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Ubiquitous learning analytics in the real-world language learning

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Abstract

In recent years, ubiquitous learning systems based on Computer Supported Ubiquitous Learning (CSUL) and u-learning have been constructed using ubiquitous technologies such as mobile devices, RFID tags, QR codes and wireless networks. These types of learning include not only in-class learning but also in a variety of out-of-class learning in spaces such as homes, libraries and museums. However, the learning materials provided by ubiquitous learning systems are, in most cases, prepared by teachers or instructional designers, and it is difficult to find relationships between a learner and other learners in different contexts. In order to link learners in the real world and ubiquitous learning logs (ULLs) that are accumulated in cyber space by a ubiquitous learning system called System for Capturing and Reminding of Learning Log (SCROLL), this paper proposes an innovative visualization system that integrates network visualization technologies with Time-Map based on Ubiquitous Learning Analytics (ULA). In this paper, a Ubiquitous Learning Log (ULL) is defined as a recorded form of knowledge or learning experiences acquired in a learner's daily life. An experiment was conducted to evaluate whether the visualization system is of benefit in finding the relationships between learners and ULLs and whether the developed layout called the Ubiquitous Learning Graph (ULG) is easy to use compared with certain previous visualization layouts. In the experiment, learners found relationships between their own knowledge and ULLs, demonstrating that the system can increase learners' learning opportunities.

Keywords: Ubiquitous learning, Ubiquitous learning analytics, Context-aware learning, Time-map, Collocational network

Introduction

In recent years, ubiquitous learning (u-learning) has been the focus of attention in educational research across the world. To develop context-aware and seamlessly integrated Internet environments, Computer Supported Ubiquitous Learning (CSUL) or u-learning has been carried out using ubiquitous technologies such as RFID tags and cards, wireless communication, mobile phones, Personal Digital Assistants (PDAs), and wearable computers (Ogata et al. 2004; Yin et al., 2010). These types of learning include not only in-class learning but also a variety of out-of-class learning in spaces such as homes, libraries, and museums. In addition, researchers in the u-learning or seamless-learning have been pointed out such as the need for effective in-class learning designs and the necessity of helping students learn across at-home and in-school contexts (Hwang 2014, 2015).

One of the application domains of u-learning or CSUL is language learning. For example, Ogata et al. (2011) introduced their u-learning system called System for Capturing and Reminding of Learning Log (SCROLL), which allows users to share information with others by recording what they have learned in a web browser or mobile device. In addition, some CSUL systems were constructed in the domains of Nature Science (Chu et al., 2010; Hwang et al., 2011) or complex science experiences (Hwang et al., 2009).

These learning logs are accumulated in cyber space by using such systems, and they include contextual data such as location and time information. Aljohani and Davis (2012) described learning analytics called Ubiquitous Learning Analytics (ULA) in order to analyze enormous learning data including contextual information. The value of ULA is discussed by considering two possible kinds of interactions. The first is the interaction between learners and their contexts, referred to as learners-to-context interaction. The second is the interaction between learners and context-based learning materials, referred to as learner-to-context-based learning materials interaction. Aljohani et al. suggested that the use of learners' contextual data can enhance the interaction between learners, mobile devices, and learning environments. In addition, analyzing or visualizing contextual data has the potential for improving knowledge of the patterns of learners' interactions with their contexts (Aljohani and Davis 2012). Similarly, Ogata et al. (2014a) reported that it is important for learners to recognize what and how they have learned by analyzing and visualizing past learning logs, so that they can improve their way of learning. However, little attention has been paid to this point. One of the issues of ULA is how to visualize learners-to-context and learner-to-context-based learning materials interactions. After that, it is necessary to present or recommend the results of the visualization on a mobile device or desktop PC.

To tackle these issues, we developed an innovative visualization system that combines network graphs with Time-Map, based on ULA. In this paper, we call graphs based on graph theory "network graphs". How can learners learn in certain kinds of learning situations by visualizing relationships between themselves and a context, and themselves and context-based learning materials? For example, if learners are at the botanical gardens in the morning, they do not have the means to learn knowledge related to the place (botanical gardens) or time information (morning). In addition, they do not know whether the knowledge can be applied to other learning environments or not. The visualization system enables learners to access such information.

The rest of this paper is constructed as follows. Section 'Related works' discusses related works. Section 'Scroll' introduces how to use SCROLL in the real-world language learning. Section 'Visualization method' describes the methods of the visualization system. Sections 'Implementation' and 'Evaluation' describe the design, implementation, and initial evaluation experiment on the visualization system. Section 'Method' summarizes the contributions made by the work.

Related works

Context-aware U-learning

Researchers on context-aware u-learning have constructed u-learning environments in which learners can study anywhere and anytime. They integrated knowledge and location information by using cutting-edge technologies such as RFID, QR-codes, NFC-tags, and GPS (Hsu et al., 2011; Lai et al., 2013; Lee and Kuo 2014). For example, Hwang et al. (2008) developed a context-aware u-learning system with an attached RFID tag for plants. The application domain of their studies is Nature Science. When a learner arrives in front of a plant, the system asks him or her questions about the plant's features, such as its trunk, shape, and color. Based on the learner's responses, the system presents a list of candidate plants. This allows the learner to understand the relationship between knowledge about the plant and the place where he or she learned it. However, the context-based learning materials provided by Hwang et al.'s system are, in most cases, prepared by teachers or instructional designers and it is difficult to find relationships between a learner and other learners in different contexts because the system provides only interaction between a learner and the context-based learning materials. For example, if a learner learns a word in an informal setting, the word might be able to be applied in various other learning environments. However, there is no means for him or her to know whether it can be applied to other learning environments or not.

On the other hand, SCROLL allows learners to record what they have learned in daily life with contextual data using GPS sensors in the real-world language learning (Li et al., 2012). This means learners can freely create context-based learning logs and share them each other. There is a possibility that the learners can apply what they have learned to other learning environments by finding the relationships between their own and others' context-based learning logs. In order to find these relationships, this paper describes our ideas based on some previous visualization methods in the next sections: Geographical Information System and Time-Map, and Collocational Network.

Geographical information system and time-Map

A geographic information system (GIS) is designed to capture, store, manipulate, analyze, manage, and present all types of spatial and geographical data. By mapping learning information on the map in the system, learners can easily reflect on what and where they have learned. However, previous GIS designs did not take time-lines into consideration for learners' reflection. To tackle this issue, Johnson and Wilson (2009) developed a visualization tool for handling temporal data within a GIS framework, called Time-Map. As shown in Fig. 1, Time-Map consists of a time-line and Google Maps. It represents the shift of learning history in accordance with the lapse of time.

Learners might forget when and where they have learned before. Therefore, Time-Map reminds them of their learning log entries recorded during a specified period of time by showing them on the timeline (default: two months before and after the set time). The visualization method can find individual learners' information in the spatio-temporal dimensions, but our proposed system can find relationships in different contexts among learners by combining Time-Map with network graphs. In the next section, this paper introduces the difference between our visualization and the related researchers' methods utilizing a series of network graphs called a collocational network.

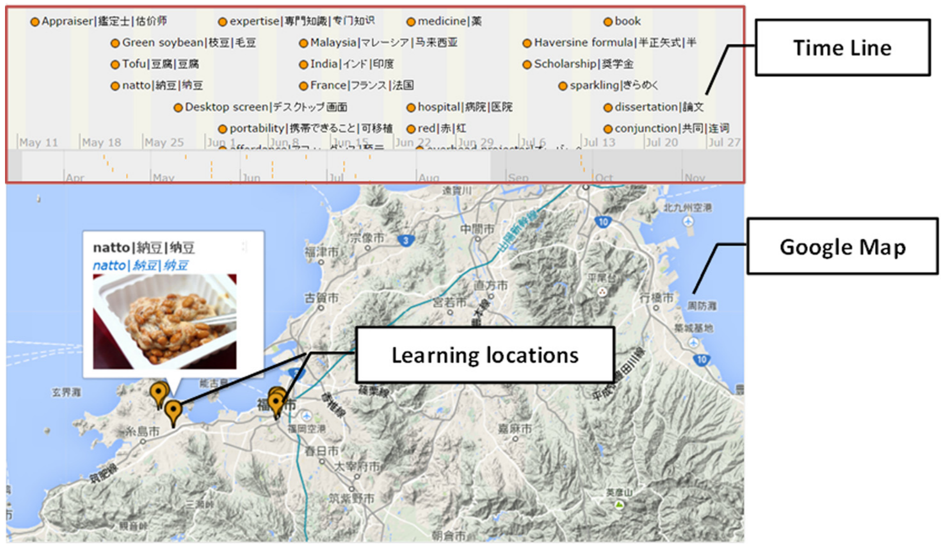

Fig. 1 Time-Map

Collocational network

Collocational networks are two-dimensional networks that contain interlinked collocation, i.e. words that occur together in a text. Williams (1998) used the collocational network as a corpus linguistic tool in order to create specialized dictionaries. Magnusson and Vanharanta (2003) described that it is important to visualize the most central concept in the text. For linguists, the relationships between words are important information. However, for learners in the real-world language learning, it is also important to grasp information such as other learners' contextual data connected to the learning contents. Our proposed system links learners' current knowledge and contexts in the real world to past learners' knowledge and contextual data that are accumulated in cyber space, by using a collocational network.

Scroll

With the evolution of mobile devices, people prefer to record learning contents using mobile devices instead of taking notes on paper. For many people, this is a simpler method of note taking, since the information can be stored in various ways such as texts, photos, audio, and videos. We call formal notes written by language learners "learning logs". In this paper, a Ubiquitous Learning Log (ULL) is defined as a recorded form of knowledge or learning experiences acquired in a learner's daily life. In order to support such formal note taking, we designed and implemented our u-learning system called SCROLL (Ogata et al. 2011). SCROLL has supported various fields of learning such as task-based language learning, science communicator and career support for international students (Mouri et al., 2013; Ogata et al., 2014b; Mouri et al. 2015).

To simplify the process of capturing learners' learning experiences, SCROLL provides a well-defined form to illustrate a ULL. For example, when learners face problems in daily life, they may acquire some knowledge by themselves or ask others for help. As shown in Fig. 2, they can record the ULL with photos using a mobile device and SCROLL. The ULL includes meta-data such as the author, language, time of learning,

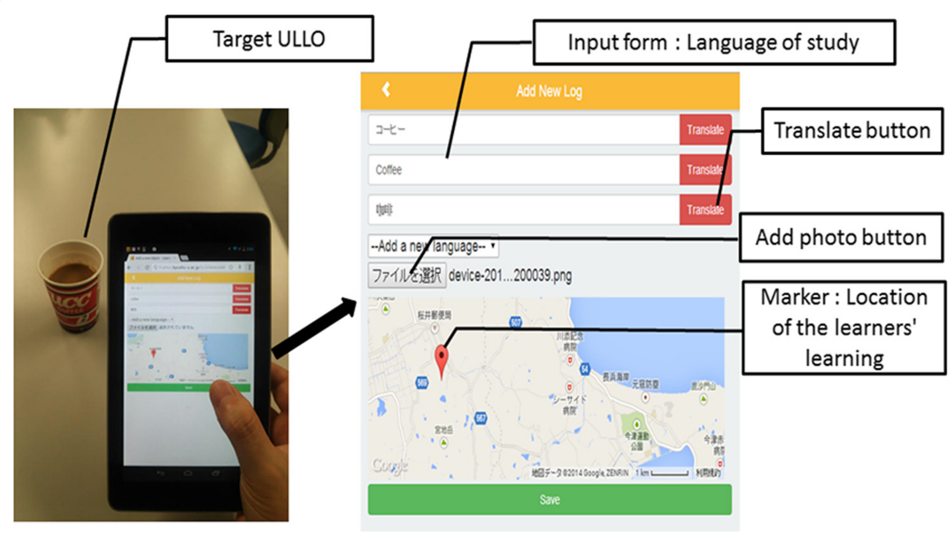

Fig. 2 An example of adding a ULL

location (latitude and longitude), place (name of nearby buildings) and tag, and the learners can search target ULLs based on the meta-data.

To date, as shown in Table 1, there are 27,867 ULLs, 1772 users, 19 native languages, 30 kinds of places (e.g., supermarket or park) and 7 kinds of times (e.g., spring or summer). The proposed system visualizes relationships between learners and context-based knowledge, and learners and contextual data, based on the learning data outlined in Table 1.

Visualization method

A scenario of using the visualization system with SCROLL

Our visualization system mainly focuses on language learning fields. One way it can be used is to assist international students to learn Japanese. Language learners who face rich learning contexts every day can gain much knowledge from their daily lives, which include different kinds of situations such as shopping at the supermarket, visiting the doctor at the hospital, having a haircut in a barbershop, or visiting a museum (Li et al., 2013). The system can compare the past ULLs accumulated in cyber space in SCROLL with the learner's current context-based knowledge and contextual information, and present the relationships on his or her mobile device or desktop PC. As shown in Fig. 3, the workflow has the following four steps:

Table 1 Learning data in SCROLL

Attribute	Description	Total
Knowledge	Content that they have learned. {e.g., natto, tofu, envelope}	27867
User	Author name (nickname on SCROLL) {e.g., Liu, Liam, James}	1772
Native Language	Learners' native language {e.g., Japanese, Chinese, Spanish, French}	19
Place	Location where the learning took place {e.g., supermarket, florist, park}	30
Time	Time when the learning took place {e.g., spring, summer, morning}	7

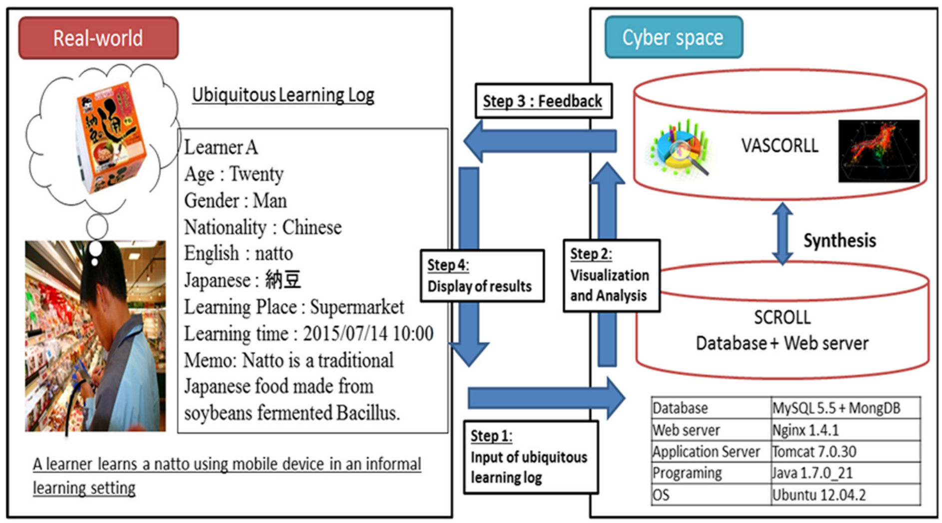

Fig. 3 How visualization system and SCROLL works

(1) Step1: As shown in Fig. 3, learner A learns about natto (a traditional Japanese food made from fermented soybeans) at the supermarket, and he records his experience in a ULL in cyber space using a mobile device with SCROLL.

(2) Step 2: The learner does not have the means to know whether the knowledge can be applied to other learning contexts or not. Using the system, he finds knowledge that can be applied in different contexts, by visualizing and analyzing a large amount of ULLs that are accumulated in cyber space with SCROLL.

(3) Step 3: Based on the results of Step 2, the system identifies and presents important relationships such as 'learner-to-contexts' and 'learner-to-context-based knowledge interactions'.

(4) Step 4: There are two ways the results of visualization can be shown, called "Display via context-based knowledge" and "Display via context".

- Display via context-based knowledge: If learner A learns about natto at the supermarket, the system will provide him with contexts such as "restaurant" and "convenience store" related to natto. After that, the learner will visit the place using the learning log navigator function (Mouri et al., 2012) and learn more information directly from there. In addition, if he wants to learn indirectly about the experience, he can do so using a re-log on SCROLL.
- Display via context: When learner A is at the supermarket in the daytime, the system will provide him with knowledge about "tofu" (a food made by curdling soymilk) and "edamame" (a preparation of immature soybeans in the pod, found in the cuisines of China, Japan, Korea, and Hawaii) related to "supermarket" and "daytime". After that, he will learn the knowledge related to the supermarket in the daytime using SCROLL.

The visualization method and the implementation we propose in the rest of this paper enable the two cases described above.

Visualizing ULLs based on a three-layer structure

To visualize and analyze several relationships between learners and ULLs, we uniquely defined them as three-layer structure, as shown in Fig. 4 (Mouri et al., 2014; Mouri et al., 2015).

The upper layer shows the individual learners. If a learner learns knowledge using SCROLL, there is a possibility that other learners have already learned it as well. The system finds these links to identify which learners have learned what kind of knowledge.

The intermediate layer contains the knowledge that learners have learned. In ULA, this means learner-to-context-based learning materials interaction. This paper calls it learner-to-context-based knowledge. In addition, some types of learning tasks can be included in this layer. For example, some task-based learning in u-learning environments can be carried out using knowledge with contexts (Sharon 2013). The scalability of the layers can be enhanced and the field of visualization can be widened by linking one's own ULLs to the knowledge learned by doing tasks.

The lowest layer contains contextual data such as location, place, and time. In ULA, this means learner-to-context interaction. The layer allows learners to grasp when and where they have learned by revealing knowledge related to certain places or times.

The analysis using the three-layer structure has the following advantages:

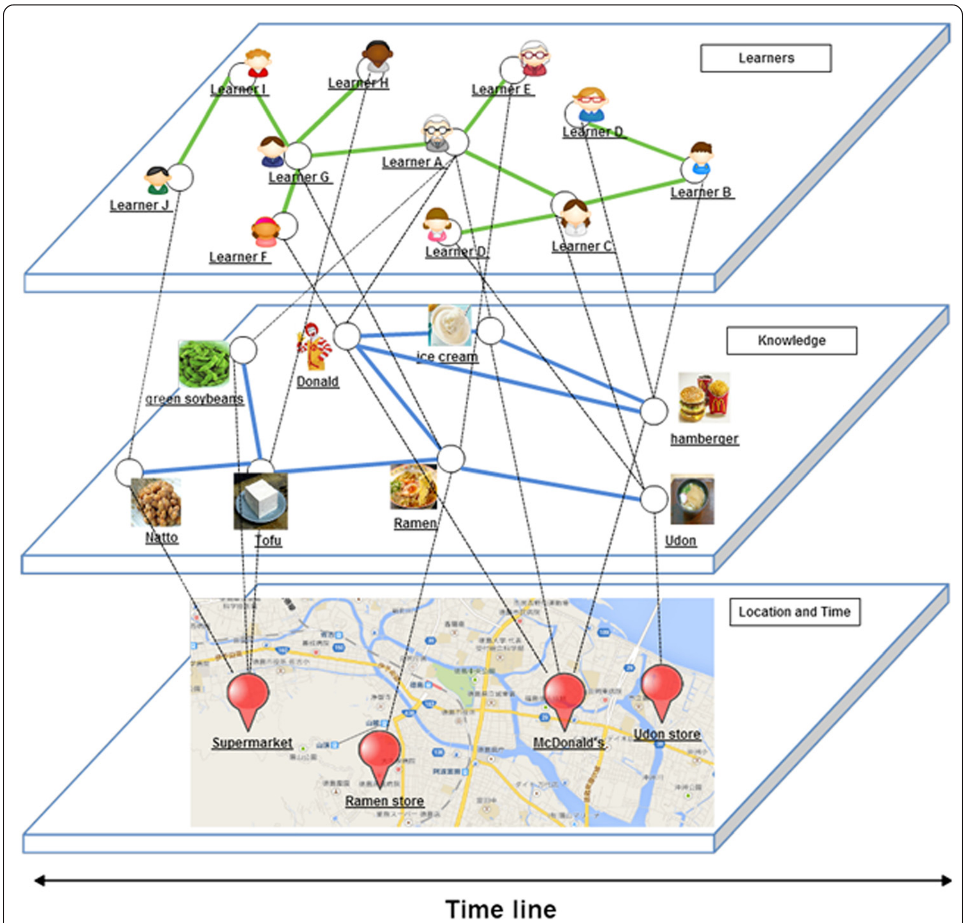

Fig. 4 Three-layer structure in SCROLL

(1) Places with a large number of links to related knowledge are places where learners can learn much knowledge. For example, if a certain supermarket or convenience store is related with various entries on natto, green soybeans, tofu, miso soup, and noodle cups, by the analyzing relationships between this knowledge and the location, the system can provide learners with valuable learning information.
(2) Knowledge that is related to many places is knowledge that can be learned in various places. For example, if a learner experiences tea ceremony of a traditional Japanese culture at the university in Japan, a set of knowledge related tea ceremonies (e.g., tea, seiza: to sit in the correct manner on a Japanese tatami mat) can be learned in various other places. The tea can be purchased at the supermarket, and the seiza can be learned at the martial arts gymnasium.

How nodes are created and connecting lines are in the three-layer structure

Firstly, the system will create 1772 authors' nodes on the upper layer based on Table 1 in the section titled "SCROLL". Secondly, the system will create 27,867 knowledge nodes on the intermediate layer. Then, it will connect the authors' nodes to any related knowledge nodes representing things that learners have already learned. For example, if learner A learns about natto, tofu, and sushi, the system will connect the "learner A" of node on the upper layer to the "natto", "tofu" and "sushi" on the intermediate layer. In addition, it will connect the related knowledge to knowledge on the intermediate layer in order to identify learner A's next learning steps.

Thirdly, the system will create a contextual node on the lowest layer. Then, it will connect knowledge nodes on the intermediate layer to contextual nodes on the lowest layer. For example, if learner A has learned knowledge of natto at the supermarket in Japan, the system will connect "natto" on the intermediate layer to "supermarket" on the lowest layer.

LKPTE model

An important goal of our visualization system is to find the most important relationships between learners and context, and learners and context-based knowledge. For example, learners do not know the distance between learners' nodes such as "Mongolian Learner A" and "Chinese Learner A", and the natto of context-based knowledge as shown in Fig. 5 (left). In order to reveal the distance between nodes, this paper proposes a model called Learner-Knowledge-Place-Time-Experiences (LKPTE), shown in Table 2. Using this model, the system finds the most important relationships between learners and context-based knowledge, and learners and contexts, as shown in Fig. 5 (right).

Learners' parameter L (Who) shows their gender (L_g), age (L_a), native language (L_n), and Japanese Language Proficiency Test (JLPT) level (L_l). Using these parameters, the system can find other learners with similar traits.

Knowledge parameter K (What) shows the level of words (K_l) as indicated by the JLPT and word type (K_t), such as noun, verb, adverb, or adjective. Parameter K is designed to indicate whether learners are at the right level of difficulty when learning from other learners' experiences.

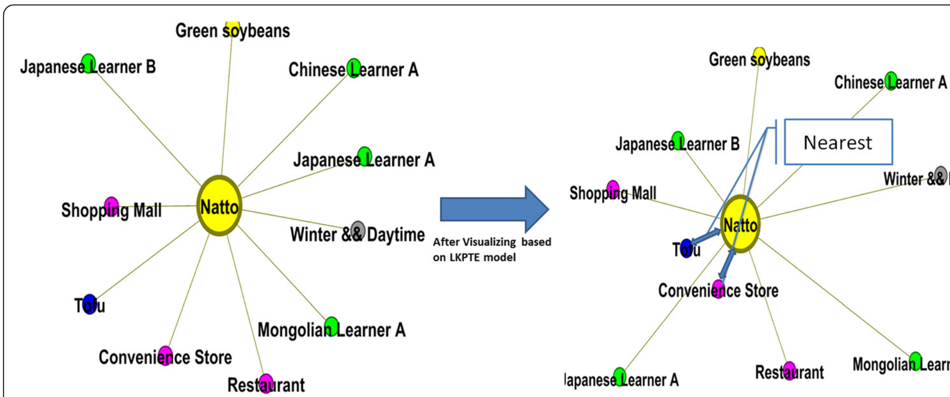

Fig. 5 An example of visualization based on LKPTE model

Parameter P (Where) shows location (P_l) and place name (P_n). There is a possibility that ULLs in the same location contain different place names such as "university" and "restaurant". In addition, the same place names may contain different locations. Parameter P distinguishes ULLs in different contexts so that the system can detect learner contexts in the real world and ULLs in cyber space.

Parameter T (When) shows the season (T_s) and time of learning (T_f). For example, the most learners have learned about morning glory flowers in the morning. However, one learner has learned about them in the daytime. Generally, people regard morning glories as flowers that bloom in the morning, but there are kinds of that are in bloom during the daytime. For reasons like these, the system detects relationships between knowledge and place in different times. By seeing these relationships, learners can grasp information regarding the time of other learners' experiences.

Parameter E (How) shows direct experiences (E_d) and indirect experiences (Ei). Direct experience (E_d) denotes experience gained through sense perception. Indirect experience (Ei) denotes experience gained through others. Learners can save others' indirect experiences as "relog" using SCROLL. According to Kolb (1984), it is important to have direct experience. By revealing the relationships between direct experiences

Table 2 LKPTE parameters

Parameter	Detail
L_g (Who)	Gender of learners
L_a (Who)	Age of learners
L_n (Who)	Native language of learners (e.g., Japanese, English, Chinese)
L_l (Who)	Level of learners (e.g., Japanese Language Proficiency Test)
K_l (What)	Level of knowledge (e.g., JLPT word level)
K_t (What)	Type of word (e.g., noun, verb, adverb, adjective)
P_l (Where)	Location of place (e.g. latitude and longitude)
P_n (Where)	Name of place (e.g. university, museum, supermarket)
T_s (When)	Season (spring, summer, fall, winter)
T_f (When)	Time of day (morning, daytime, night)
E_d (How)	Direct experience
Ei (How)	Indirect experience

and indirect experiences, the system prompts learners to change from observers to doers by engaging in task-based learning (Mouri et al., 2013).

To reveal the distance between learners and ULLs, this paper measures the distance of connecting lines using cosine similarity (1). This paper defines the following vectors V_i (2) based on the parameters of LKPTE model.

$$similarity = \frac{\sum_{i=1}^{n} V1 \times V2}{\sqrt{\sum_{i=1}^{n}(V1)^2} \times \sqrt{\sum_{i=1}^{n}(V2)^2}} \quad (1)$$

$$V_i = \{L_g, L_a, L_n, L_l, K_l, K_t, P_l, P_n, T_s, T_f, E_d, E_i\} \quad (2)$$

Implementation

This section describes the implementation of the visualization system with the three-layer structure using network graphs with Time-Map.

The layout types of the network graph

This paper implemented the network layout as shown in Figs. 6 and 7. The network layout consists of using three basic layouts and the Ubiquitous Learning Graph (ULG) we developed.

The first layout consists of the random network shown in Fig. 6 (left). It uses a simple algorism that generates nodes randomly on the graph, and then the system links related nodes.

The second layout, shown in Fig. 6 (right), is a force-directed layout. It uses the force vector algorithm proposed in the Gephi software, appreciated for its simplicity and for the readability of the network it helps to visualize (Mathieu et al, 2014; Noack, 2009; Fruchterman and Reingold, 1991).

The third layout consists of the Yifan Hu Multilevel Layout, as shown in Fig. 7 (left). It uses a very fast algorithm to reduce complexity (Hu and Scolt 2001, 2005). The repulsive forces on one node from a cluster of distant nodes are approximated by a Barnes-Hut calculation, which treats them as one super-node (Barnes and Hut 1986).

The final layout, shown in Fig. 7 (right), consists of using the ULG we developed. The ULG is divided into four areas: top-left, top-right, bottom-left, and bottom-right.

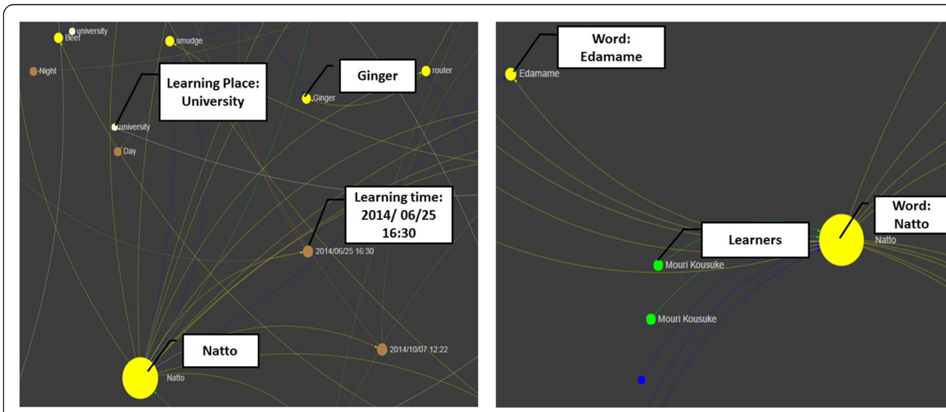

Fig. 6 Random and force-directed layout

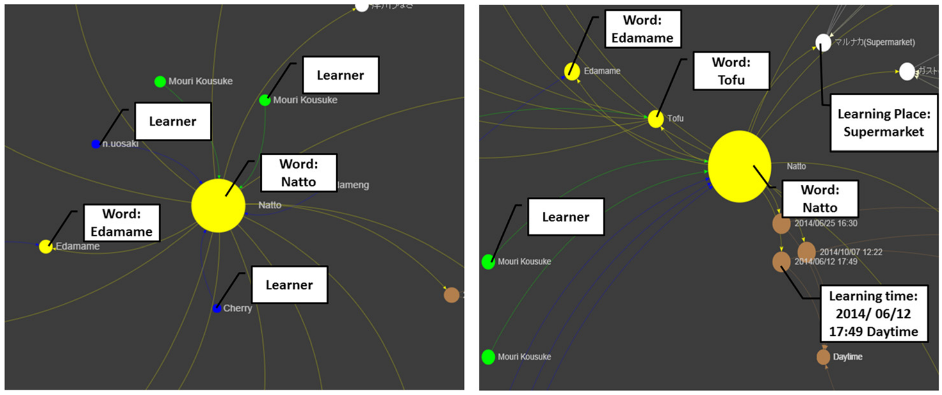

Fig. 7 Yifan-fu-multilevel and ubiquitous learning graph layout

The center node on the network graph shows the central topic that learners want to know about. The top-left area shows others' knowledge related to this topic. In this case, learners can understand what other learners have learned about tofu and edamame right after learning about natto. The top-right area shows places related to the topic. For language learners, this is important information needed in order to apply their knowledge to other learning places, as described in the section titled "Collocational Network". The bottom-right area shows seasons or day of time such as "daytime", "spring" and "summer" related to the topic. Similarly, the bottom-left area shows places such as "university" and "supermarket" related to the topic.

Color coding of the visualized nodes

To avoid having learners feel confused when they see the past ULLs because there might be too many visualized nodes, it is definitely necessary to establish some criteria for the distinction of each node. To effectively distinguish each node, we created a color coding scheme for the nodes, shown in Table 3.

(1) Green nodes show the learner's own name on the upper layer. If a green node is connected to a yellow node on the intermediate layer, the connecting line is pink so that it can be easily recognized as the learner's own entry.
(2) Blue nodes show the names of other learners on the upper layer. If a blue node is connected to a yellow node on the intermediate layer, the connecting line is blue.
(3) Yellow nodes show both the learner's own knowledge and the knowledge of other learners. For example, the learner can recognize his own knowledge because the line connecting his name on the upper layer to the knowledge node on the intermediate layer is pink. In addition, the learner might discover the knowledge of other learners related to his own knowledge.
(4) White nodes show the location of the learners on the lowest layer. These nodes include latitude, longitude, building names, and other location attributes
(5) Brown nodes show the time that the knowledge was learned on the lowest layer. The time of learning is made up of attributes representing the time of day ("morning", "daytime", "night") and season ("spring","summer","fall","winter").

Table 3 Color coding to distinguish the kinds of nodes

Node	Layer	Node color
Learner's own name	Upper	Green
Names of other learners	Upper	Blue
Knowledge of learners	Intermediate	Yellow
Location of learners	Lowest	White
Time the knowledge was created	Lowest	Brown

Visualization system combined with network graphs and time-Map

The interface combining network graphs and Time-Map for visualizing the complex relationships between learners and ULLs is shown in Fig. 8 (left). It contains the following components:

- Search and layout form: Learners input target words they want to learn about and choose a layout (Random layout, Force-directed layout, Yifan Hu layout, or ULG).
- Network graph: The network graph shows the layout calculated by the LKPTE model. Figure 8 (left) shows a sample of the ULG. Figure 8 (right) shows the enlarged network graph. In these two cases, learners can grasp that the target word (natto) is most similar to tofu based on the LKPTE model and cosine similarity. Similarly, they can see that natto is most similar to some contexts such as the supermarket (a place where they frequently learn about natto) and night (when they frequently learn about natto).
- Time-Map: Learners might forget their ULL entries or when and where they have learned before. Therefore, the system reminds them of their log entries recorded during a specified period of time by showing them on the timeline (default: two months before and after the set time). Further, the network graph and time map functions are linked to each other. For example, if a learner clicks a certain node on the network graph, the time map will show the location and time corresponding to it. Therefore, learners can obtain its location and time information.

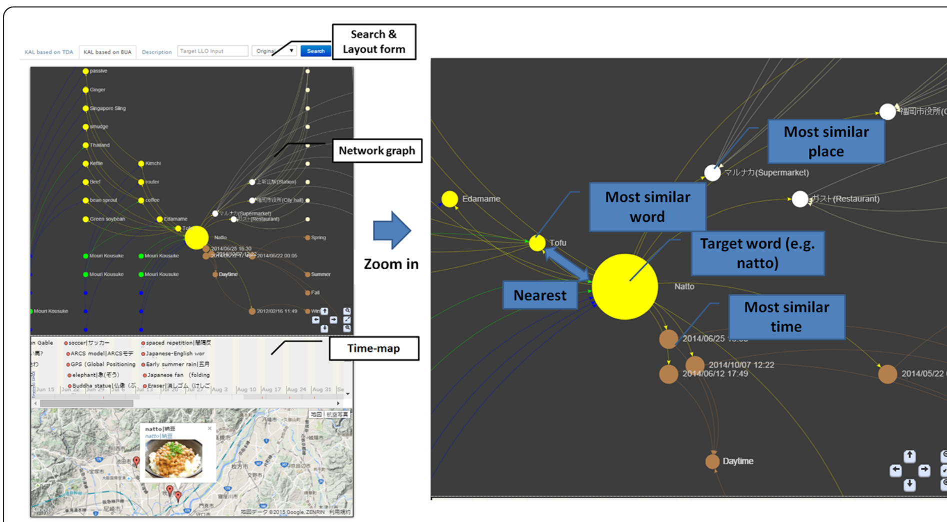

Fig. 8 Visualization interface based on collocational network with Time-Map

Evaluation

Seventeen international students studying at the University of Tokushima and Kyushu University participated in the evaluation experiment. They were from China (10), Mongolia (6) and Malaysia (1) and aged 23 to 31. Their length of stay in Japan ranged from 1 month to 5years, and their JLPT levels were from 1 to 3 and no qualification. The evaluation experiment was designed to evaluate whether the visualization system would be of benefit in finding the relationships between the learners and ULLs and whether the newly developed ULG would be easy to use compared with previous visualization types such as the random layout, Yifan Hu layout, and force-directed layout.

Method

Before the evaluation began, we explained to the participants how to use the visualization system and SCROLL. In addition, since they had never used SCROLL before, they practiced using it for one day before using the system. After that, they recorded learning logs using SCROLL and then used it to visualize the relationships between themselves and their ULLs for two weeks. The participants used their own smart-phones (iPhone or Android device) to record their ULLs in formal and informal settings anytime and anywhere. The mobile devices used in the evaluation experiment were five iPhone 4s, eight iPhone 5s, and four Samsung Galaxy Note 3s. After the evaluation, the participants were asked to complete a questionnaire that used a five-point-scale to evaluate the system's performance and usability, as well as the ease of understanding the content and finding other ULLs using the system.

Results and discussion

The questionnaire results are presented in Table 4.

Q1 and Q2 ask about the usability and usefulness of the network graph. Q3 and Q4 ask about the importance and performance of the system.

The results of Q1 and Q2 revealed that the learners efficiently grasped their own or others' knowledge using the network graphs for visualizing ULLs. Through the evaluation we found out how the participants learned from others' knowledge and contexts. Many Chinese learners spent much time at the university in the summer during the evaluation experiment, and they had opportunities to find relationships between themselves as learners and the university. After visualizing knowledge such as "electric fan" (扇風機) and "air-conditioning" (空気調節) related to "university" and "summer" through the contextual data accumulated in cyber space in SCROLL, the system displayed the results of visualization on the learners' desktop PCs or mobile devices. Consequently, the learners could understand the relationships between their knowledge and the university in the summer.

Table 4 Questionnaire results

Question	Mean	SD
1. Were the network graphs useful to find the relationships between you and others' contexts?	3.27	0.50
2. Were network graphs useful to find the relationships between your and others' knowledge?	3.52	0.48
3. Was Time-Map with the network graphs useful to grasp your or others' contexts?	3.92	0.59
4. Was Time-Map with the network graphs useful to grasp your or others' knowledge?	3.85	0.66

The results of Q3 and Q4 indicated that the learners grasped their or others' context and knowledge. These questions were used to evaluate ULLs in the spatio-temporal dimension. For example, when a Chinese learner learned about natto at the supermarket, he or she used Time-Map to find more places, such as a "restaurant" or "shopping mall" where other learners had also learned about natto. Next, the learner was able to apply his or her knowledge about natto to other learning places such as restaurants and shopping malls.

We also evaluated the network layouts used in the previous studies and the ULG we developed. For the comparison, the participants used some of the conventional layouts during the experiment and completed the questionnaire shown in Table 5.

The aim of Q5 was to evaluate the usability of the layouts, and aim of Q6 was to evaluate the learning effectiveness. Figure 9 shows the results of the questionnaires about layouts. The results indicated that for both usability and effectiveness, many participants preferred the ULG to the other layouts. They reported that they were able to grasp WHO was learning WHAT, WHEN, and WHERE in the ULG where these four categories were visualized. In regard with the usability and effectiveness, we interviewed the participants to compare the ULG with other layouts.

(1) ULG versus Random layout

The random layout enabled it to run faster than other layouts. However, the participants commented as below because the algorithm of the random layout generated nodes randomly on the graph.

- "When I used the random layout, it was difficult to find my knowledge and other contexts because I was not able to grasp the position of contexts on the graph."
- "In the point of usability and effectiveness for learning, it was worse than other graph layouts. But, it is good in terms of processing speed."

If comparing the ULG with the random layout, the processing speed of the ULG is slow, but it is very useful in finding the relationships between their own knowledge and other contexts. In addition, the random layout is not good layout for learning because the participants were not able to grasp the position of contexts on the graph.

(2) ULG versus Force-directed layout versus Yifan multilevel Layout

As for the force-directed layout shown in Fig. 9, both usability and effectiveness for learning are lower than the ULG and Yifan multilevel layout. To compare the force-directed layout with the ULG and the Yifan multilevel layout, we asked the participants to comment "why did you prefer to the ULG and the Yifan multilevel layout than the force-directed layout?" The comments are as follows:

Table 5 The questionnaire about layouts

Question
Q5. Which layout is the easiest to use?
Q6. Which layout is the most effective for learning?

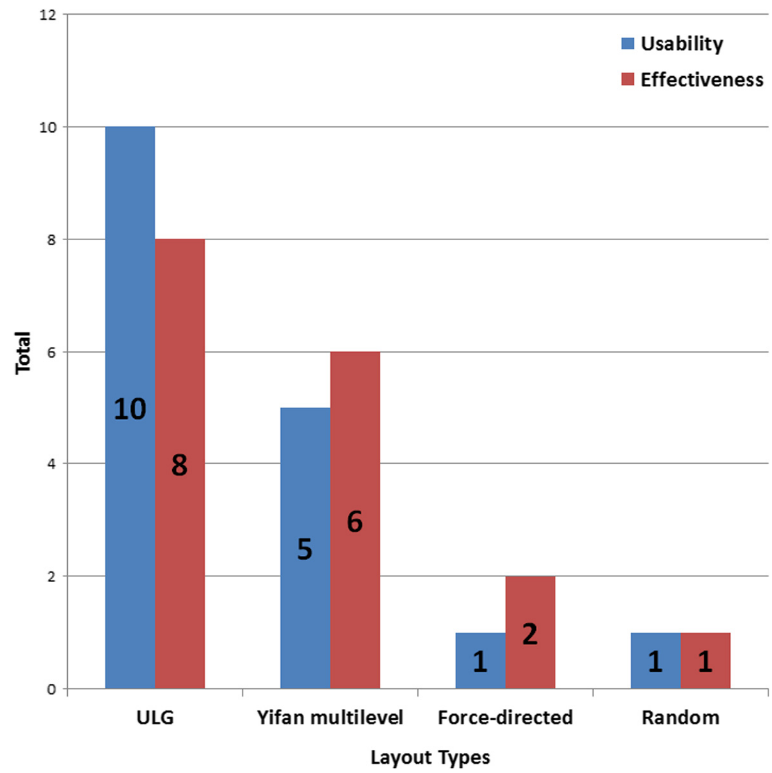

Fig. 9 The number of selected layouts by each participant in the evaluation experiment

- "Yifan multilevel layout is easier to read than other layouts. Especially, the beautiful layout gave me the motivation for learning."
- "I think that the speed of visualization of the ULG is slow. But, if reviewing comprehensively in terms of easy of understanding the content and effectiveness for learning, I will select the ULG."

Though we had expected that the ULG would be useful layout in terms of the effectiveness for learning, it did not. But, if comparing usability of the ULG with the Yifan multilevel layout, the usability score is twice as high as that in the Yifan multilevel layout. That means the ULG is most useful layout for understanding the content.

After the experiment, we asked the participants to give comments and share their experiences of using the system. Examples of some positive comments are as follows:

- "It is very beneficial to find links between my knowledge and other learners' contexts. Especially, visualizing my current location or place is impressive for learning. When learning at the laboratory at the University of Tokushima, I often used to find relationships between the university and other learners' knowledge."
- "I'm from Mongolia. I always wanted to know about many learning events similar to what other Mongolian learners have learned. It is very helpful to know the learning spots where other Mongolian learners have been."
- "The advantage of the system for visualizing relationships between the word and the geographical data, for me, is that it gave me the motivation to learn Japanese."

- “It is very interesting to visualize other learners’ vocabularies based on natto, a Japanese food.”
- I thought that morning glories bloom in the morning, but actually, I noticed that there are kinds of morning glories that are in bloom even in the daytime, by using this system.

These positive comments and episodes show that the system helps find the relationships between learners and ULLs. Its advantage is that it helps learners grasp the relationships between what they have learned in their daily lives and other learners’ contexts. However, there were also some negative comments.

- “Japanese words written in Kanji are quite difficult for people who don't know Japanese. The words visualized from other people’s vocabularies were in Kanji. If the word details were in Hiragana, they could help beginners to learn the language.”
- “I’m at JLPT level 1. The words visualized in two different locations were very simple words. There was almost no word to directly experience something or do a re-log. I wanted more difficult vocabulary and challenging learning situations.”
- “It was little bit difficult to understand how to use the system. In addition, the function of saving learning logs is very good, but I prefer to write papers.”
- “Sometimes the speed of visualizing learning logs in the system is too slow. (It took about 10 ~ 20s)”

From these comments, the participants would suggest that the system developer take into account learners’ Japanese levels. This means that the L_l parameter in the LKPTE model is not enough. In addition, we need to improve the system’s speed in visualizing ULLs. In consideration of these issues, our future works are described in the next section.

Conclusion

This paper described a system for visualizing relationships between learners and ULLs. International students can add their knowledge to a ULL in SCROLL, and then SCROLL can present the learning contents to help them recall their knowledge based on their learning contexts.

By using SCROLL with the system that we proposed, the international students learned interesting knowledge that others had recorded. When the participants learned “electric fan (扇風機)” word in Japanese in the university or in a formal learning setting during evaluation experiment, our proposed system visualized to links the relationships “electric fan” and other contexts such as “electrical store” and “Shopping mall”, and provided them. Also, six learners have learned “morning glory” in the morning while two learners have learned it in the daytime. It indicated that most morning glories bloom in the morning, but there are some varieties that bloom during the daytime. Our system was able to detect relationships between knowledge and time, and notify those who learned it in the morning that there exist ones which bloom in the daytime. In this way, learners were able to deepen their knowledge about “morning glory” through other learners’ experiences.

The evaluation was conducted after the implementation of the function to visualize learners and ULLs. A questionnaire with a five-point-scale administered after the evaluation showed that the system supported the international students by visualizing ULLs. As mentioned in the section titled "Results and Discussion", the system needs improvement so that it can recommend more appropriate learning contexts or materials in accordance with learners' situations. In addition, we will consider making improvements because the L_l parameter in the LKPTE model was not sufficient.

In the future, the use and evaluation of the visualization system will continue, and we will improve the system as described above. Our next consideration is to support international students who are studying for the JLPT by having them use the system to enhance their Japanese language skills.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

KM carried out design of the ubiquitous learning analytics study, collection and assembly of data, and analysis and interpretation of data. In addition, KM drafted this manuscript. HO performed the critical revision of this manuscript for important intellectual content, and final approval of this manuscript. This manuscript has not been published and is not under consideration for publication elsewhere. All authors read and approved the final manuscript.

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