Knowledge Map for kXpert: Humanising the Quest of Finding Experts

Shahrinaz Ismail[1], and Afifah Aliah Ahmad Suhaimi [2]

[1]*Universiti Kuala Lumpur, Malaysian Institute of Information Technology, Malaysia {shahrinaz@unikl.edu.my}*
[2]*Jade E Services Sdn Bhd, Commercial-Marketplace, Malaysia, {leyasuhaimi@gmail.com}*

ABSTRACT

The global pandemic of Covid-19 in 2020 has brought upon an impact to the economy, with high unemployment rate in all countries including Malaysia. Organisations experienced high employee turnover and knowledge loss along with the employees who left them. This impact has beckoned the ever-needed quest of finding experts, with expertise verified from reliable knowledge sources. This paper looks into the design of knowledge map for kXpert framework that humanises the online search for experts, based on the common practice in a knowledge-intensive organisation. The knowledge map is expected to reduce the time and effort of engaging in conversation to get to know a person to verify whether he or she is the right expert in demand. Nevertheless, this knowledge map is only part of the overall framework of knowledge-based information retrieval for expert profiling (kXpert), which provides the guide for the system development at later stage.

Keywords: knowledgebase, information retrieval, expert profiling, knowledge expertise mapping.

I INTRODUCTION

The year 2020 has brought upon an experience of global pandemic that affects everything in a normal human life, including economic, social, technology, politics, and especially humanity. The impact of this pandemic has affected many workers especially in service providing companies. The unemployment rate in Malaysia alone has increased quite drastically since the commencement of Movement Control Order (MCO) in March 2020. A total 67,068 cases of unemployed citizens were reported as of July 31st, 2020, with Selangor recording the highest among the states with about 30 percent of the unemployment figure of 19,914 cases (Zainuddin & Kaur, 2020). In the overall view of the nation's unemployment rate shown in Figure 1, there is a sharp increase from 3.9 percent in March 2020 to 5 percent in April 2020, and this rate remains high between 4.7 percent to 5.3 percent from May 2020 to August 2020 (DOSM, 2020).

The impact of this unemployment rate hits the organisations as well, as people are retrenched amid the ongoing COVID-19 pandemic. In a Malaysian institute of higher institution, five academicians with PhD qualification resigned, two professors retired and more than three contract-based employees did not get their contract renewed during the pandemic, and these are only for one of the thirteen faculties it governs. As the number of employees dwindles, so do the knowledge experts that the organisation possesses. The demand for knowledge experts is so significant during this time unlike never before.

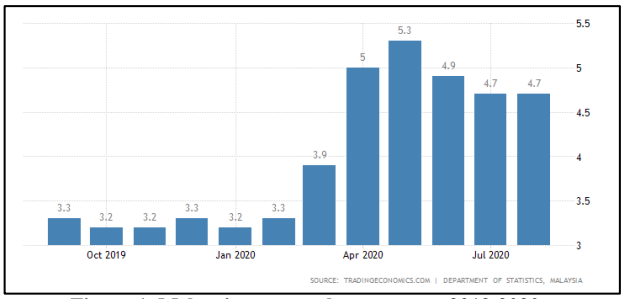

Figure 1. Malaysia unemmployment rate 2019-2020.

The quest of finding experts does not rely on personally knowing the people anymore, since the pandemic has confined the knowledge seekers from personally meet new people and learn from them. There is less opportunity to embark in face-to-face conversation to verify that they are truly the experts these seekers are looking for. Everything has to be done online, over the Internet, provided that the experts are keen to be contacted and communicated online. Due to the difficulty and stress that the pandemic and MCO affect, experts, who are also humans, may not indulge in communication with potential seekers whom they have never met.

However, most of the expertise information is already made available online by the experts, which in turn represents their personal portfolio. Hence, there is an opportunity to "knock on the door" of these locations and access the information that tells "who knows what" regarding an expertise domain. It is also part of the tasks common to a university when they need to verify a researcher's expertise domain in finding the right people to do certain jobs, like mentoring a new project, supervising new postgraduate students, and participate in new collaboration with industry. In a medium-to-large organisation with high employee turnover, especially during pandemic, the quest of finding the right experts among the existing employees could be significant as well, since people still work in silos for many personal reasons and beliefs.

In fulfilling the purpose of solving the issues mentioned above, the main objective of this paper is to design a knowledge map of experts to knowledge domain, to be managed in the knowledgebase of kXpert. The knowledge source for this mapping is mainly from external sources made available in the trusted sites, even though the experts are from the same organisation as the knowledge seekers. This paper is an extension of work originally presented in the Applied Informatics International Conference 2020 (Ismail & Ahmad Suhaimi, 2020).

II RELATED WORKS

This section covers two domains of related works, namely knowledge-based expert profiling and knowledge map design.

A. Knowledge-based Expert Profiling

Expert profiling often relates to human point affiliation, but it is not limited to the business or organisation that the expert is working for. The yield of profiling an expert is a positioned rundown of points that are related to particular individual (Becerra-Fernandez, 2000). Knowledge seekers, or people who are in search of knowledge experts, can utilise the expert profiles in framing exact recognitions, clarify misconceptions, and create inspiration when seeking after an expert in a knowledge area (Ismail & Ahmad Suhaimi, 2020). They can benefit from the master profiles that convey the mixture of explicit information, knowledge and intelligence, as well as innovativeness, characterising the expert performance in the expertise (Sternberg, 2003).

In adopting the knowledge management concept, frameworks were proposed based on community question answering, in which knowledge experts are identified based on their activities of answering questions in online platforms. A framework by Riahi et al (2012), for example, automatically route a newly posted question to an expert user, as that expert was earlier identified in a community platform, using statistical topic models. This work was then extended to a bigger picture by Pal (2015) to solve the issue of routing a right question to the right community, and finding relevant communities for a question. These two frameworks efficiently find experts by improving time, but time was not the only issue in finding the right knowledge expert. An improvement was made by Neshati et al (2017) who identifies future experts by ranking them on expertise evidence observed in the current time.

Unlike the works mentioned above, this study focuses on certain criteria in finding and profiling knowledge experts. Among the existing frameworks relevant to this study are knowledge-based framework (Rodrigues et al, 2015), expert finding (Balog et al, 2012), and expert profiling (Silva & Ma, 2017). In general, these frameworks provide reliable and secured processes that link people in a system, facilitating knowledge seekers in search for the right experts. Table 1 presents the brief summary of these frameworks.

Table 1. Expert Profiling Frameworks.

Framework	Knowledge-based Framework	Expert Finding	Expert Profiling
Author	Rodrigues et al (2015)	Balog et al (2012)	Silva & Ma (2017)
Process	Identify, capture, evaluate, retrieve and share organisational information asset	Map tacit knowledge for better awareness on which individual knows what; Extend social network to improve connection; Increase conversation between people	Link humans to expertise areas; Identify the best match between an expertise need and the expert's document content; Improve expertise search with more visibility; High potential of accessibility, reliability, physical proximity and freshness

The main aim of expert finding framework by Balog et al (2012) is to connect the person who are searching for knowledge expert to the sources. As shown in Figure 2, it is performed by a source-selection process based on selection criteria determined by the context and the needed task and information. Comparing this with the expert profiling framework by Silva and Ma (2017), the latter starts with a research problem that is broken down into "expertise topics" during problem analysis process, which are then mapped to the available potential experts. As shown in Figure 3, the other side of this framework has the potential experts (who want to be found) going through a profiling process that generates individual profiles for the expertise mapping.

From the related works covered in this section, it is summarised that the gist of an expert profiling system is the knowledge map, or the mapping of experts to the expertise. Knowledge mapping opens the door to organising knowledge in many ways including learning design, path and problem solving, as well as online learning and distance education (Okada & Shum, 2006). There is a technique to develop a knowledge map for industrial organisation through capturing and demonstrating organisational

knowledge, as suggested by Kim et al (2003). From the experience in research, Kim et al (2003) stated that knowledge map is the best tool to represent knowledge in an organisation. On top of that, knowledge map development can assist administrator or developer to build and enhance training support system as it will encourage effective teamwork and knowledge relations within and across knowledge areas in an organisation (Balaid, 2013).

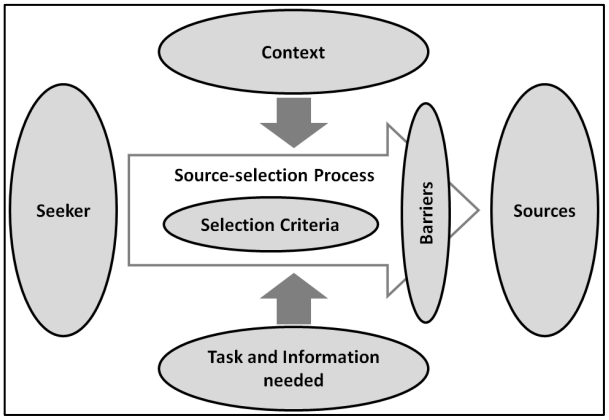

Figure 2. Expert finding framework by Balog et al (2012).

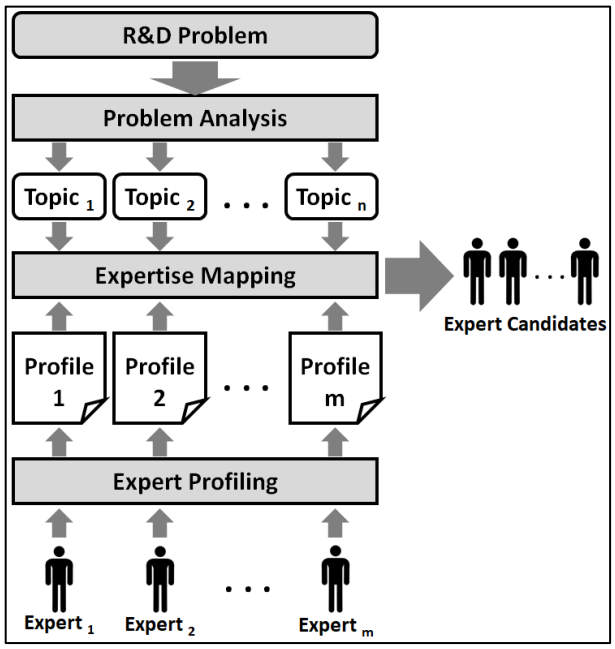

Figure 3. Expert profiling framework by Silva and Ma (2017).

B. Knowledge Map Design

A knowledge map is a visual aid that illustrates where knowledge can be found within an organisation, and directs on how to locate the person with most expertise in the specific domain. Knowledge map can be a powerful tool that includes knowledge, not just information. Capturing and representing knowledge buried in individuals and organisation are the basic building blocks of implementing the knowledge map in the context of knowledge management (Kim et al, 2003).

Balaid et al (2015) summarized different methodologies of building knowledge maps, as they found many different methodologies of constructing knowledge maps, proposed in the last few decades, each with different set of principles, design criteria and phases. For example, Vail (1999) introduced a nine-step methodology, starting with sponsor identification up to the final step of knowledge map development. It focused on the growth process instead of paying ample attention to the core competencies within an organisation. The drawback of this methodology by Vail (1999) is the difficulty in knowing who has unique expertise to solve a particular problem and how to identify information within the company in a better way. In another example, Bargent (2002) suggested a typical lifecycle method of building a knowledge map, which has 11 steps like identifying requirement, reviewing and evaluating the information until it generates the link between the people and the affinities, conducting information audit, and such.

In the essence of knowledge map, Kim et al (2003) explored a techniques used for the representation of information maps and suggested a guideline for the development of a general map of information. The guideline consists of six steps: understanding the knowledge within the organisation; analysing the knowledge process map; extracting knowledge; profiling knowledge; linking knowledge map; and validating the proposed knowledge map (Kim et al, 2003). In a more recent work, Pei and Wang (2009) focused on the knowledge management network for matrix organisation in their methodology. From their research, it was found that the experts were not readily available in the matrix organisation, as they may not stay around at the same place in the organisation at any time. Without proper access for the exchange of knowledge among the members of the organisation, the general organisational performance would be in serious danger, hence the suggestion to develop the knowledge map.

Table 2 presents the comparison summary among the four methodologies discussed in this section, showing some similarities in processes, in terms of identifying and evaluating knowledge. Some methodologies take more steps than others, and some take an effort to validate first before defining the mapping instead of the other way around. The similar processes are shown with the same symbol next to the words. For example, "produce initial knowledge map" by Vail (1999) and "produce extracted knowledge" by Kim et al. (2003) are similar and indicated with asterisks (*). Another similarity is found on "testing of knowledge map" by Bargent

(2002) and "evaluate the knowledge map" by Pei and Wang (2009). This paper refers to the processes presented in Table 2, to design the knowledge map for kXpert framework. The steps selected as suitable to be adopted in this study are as shown in bold and italic fonts in Table 2. Detailed explanation on this will be covered in the next section.

Table 2. Methodologies for Designing Knowledge Map.

Step	9-step methodology (Vail, 1999)	11-step methodology (Bargent, 2002)	6-step methodology (Kim et al., 2003)	7-step methodology (Pei & Wang, 2009)
1	***Identify the objective***	Identify requirement	Define knowledge map	Set up project team
2	Determine the objective	Information evaluation	Analyse process map	Analyse source
3	Education plan	***Review information***	***Knowledge extraction***	***Set up knowledge boundaries***
4	Identify stakeholder	Modify stop word	*Produce extracted knowledge	***Structuring the knowledge extracted***
5	Involving key people	Assigning of different sets of rules	***Identify knowledge link***	**Evaluate the knowledge map
6	Construct technical committee	Generate profiles	Validate knowledge map	***Locate knowledge resources***
7	Construct evaluation strategy	Set up of data source		***Update the knowledge content***
8	Identify maintenance process	Creation of knowledge map		
9	*Produce initial knowledge map	Training of knowledge map		
10		Generate affiniates		
11		**Testing of knowledge map		

*Note: Similar processes are noted with same symbols, i.e. * and **. Bold and italic fonts indicate the processes adopted in this paper.*

Looking at the important issue from the perspective of an expert who constantly needs to update his/her knowledge in the field to avoid being saturated in the field of expertise, a new method was proposed for expert finding. This recent method of T-shaped expert finding is based on temporal expert profiling (Dehghan, Biabani & Abin, 2019). It takes the temporal property of expertise to mine the shape of expertise for each potential expert, based on the expert's profile. What this method does for each potential expert is taking the snapshots of the person's expertise trees at regular time intervals, while learning the relation between temporal changes in different expertise trees and the person's profile. These snapshots go through a filtering process applied on top of the profiling method, in order to find the shape of expertise (Dehghan, Biabani & Abin, 2019). According to the concept of stack overflow, the T-shaped experts are categorised as having deep knowledge or skills in a skill area and a broad base of general supporting knowledge or skills (Gharebagh et al, 2018). This deep architecture for T-shaped experts finding is based on Convolutional Neural Networks, in the domain of artificial intelligence.

III METHODOLOGY

This research is based on a case setting of a Malaysian private university, in which the need to improve the expert database is important for the work employees' efficiency. With the recent pandemic, the requirement for the knowledge map is more significant as the employees are mostly working from home during the MCO. The improvement required is in the context of information retrieval mechanism and knowledge repository efficiency, which can be achieved with a structured knowledge map design to support the framework.

This study adopts the main principles from the related works, i.e. literature review, presented in Table 2, taking into account processes deemed suitable, based on the needs and focus on how the knowledge map needs to be designed. From Table 2, eight steps are chosen after going through a process of content analysis, and presented in Figure 4. The aim in mind during the content analysis is to make the kXpert process as close as possible to the human behaviour of searching for experts. It is understood that the common practice is to have an objective beforehand, locate the source of knowledge that is reliable and has credentials, understand the gist of information from the source, and access to extract that knowledge from the source once the review is satisfied. The process may end at knowledge extraction, but for the purpose of making the knowledge constantly updated and stored in the knowledgebase in a structured way for efficient access, there is a need to set up the boundaries for the retrieved knowledge. This is the part where the knowledge map is purposely designed.

Figure 4 shows the knowledge map design process, derived after going through the content analysis. As shown in Figure 4, this study started off with requirement analysis phase, with the representatives from the case organisation took part for three steps. The first step is to identify the objective, in which the goal of the knowledge map is decided and set. In this step, all stakeholders (i.e. users, namely knowledge seekers and knowledge experts) are identified, and scope of the knowledge map is identified as well. The second step is to locate knowledge resources, in which the requirement of the stakeholders is clarified

and analysed, in terms of the form of knowledge (source), and where it is located. Once the location is defined, the third step is to review information, in which the generated list of information is reviewed and refined, and a new list with all necessary sources is generated. The new list contains all the sources necessary for knowledge map development by putting the most relevant document and their sources as the top priority to be included in the process.

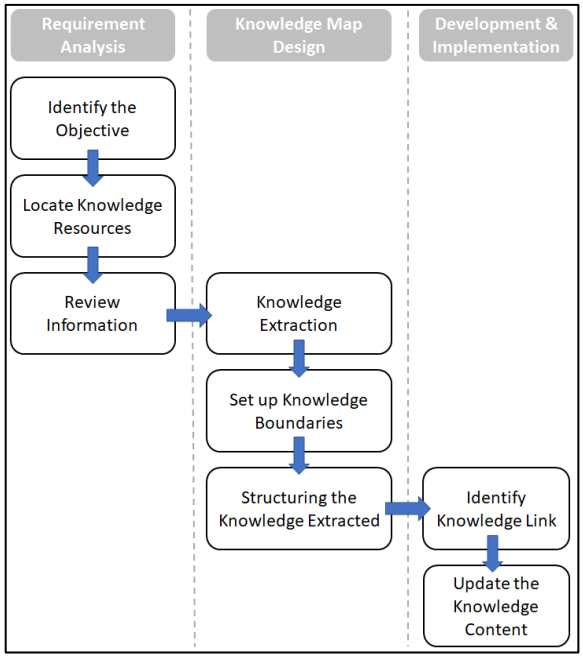

Figure 4. Methodology for knowledge map design.

The next phase of the methodology is the design work itself, i.e. knowledge map design. It consists of three steps, namely knowledge extraction, set up knowledge boundaries and structuring the knowledge extracted. Knowledge extraction, i.e. step 4, involves planning the process map for knowledge extraction from the source. This is basically done as closely as possible to the way stakeholders (human) perform the task of extracting knowledge online. This is followed by step five, where knowledge boundaries need to be set up to avoid information overload and unnecessary linkage between the experts and expertise that will affect the performance of the kXpert. The boundaries were defined according to the scope given by the case organisation. The final step (i.e. sixth step) in this design phase is to determine the structure and elements that define the relationship between the expert and expertise, and identify the similarities, logics and ranks for the mapping results.

The last phase is the part where the final outcome of the knowledge map is produced, and revised to meet the requirement of the kXpert framework. Step seven requires knowledge link to be identified, by creating knowledge profile from the structure created in the sixth step, and identifying the link between the elements in the knowledge map, using arrows. Finally, the eighth step is to update the knowledge content accordingly, in which the knowledge content in the repository would be updated and evaluated according to the process defined in the knowledge map, and the expert-resource relationship would be updated as well.

IV KNOWLEDGE MAP FOR KXPERT

From the scenario given by the case organisation during the requirement analysis phase, a knowledge seeker in the company will seek for experts using a keyword, which will be referred to in the expertise knowledgebase. In the background, knowledgebase would update the request to the kXpert system, and the system will access the knowledge source based on the given keyword and affiliation, i.e. the case organisation. Knowledge source would be the external source that is often identified through its credential and quality of knowledge provided, and generally in the form of works published and recognised worldwide. When the knowledge source is accessed, the system will generate the program based on the knowledge map, to translate the knowledge expertise of the experts into expert profiling. The system will return the result to the knowledge seeker with the expert's details based on the keyword on the front end, and update the mapping and store the mapped result in the expertise knowledgebase on the back end. In a glimpse, the knowledge seeker will see the result as the name of the expert suggested by kXpert system, which is based on the given keyword. This covers the overall scenario on how the kXpert framework looks like.

Analysing the existing frameworks is part of the requirement analysis process too. The result from the analysis is then tabulated in Table 3. The summary of the findings is analysed to compare between the components and to identify the differences. Table 3 shows the comparison between these two frameworks by Balog et al (2012) and Silva and Ma (2017), because they are the closest similarity to the proposed kXpert, and the considerations to be considered in this study.

The proposed knowledge map is based on the process performed by kXpert framework, which are: the retrieval of expertise in the form of keywords; search of keywords based on affiliation name in credential site(s); retrieval of search results to be imported to the knowledgebase; knowledge expertise mapping in the knowledgebase; and displaying of results to the knowledge seeker. The results will be customised based on the needs of information details, such as name of experts, affiliated faculty/campus, expertise topics, and number of publications based on the expertise topics (keywords).

Table 3. Comparison of Expert Profiling Frameworks for kXpert.

	Expert Finding (Balog et al. 2012)	Expert Profiling (Silva & Ma, 2017)	Considerations for kXpert
Input	- Context, criteria (from Seeker), task, information	- Problem, topic, expert profile	- Keywords (topics), affiliation of experts, name (if required for updates)
Process	- Source-selection process	- Problem analysis, expertise mapping, profiling of experts	- Search, retrieval, knowledge expertise mapping
Output	- Selected source (link to the identified sources)	- Experts identification	- Experts identification with number of publications on keywords (topics)

Figure 5 shows text-based knowledge map design, that acts as a blueprint. Figure 6 shows the result of knowledge map design translated from Figure 5, which acts as the rules for the kXpert framework to run. The rules start with entering the keyword by the users, in which the keyword will belong to the research paper that is published on the designated website. The paper is written by researcher who belongs to a domain or research area. From there on, two possibilities to be expected where once the researcher is found in the domain, they are proficient; however, should the researcher's name is found in multiple papers or to be the main author, the researcher is an expert in the specified field of study.

```
Keyword
        belongs to Paper
                belongs to Domain
                written by Researcher
                        belongs to Domain
                        means Proficient
                                but if Many Papers
                                means Expert
                        but if First Author
                        means Expert
```

Figure 5. Text-based knowledge map design.

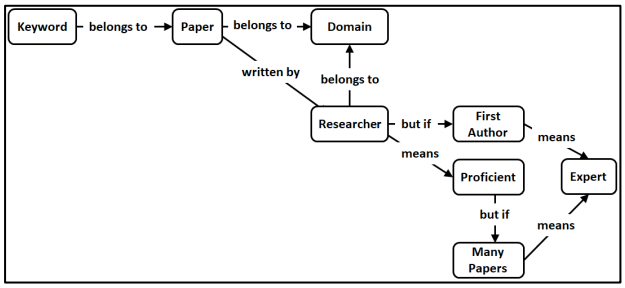

Figure 6. Knowledge map for kXpert framework.

V DISCUSSION

The knowledge map that is designed is a result of the objective in this paper. The whole framework relies on this knowledge map, which is set to be the rules stored in kXpert. The knowledgebase will store the mapping once linked and the rule will be looped for every search and rely on the following factors: the language used and the competency of the software and hardware. The knowledge map provides the base for the full prototype development of the kXpert, in which it can be used as part of the pseudocode and algorithm. From the look of it, the knowledge map can be further enhanced with ontology if the situation calls for it, like foreseeing that the system could be more complex and scalable in the near future once implemented.

The proposed knowledge map in this paper has followed the considerations derived from the comparison of existing frameworks that is presented in Table 3 and the proposed kXpert framework. As a recap, the keyword that is the starting point of the knowledge map and the input by the knowledge seeker is comparable to the topic or problem proposed in expert profiling (Silva & Ma, 2017), and context and criteria proposed in expert finding (Balog et al., 2012).

In terms of process, Silva and Ma (2017) proposed expertise mapping and profiling of experts, in which kXpert adopts in the sense of knowledge expertise mapping, hence the mapping from paper to researcher in the knowledge map as shown in Figure 5 and Figure 6. In fact, the whole knowledge map proposed for kXpert is the process of how the mapping is done to produce the expert profiles. This does not mean that this paper disregards the significance of source-selection process by Balog et al. (2012), but merely translating the process in more detail and straight-to-the-point that the kXpert will process the tasks of search, retrieval and mapping.

In terms of output, kXpert knowledge map adopts the output of experts' identification from Silva and Ma (2017) but with number of publications on the requested keywords tagged to the expertise details. This number of publications can be produced by kXpert every time it runs the code to decide on expert candidates' level of expertise, i.e. whether the candidate is "expert" of "proficient" based on number of papers and candidate being identified as main author or co-author (as shown in Figures 5 and 6). This contradicts with Balog et al. (2012) that merely links the seeker to the identified sources, i.e. research papers or other types of files available and found. Nevertheless, it complements the methods of T-shaped expert finding and temporal expert profiling by Dehghan, Biabani and Abin (2019).

The challenges faced in this study revolves around meeting the requirements of the kXpert framework. This paper presents the work that is mostly on research part, in which the results would prepare the developer for the next phase of kXpert system development. There are no specific development tools or programming language that are covered in this study; however, this paper covers the design for the knowledge map, useful as blueprint for the system development phase. It is more flexible and less constraint, allowing the use of any language that can retrieve information from external source or sources to be added into the knowledgebase.

In previous literature, it is stated that knowledge (and process) maps are both used to analyse business problems in terms of transferring some aspects of knowledge into a clear form, mostly in graphical form (Eppler, 2004). Referring to this, Tawana (2008) has suggested an approach using Petri Nets to develop and validate a knowledge-based system, in which Petri Nets are found "well-suited for the design, specification and formal verification of complex information systems" (Sakthivel & Tanniru, 1989). This proves that there are a number of ways to validate a knowledge map and its framework. However, in most cases, a solid validation can only be satisfied with prototype development and data collection and analysis that support the system functions and features, which then supports the validity of the framework.

VI CONCLUSION

In this paper, the knowledge map for kXpert is proposed and designed to elevate the current standard of knowledge-based information retrieval and help the organisation to organise, convey, and encourage learning results. The idea is to humanise the way the employees search for experts in a system, or in other words, making the system works as closely as possible to the way humans do and expect when searching for expertise. The outcome of this work is to show that we can improve the performance of information retrieval with expert profiling, which is not currently available. The achievement of the objective of this study will contribute to a useful and effective knowledge-based framework and knowledge map, catered to the needs of mitigating knowledge expertise loss in an organisation, especially due to the pandemic crisis.

In terms of limitations, this study is based on the current knowledge map methodologies, which do not have the same degree of maturity and thus no latest standard methodology is available. This research covers the design part from literature review and requirement analysis by the case organisation, yet it does not cover the (prototype) development that could further validate the completeness and fitness of the kXpert framework.

As this study shed a light on the research and design of kXpert knowledge map, it is recommended for future researchers to further consult experts on their views and validation towards kXpert. To further extend this study, observation can be done on the development of the system using pseudocode, algorithms and suitable language.

REFERENCES

Zainuddin, A., & Kaur, D. (2020). Job Losses Surpass 67,000 as at end-July. *The Malaysian Reserve*, 12 Aug.

Department of Statistics Malaysia. (2020). Malaysia Unemployment Rate. *Trading Economics*. https://tradingeconomics.com/malaysia/unemployment-rate.

Ismail, S., and Ahmad Suhaimi, A.A. (2020). Conceptual Framework of kXpert: Knowledge-based Information Retrieval for Expert Profiling. *Applied Informatics International Conference (AiIC)*, 12-13 August, Malaysia.

Becerra-Fernandez, I. (2000). The role of artificial intelligence technologies in the implementation of PeopleFinder knowledge management systems. *Knowledge-Based Systems*, *13*, 315–320.

Sternberg, R. (2003). What Is an "Expert Student? *Educational Researcher*, *32*, 5-9.

Riahi, F., Zolaktaf, Z., Shafiei, M., & Milios, E. (2012). Finding expert users in community question answering. *Proceedings of the 21st international conference on world wide web*, 791–798.

Pal, A. (2015). Metrics and algorithms for routing questions to user communities. *ACM Transactions on Information and System*, *33*, 14:1–14:29.

Neshati, M., Fallahnejad, Z., & Beigy, H. (2017). On dynamicity of expert finding in community question answering. *Information Processing & Management*, *53*(5), 1026-1042.

Rodrigues, D., Zaniolo, R.R., & Branco, K.R.L.J.C. (2015). Knowledge-Based Framework: Its specification and new related discussions. *Journal of Physics: Conference Series*, *633*(1) https://doi.org/10.1088/1742-6596/633/1/012052

Balog, K., Fang, Y., Rijke, M., Serdyukov, P. & Si, L. (2012). Expertise Retrieval. *Foundations and Trends in Information Retrieval*, *6*(2), 127-256. http://dx.doi.org/10.1561/1500000024

Silva, T., & Ma, J. (2017). Expert profiling for collaborative innovation: big data perspective. *Information Discovery and Delivery*, *45*(4), 169-180. https://doi.org/10.1108/IDD-03-2017-0021

Okada, A., & Shum, S.B. (2006). Knowledge mapping with Compendium in academic research and online education, *22nd World Conference, International Council of Distance Education*.

Kim, S., Suh, E., & Hwang, H. (2003). Building the knowledge map: An industrial case study. *Journal of Knowledge Management*, *7*(2), 34-45. https://doi.org/10.1108/13673270310477270.

Balaid, A.S.S., Zibarzani, M., & Abd Rozan, M.Z. (2013). A Comprehensive Review of Knowledge Mapping Techniques. *Journal of Information Systems Research and Innovation*, 3, 71-76.

Vail, E.F. (1999). Knowledge mapping: Getting started with knowledge management. *Information Systems Management*, *16*(4), 37-41.

Bargent, J. (2002). 11 Steps to Building a Knowledge Map. Provider's Edge. http://www.providersedge.com/docs/km_articles/11_Steps_to_Building_a_K_Map.pdf.

Pei, X., & Wang, C. (2009). A study on the construction of knowledge map in matrix organizations. *Proceeding of the International Conference on Management and Service Science*, 1-5.

Eppler, M. (2004). Facilitating knowledge communication through joint interactive visualization. *Journal of Universal Computer Science*, *10*(6), 683–690.

Tawana, M. (2008). Knowledge-Based Expert System Development and Validation with Petri Nets. *Journal of Information & Knowledge Management*, *7*(1), 37–46.

Sakthivel, S., & Tanniru, M.R. (1989). Information verification and validation during requirement analysis using Petri nets. *Journal of Management Information Systems*, *5*(3), 33–52.

Dehghan, M., Biabani, M., & Abin, A.A. (2019). Temporal Expert Profiling: With an Application to T-shaped Expert Finding. *Information Processing & Management*, *56*(3), 1067–1079. https://doi.org/10.1016/j.ipm.2019.02.017

Gharebagh, S.S., Rostami, P., & Neshati, M. (2018). T-shaped Mining: A Novel Approach to Talent Finding for Agile Software Teams. *Processing of the European Conference on Information Retrieval*, Springer, 411–423.