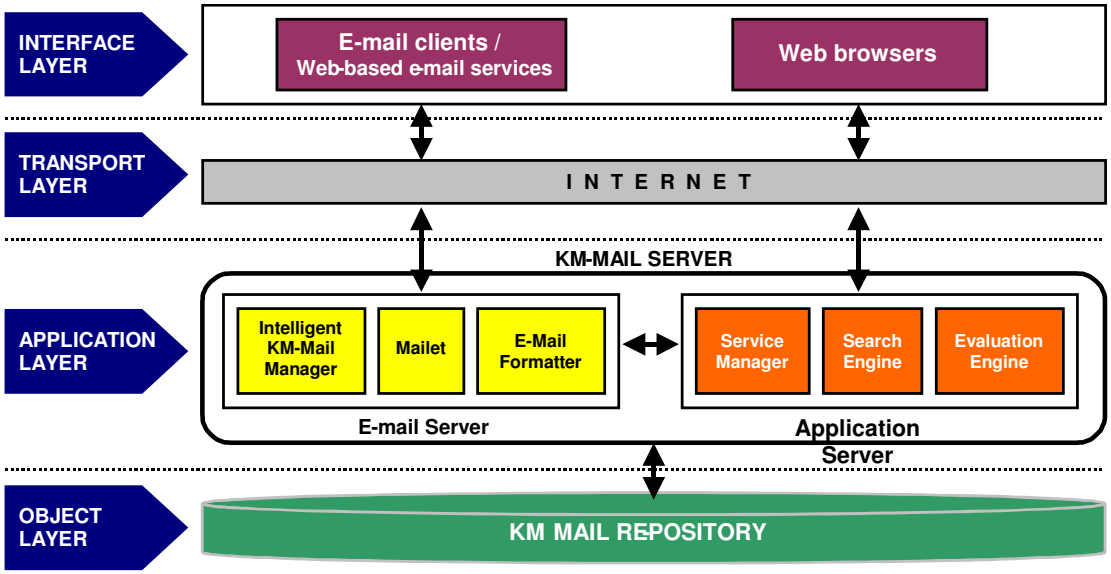

Figure 3: The four-layered KM-Mail architecture

knowledge. These search protocols allows search criteria to be specified more intuitively and explicitly so as to facilitate current search algorithms to produce more accurate search results. Main sub-components of this knowledge identification agent are:

- *Multi-Query Acquisition Sub-Component*: This sub-component intelligently captures the queries of the users using a novel protocol that dynamically adapts to the way the user specifies a query. This minimises any ambiguity in the query.
- *Query Optimisation Sub-Component*: Upon receiving the query, this sub-component reformats the query into a concise and easily transmitted format.
- *Knowledge Identification Dispatch Sub-Component*: This sub-component takes on the behaviour of a mobile agent to 'publicise' the query to other mobile agents.
- *Knowledge Matching Sub-Component*: This sub-component ultimately identifies (searches) and retrieves the required knowledge for the user.

The knowledge sharing agent complements the efforts of the knowledge identification agents where new protocols would be employed to dynamically allow healthcare experts to share relevant information and their experience (knowledge) seamlessly. This can be achieved via a system that is integrated into or is equipped with commonly used applications, e.g. e-mail, word-processing, etc. Main sub-components of this knowledge sharing agent are:

- *Sharable Knowledge Detection Sub-Component*: This sub-component employs some language analysis to proactively detect documents or e-mails that potentially contains experience-related material. Alternatively, this sub-components also allows reactive submission of such documents by the healthcare experts themselves.
- *Knowledge Formatting Sub-Component*: This sub-component complements the Knowledge Matching Sub-Component by ensuring that the shared knowledge is in a format that can be effectively identified and retrieved.
- *Knowledge Sharing Dispatch Sub-Component*: This sub-component is a mobile agent that 'publicises' knowledge that is sharable.

The Knowledge Identification and Sharing Tool monitors knowledge identification and sharing activities, whilst maintaining an awareness of the knowledge content and quality. This tool also utilises healthcare ontologies (Musen, 2000) as a means of standardising healthcare concepts and terminologies during agent negotiations. This tool potentially acts as a secondary feed to a knowledge acquisition tool where knowledge can be stored in a repository. Figure 4 provides an overview of the components of the Knowledge Identification and Sharing Tool.

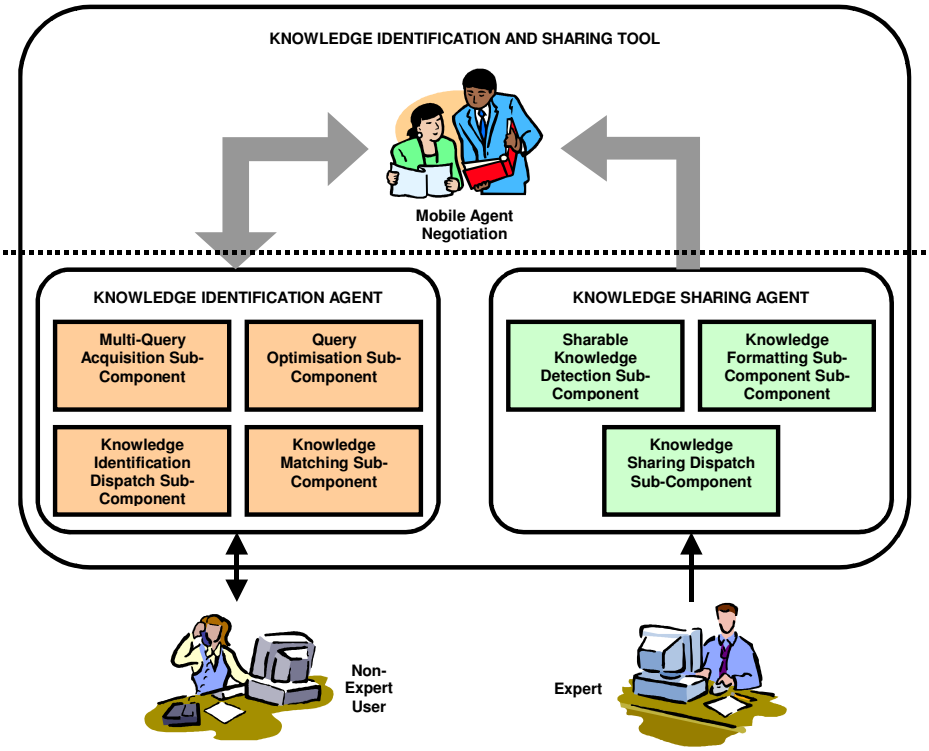

Figure 4: Overview of the Knowledge Identification and Sharing Tool

3.3 Knowledge Organisation and Reutilisation Tool

The Knowledge Organisation and Reutilisation Tool consists of three main components: an intelligent agent-based knowledge management framework (similar to that of the Knowledge Identification and Sharing Tool), an agent-based knowledge organisation agent and an agent-based knowledge reutilisation agent.

The knowledge organisation agent would focus on how intelligent agents can play a crucial role in autonomously organising the various healthcare knowledge repositories into categories for easy access. Knowledge crystallisation, cellular automata, neural network and genetic algorithm techniques would be utilised to achieve this objective. Main sub-components of this agent include:

- *Repository Seeding Sub-Component*: This sub-component allows repository administrators or healthcare experts to determine or to 'seed' sub-repositories based on certain criteria.
- *Repository Organisation Sub-Component*: Based on the repository seeding exercise, the knowledge in the repositories would automatically organise themselves according to specific protocols or algorithms, e.g. knowledge crystallisation, cellular automata, etc. These protocols would differ in terms of their accuracy and level of autonomy in carrying out the organisation exercise.
- *Garbage Collection Sub-Component*: This sub-component ensures that only the latest up-to-date knowledge is maintained in the repository. A garbage-collection algorithm removes old and under-utilised knowledge items.

The knowledge reutilisation agent basically aims to give knowledge a second-look and focuses on knowledge adaptation, information personalisation and knowledge collation in order for previously used healthcare knowledge to be reutilised effectively to solve current problems, thus advocating knowledge reuse. Techniques such as case-based reasoning and constraint satisfaction (Torrens and Faltings, 1999) would be utilised. Main sub-components include:

- *Knowledge Adaptation Sub-Component*: Previously used healthcare knowledge or solutions are adapted and modified to suite new problems or queries based on adaptation algorithms.
- *Knowledge Personalisation Sub-Component*: The adapted knowledge or solutions are then personalised to take into account certain health-related constraints or preference that a user may have. This is necessary as not all knowledge can be generically applied to all users. Differences in age, educational background, physical activity, past experience and family/medical history, etc. can affect how health-related knowledge is consumed.
- *Knowledge Collation Sub-Component*: This component takes all knowledge that has been adapted and personalised and repackages into a seamless document that allows the user to digest the output easily and effectively.

The Knowledge Organisation and Reutilisation Tool (see Figure 5) would then be a consolidation of the knowledge organisation and knowledge utilisation agents to form a seamless tool.

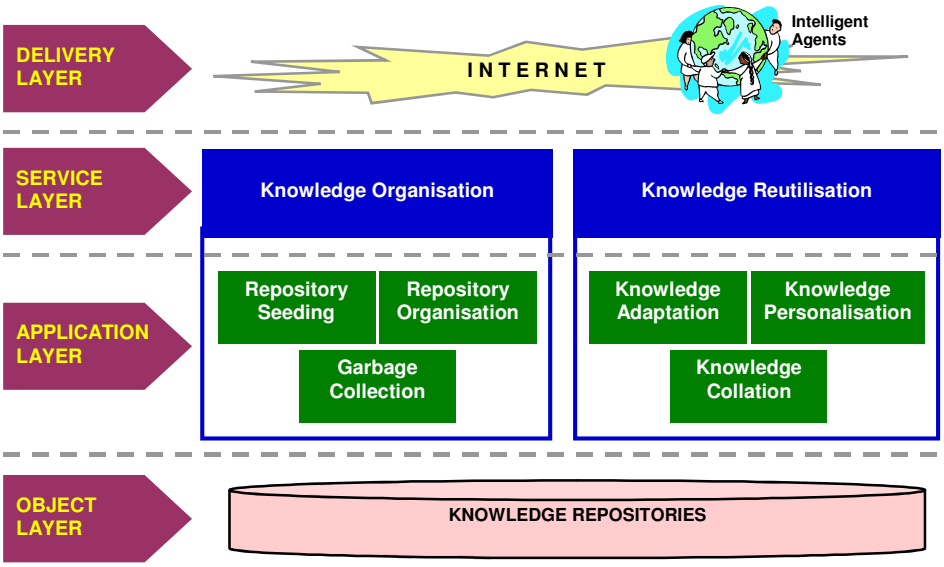

Figure 5: Four-layer Knowledge Organisation and Reutilisation Tool

4.0 STRATEGIC VISUALISATION, PLANNNING AND COALITION FORMATION SERVICE SUITE

The Strategic Visualisation, Planning and Coalition Formation Service Suite caters for the effective utilisation and operationalisation of the supporting knowledge management applications detailed earlier. It provides critical support for healthcare decision making and action planning. Here is where the objectives or output of the Intelligent Agent-Based Knowledge Management Application Suite can be effectively utilised for the creation of value in healthcare enterprises, thus, leading not only towards higher return-on-investment but also higher return-on-knowledge and experience in the healthcare industry.

Notwithstanding its complementary nature with the knowledge management application suite, the tools within this service suite also complement each other. Each tool would provide a specific knowledge-based service whilst sharing its output with another service. Very loosely, these tools fit into a cycle of a dynamic and continuous knowledge-based, enterprise-wide decision support process. This suite provides three essential knowledge-based decision support and action planning service, i.e. visualisation (to overview), planning (to look ahead) and coalition formation (to execute). Figure 6 illustrates this cycle.

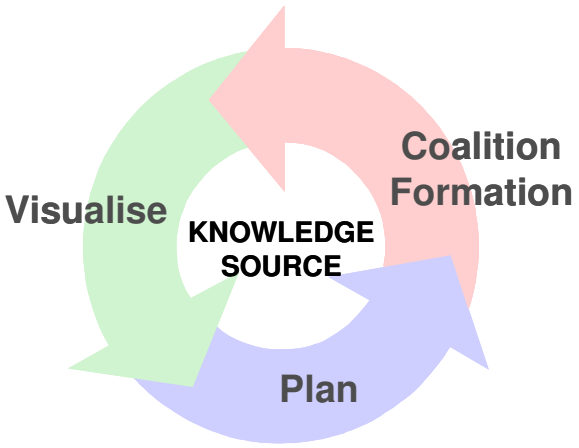

Figure 6: Visualisation, Planning and Coalition Formation Cycle

We now describe in detail the components of the Strategic Visualisation, Planning and Coalition Formation Service Suite.

4.1 Dynamic Healthcare Knowledge Visualiser

This visualisation tool consists of eight main components: knowledge discovery engine, knowledge query agent, knowledge structuring engine, knowledge structure infobase, graphics rendering engine, knowledge visualisation agent, knowledge pruning and reduction engine and novel knowledge discovery agent. These five components play a crucial in the four phases of the knowledge visualisation and operationalisation lifecycle (see Figure 7):

- *Knowledge Generation*: This is a mechanism to perform healthcare knowledge discovery or data mining tasks such as rule generation, trend analysis, clustering and classification. These tasks are performed on data sets such as laboratory data and electronic patient records. In addition to these, the discovered knowledge is further enhanced by embedding knowledge extracted from documents such as e-mails, forums, health-related documents via ontologies and thesaurusi. These tasks are performed by the Knowledge Discovery Engine.
- *Knowledge Amalgamation*: This is an agent-based strategy that will interact with the expert to generate queries. Domain expert would provide parameters related to the knowledge to be visualised to the Knowledge Query Agent. The Knowledge Query Agent would then interact with the Knowledge Structuring Engine to build a single or multi-dimensional visual map of the knowledge to be visualised. A vast library of rules called the Knowledge Structure Infobase is used to build the knowledge structure.
- *Knowledge Visualisation*: The knowledge structure generated by the Knowledge Structuring Engine is then graphically rendered by the Graphic Rendering Engine using existing techniques used in 2D and 3D games that employs Direct-3D and Direct-Draw. The expert would then view and navigate through the structure with the guidance of Knowledge Visualisation Agent.
- *Knowledge Operationalisation*: This is a mechanism that allows the expert to create new links among existing knowledge structure or even to discover new knowledge. This is performed with the help of the Novel Knowledge Discovery Agent. Furthermore, the expert will be able to prune and reduce existing knowledge, i.e. removing invalid and redundant knowledge, using the Knowledge Pruning and Reduction Engine. The resulting knowledge is added to the knowledge base which is then operationalised by a myriad of reasoning engines.

4.2 Dynamic Lifetime Health Planner

There are two activities involved in the lifetime planning for healthcare enterprises and individuals: Dynamic Lifetime Health Plan (DLHP) Generation and DLHP Delivery (Abidi and Yusoff, 1999). The former involves periodic generation of comprehensive healthcare enterprise plans and individual health plans. The latter involves global access to the generated plans, via a 'live electronic consultation session' (that entails the generation of ‘dynamic’ web-based questionnaires) in a timely manner as a healthcare enterprise progresses or the individual moves through life.

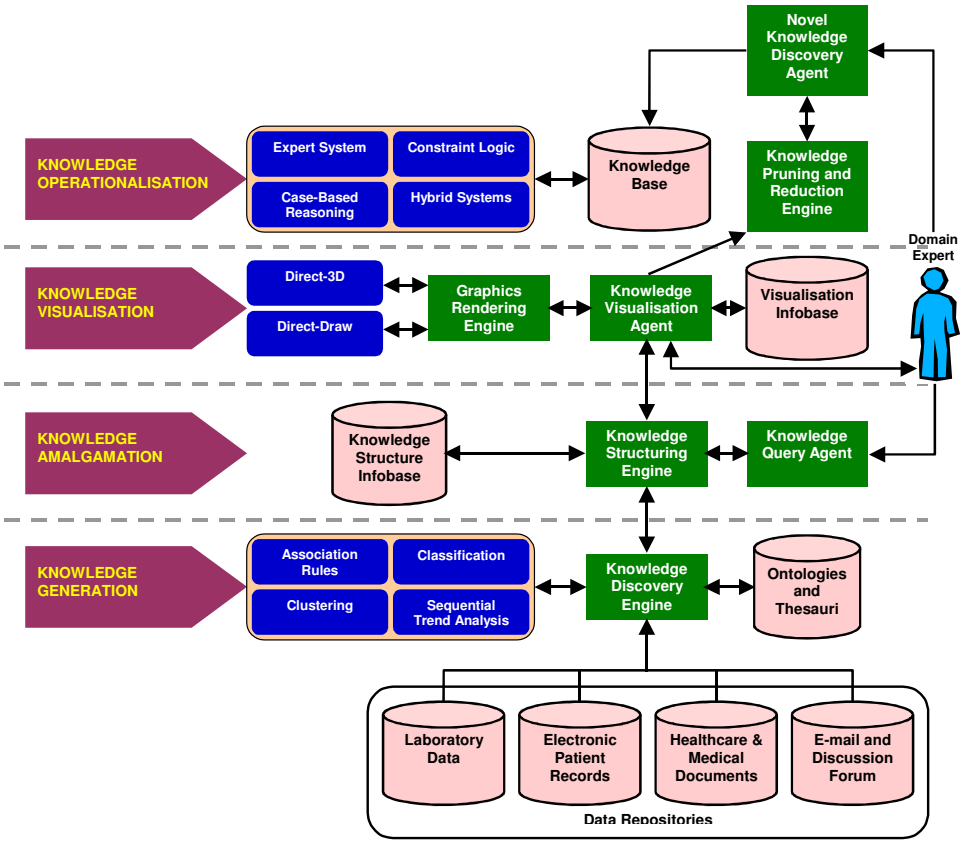

Figure 7: Functional architecture of the Dynamic Knowledge Visualiser

The DLHP Generation component is implemented in terms of three main sub-components:

- *Generic Plan Repository (GPR)*: GPR is an electronic archive to store a suite of (a) generic enterprise plans for healthcare enterprises and (b) generic health plans for individuals. Each generic enterprise plan will be operation-oriented and will cover the timing, procedures, policy and rules to comply with in executing a specific operation. On the other hand, each generic health plan will be wellness-oriented and will incorporate specialised guidelines, procedures, milestones, observations, advice, treatment and test schedules.
- *Enterprise Resource and Schedule Repository (ERSR)*: ERSR is a storage of healthcare enterprise resource and schedules that give information such as the health status of an employee or the resource storage condition of the enterprise.
- *Intelligent Dynamic Planning Agent (IDPA)*: The IDPA is the core engine responsible for the autonomous and 'intelligent' generation of 'basic' enterprise plans and individual health plans. A basic enterprise plan reflects the various operational aspects of the enterprise that need to be handled by the enterprise whereas a basic health plan reflects the various health aspects of a healthcare enterprise employee that need to be addressed by the employee. The resultant basic plan is deemed as being complete, consistent, satisfying multiple constraints (Torrens and Faltings, 1999) and operable. The IDPA works in concert with the GPR repository and the ERSR repository. Note that The IDPA is activated whenever a new plan needs to be generated.

The DLHP Delivery component is achieved by the implementation of the following two sub-components:

- *Intelligent Plan Customisation Agent (IPCA)*: The IPCA is the core 'intelligent' engine responsible for the dynamic and automated customisation of (a) healthcare enterprise plans based on the latest developments of the enterprise and (b) health plans based on the employee's most recent health status. The IPCA will direct all user-DLHP transactions via a web-based virtual 'consultation session', during which it will inquire from users (using electronic questionnaires) to acquire updated information based on the existing plan. From the responses obtained, The IPCA will dynamically customise the enterprise plans and the health plans.

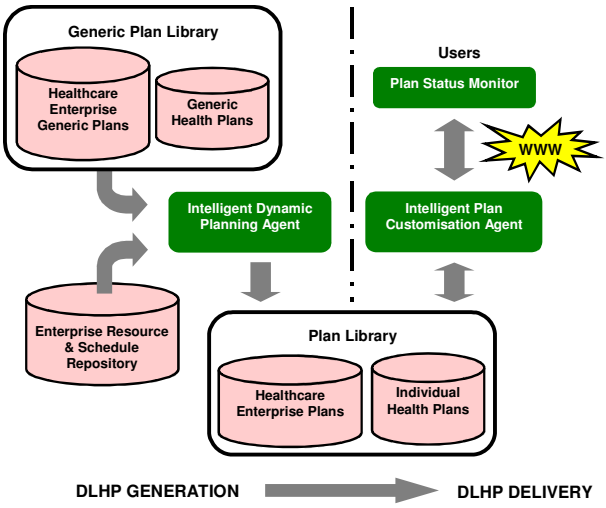

Figure 8: Dynamic Lifetime Health Planner architecture

- *Plan Status Monitor (PSM)*: The PSM is a plan maintenance application that can be used to either monitor the progress of the enterprise plan or the personal health status of the healthcare enterprise employees.

Finally, we aim to build a sophisticated and comprehensive planning system for healthcare enterprises that combines various components into a seamless Dynamic Lifetime Heath Planner. Figure 8 illustrates the infrastructure for implementing the two components.

4.3 Knowledge-Based Healthcare Coalition Formation Tool

The Knowledge-Based Coalition Formation Tool is made up of three main components (Neoh and Cheah, 2003): knowledge bases, coalition formation agents and the coalition formation delivery interface.

The function of the knowledge base component is to store various healthcare knowledge objects and resources. Basically, these are categorised into three types of resources:

- *Material resource (M-resource)*: These resources are passive resources that are usually associated with human resources. Examples of such resources are anaesthetics, medication, various machines and other resources.
- *In-need resource (In-resource)*: These resources represent the goals that need to be achieved. Details of these resources would include the type of goal, dateline, user requirements, etc.
- *Human resource (H-resource)*: These resources represent the healthcare staff involved, e.g. surgeons, doctors, staff nurses and attendants. Each H-resource has two types of knowledge: public knowledge and private knowledge. Public knowledge includes a resource's name, department and services offered. Private knowledge includes the weight of dependencies between resources in successfully achieving the goal, the preferences, restrictions or constraints in forming a coalition, etc.

The next main component is a group of three coalition formation agents:

- *The Coalition Manager*: Its main purpose is to (a) allow registration and processing of healthcare enterprise goals; and (b) to provide information of assigned staff and facilities to the administrator.
- *The Resource Manager*: This agent monitors staffing patterns and practices. The running of the coalition formation system is facilitated by a well-conceived organisational structure and staffing pattern to ensure high-quality services, high staff productivity and effective utilisation of resources at optimal costs. This is achieved by applying a coalition evaluation function to achieve an optimal combination of staff and resources.
- *The Schedule Manager*: Here, the coalition teams are assigned suitable time slots to execute the necessary tasks in achieving their goals. Again, an evaluation function is applied to evaluate the fitness of the generated schedule.

The coalition formation delivery interface is the front-end of the system. It serves as an input interface to record the user's request and to display the final output, i.e. the assigned coalition team (e.g. a surgical team and relevant resources) and the assigned slot or schedule for the request.

The three main components would be consolidated into a seamless Healthcare Coalition Formation Tool based on a knowledge-based coalition formation framework (see Figure 9) that integrates the various agents.

5.0 CONCLUSION

Enterprise-wide knowledge management solutions are not uncommon. However, we would like to stress on the fact that existing solutions appear to be varied and focus mainly on

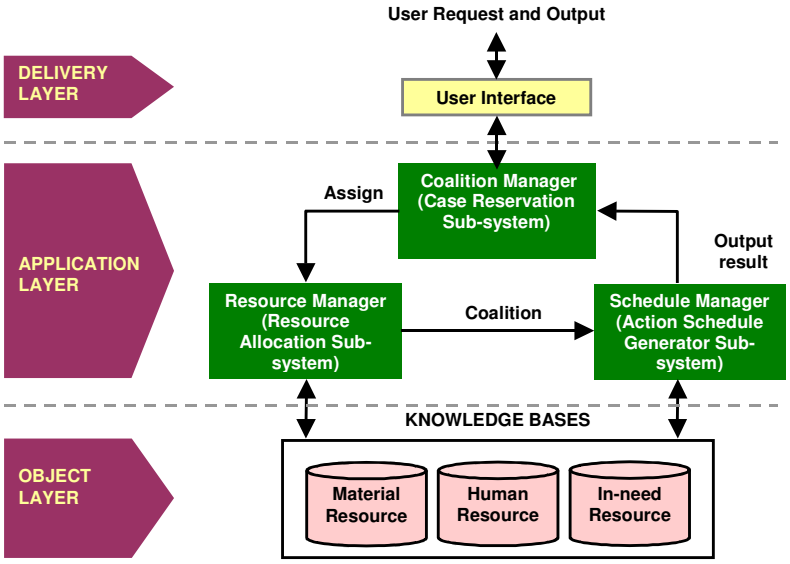

Figure 9: Knowledge-Based Coalition Formation framework

information or document management and communication features. Here, we note that existing knowledge management solutions appear to dilute the true essence of the knowledge management processes and do not sufficiently offer the wide spectrum of applications that is needed for truly effective experience-rich and enterprise-wide knowledge management. Therefore, the Intelligent Agent-Based Knowledge Management Application Suite is tailored in such a way that its constituent sub-projects cover the key knowledge management processes.

Present knowledge management solutions are often bundled with supplementary services such as collaborative tools, search facilities, file or resource sharing services, etc. Normally, existing solutions would focus on perhaps only a subset of the possible services that can be offered. The Strategic Visualisation, Planning, Coalition Formation and Advisory Services Suite does not aim to provide a complete range of healthcare knowledge-based services as this would be difficult to achieve. Rather, we have selected three key functions that are not only complementary to one another but are also deemed useful and practical.

The KM-Platform is presently at a very preliminary stage of development. Its eventual development and completion would give rise to more effective and intuitive ways of managing healthcare knowledge. We envisage that this can be effectively extended to other domains such as business and education, thus bring us closer towards realising a Malaysian K-Economy.

6.0 REFERENCES

Abidi, S.S.R. and Yusoff, Z. (1999). *Telemedicine in the Malaysian Multimedia Super Corridor: Towards Personalised Lifetime Health Plans*. In Kokol, P., Zupan, B., Stare, J., Premik, M. and Engelbrecht, R. (eds.), *Medical Informatics Europe (MIE '99)*. Amsterdam: IOS Press.

Cheah, Y.-N. and Lim, K.G. (2003). *An Approach for Sharing, Evaluating and Organizing Knowledge-Rich E-mail*. In Proceedings of the 2003 International Conference on Information and Knowledge Engineering (IKE 2003), Las Vegas, Nevada, USA.

Lacher, M.S. and Koch, M. (2000). *An Agent-based Knowledge Management Framework*. In Proceedings of the AAAI Spring Symposium. 145-147. Stanford, California, USA.

Musen, M.A. (2000). *Modeling for Decision Support*. In Bemmel, J.H. van and Musen, M.A. (eds.), *Handbook of Medical Informatics*. 431-448. Heidelberg, Germany: Springer Verlag.

Neoh, S.L. and Cheah, Y.-N. (2003). *A Knowledge- and Agent-Based Coalition Formation Framework for Surgical Team Formation and Resource Allocation*. In Proceedings of the International Symposium on Information Technology 2003 (ITSIM 2003), Kuala Lumpur, Malaysia.

O'Dell, C. and Grayson, C.J. (1997). *If We Only Knew What We Know: Identification and Transfer of Internal Best Practices*. American Productivity and Quality Center White Paper.

Torrens, M. and Faltings, B. (1999). *SmartClients: Constraint Satisfaction as a Paradigm for Scaleable Intelligent Information Systems*. In Proceedings of the Workshop on Artificial Intelligence on Electronic Commerce (AAAI-99). Orlando, Florida, USA.