Spacelog Concept and Issues for Novel u-Services in Smart Spaces

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Abstract

Spacelog is a continuous collection of existence states and activity experiences of various entities in a physical environment, and it can be regarded as a special database or conceptually seen as a memory organ specifically for a real spatial site such as a home and a laboratory. Different from lifelog that is a personal database for a single individual, the entities in the spacelog cover multiple forms including people, facilities, artifacts, and space-related states in a site. This paper first explains the spacelog concept as compared with concepts of log, lifelog, monitoring cameras and context history, then discusses the fundamental features of the spacelog as well as related technique issues faced to develop spacelog systems, and finally describes the possible novel services and applications using spacelog in smart spaces.

1. Spacelog Motivation and Concept

Log is generally some kind of records about history or experience of an entity in a certain period. For instance, a log file automatically recorded on a computer is about all changes of hardware and software made on this computer. Another popular example is a web server log that records all clients' access history to the server, and enables its administrator to know where clients were from, when they accessed the server and which web pages were accessed so as to improve quality of the web services.

Lifelog is a sequence of data records about an individual's life experience. The initial lifelog idea may be dated back to V. Bush who imagined a machine called MEMory EXtender (MEMEX) that can keep written memos and their related materials so as to enhance human's memory [1]. Currently, some projects, e.g., LifeLog/ASSIST [2], MyLifeBits [3], LifePod [4], Ubiquitous Memories [5], and our study on modeling and analyzing individual's daily activities using lifelog [6], are trying to realize this MEMEX's idea by recording all the states and acts of an individual's daily life with continuous capture using various sensors. These captured data records can be regarded as a personal database of life experiences, which can be retrieved when necessary and used as reference to improve the person's life quality.

Spacelog is a continuous collection of digital records on existence states and activity experiences of multiple entities in a real space or physical environment such as a laboratory, a classroom, a library, a home, a clinic, a shop, a restaurant, a farmland, or a construction field. The entities in a space can be people, facilities, artifacts, and space-related states, e.g., temperature distribution, air quality, noise level, sound source, etc. This variety of possible entities in a space marks one essential difference of the spacelog from the lifelog, which the latter refers specifically to activity records of a person - single entity. Furthermore, while monitoring cameras are widely used to record raw video data for security surveillance, the spacelog is to automatically collect different kinds of data related to multiple entities via various sensors distributed in a space, and efficiently keep the data in an integrated database, which can be regarded conceptually as a special database of a physical environment to automatically record what occurred inside it.

A smart space is an intelligent real environment such as a room equipped with sensors, actuators and other devices, which can provide automatic responses according to users' needs and contextual information in the environment [7]. The smart space or environment, as one of the major ubicomp/percomp areas, has recently received much attention, such as ATR's Creative Space, CMU's Aura, IBM's Dream Space, MIT's Oxygen, Philips' Home of the Future, UF's Assistive Smart House, Keio's SSLab, etc. So far there are lots of studies about how to acquire and use contexts, i.e., information used to characterize the situation of an entity [8], but very less study has been done on how to keep, manage and utilize the context history although it has been realized as a key issue in smart spaces [9]. Therefore, the spacelog can also be seen as a context history database in a smart space system, and functioned as a "memory organ" of an intelligent real environment.

The spacelog concept, first proposed by us, was motivated by the outcomes of our three previous research streams: (1) context-aware smart applications [10, 11], (2) robot-integrated smart space [12], and (3) outdoor lifelog analysis [13, 14]. The spacelog can be exploited to extend

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functions of physical environments and provide many novel services, including but not limited to (a) effective retrievals of past events that happened in a space; (b) systematic summaries of entities' experiences which occurred in a specified period; and (c) automatic detections of important events or changes for prompt reactions. Furthermore, the intelligent capability of smart spaces/environments can be greatly enhanced when incorporated with the spacelog, and the whole individual's lifelog may be conveniently composited by combining spacelogs in different environments where the individual has ever stayed.

2. Spacelog Features and Issues

The spacelog, as a special database specifically for a real space/environment, brings new features and issues in developing a spacelog system, which is conceptually shown in the figure below.

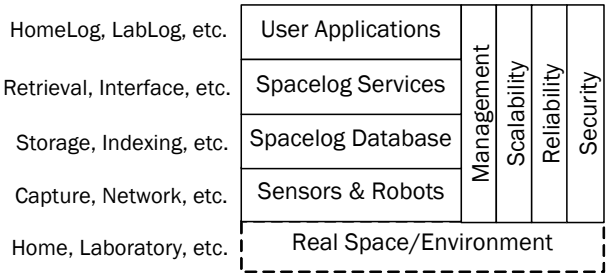

Figure 1. Spacelog System and Layers

As mentioned previously, spacelog is continuously collected using various devices such as cameras, microphones, sensors, RFID tags, etc., which are either fixed somewhere in a physical environment, e.g., a home, a laboratory, an office, a classroom and a library, or carried by robots that can move in the environment to get log information in different locations. Three fundamental features of spacelog data directly acquired from the devices are as the following.

- *Continuity* – fast spacelog accumulation along time
  The amount of spacelog data increases very fast along time. Suppose the average data amount generated by all sensing devices in one second is R B/s (Bytes per second), then the data amount will roughly be $30R$MB/year, that is, about 30TB in a year if R=1MB/s just for a single environment. Such continuous data accumulation must be one of the important factors to be taken into consideration when studying spacelog to efficiently capture and store spacelog data in making spacelog systems.
- *Heterogeneity* – various forms and demands
  The heterogeneity covers different spaces, devices, media, entities, and various demands of applications as well as users, etc. One of the main goals of the spacelog study is to find the common features/rules, general methodologies, effective approaches and associated techniques to deal with the great heterogeneity.
- *Complexity* – spacelog semantic meanings/levels
  The raw data taken directly from sensors is the most original space logs, which are the detailed records but with the least semantic meanings. The two main problems in the lowest level spacelog are (1) the amount of data is large with high data redundancy; (2) the meanings are less clear and compact not suitable for users. Actually, one core issue in spacelog study is how to process and interpret the raw spacelog data to form the high level of meaningful spacelog.

There are lots of technical problems existing to design and develop practical spacelog systems. What log data should be captured with using what devices? How and where to capture? What pre-processing on the raw log data is necessary to remove redundant or useless data? How to efficiently and synchronously keep the records from different devices with varied media forms into the available storage? What's a unified format of log records for storage, representation, presentation, etc.? What are general models and approaches for spacelog analysis, mining, indexing, summarization, retrieval, presentation, key information extraction, etc.? How to update and manage spacelog with considering system scalability, reliability and security as well as privacy protection? How to use log data conveniently and flexibly by other modules or applications? What are suitable interfaces and interactions between human and spacelog systems?

Actually, the spacelog shares some common issues in other areas such as database, multimedia, sensor networks, pattern/activity recognition, AI, agent, data mining, etc. However, the question is that issues in spacelog cannot be all solved by simply applying available techniques in these areas, and thus new approaches and techniques must be put forward to deal with the new features and solve the new issues required specifically by the spacelog and related applications.

Currently, our study on spacelog covers some core issues in the following aspects: (1) a general scalable framework to deal with heterogeneous devices, networks, data types and so on; (2) basic relationships and principles to get more information with using less number of sensors as well as their optimal installation positions and combinations; (3) flexible spacelog acquisitions using robots and their cooperatively working with other devices in smart spaces; (4) a spacelog database and related techniques to extract and index

captured raw spacelog data with a unified spacelog description scheme for effective retrievals and summarizations of interested states and events occurred in an environment.

3. Spacelog Services and Applications

The "space" in the spacelog can be any real site, such as a home, a laboratory, a classroom, a kindergarten, an office, a shop and a clinic, accordingly, the spacelog can be used in many people's daily environments for a variety of novel services. The possible applications may be fallen into the following categories:

- Find/retrieve necessary detailed information from the spacelog
  Examples: (1) Which facility consumed much electricity in the last week? Why? (2) Does a book in this site, and where is it? (3) Did somebody join the meeting? What did he/she said in the meeting?
- Get a summary of activities/changes related to an interested entity in some period
  Examples: (1) What's the electricity consumption situation of my home in the last month and how the consumption is distributed by categories or facilities? (2) What did my child do after school when I was not at home? (3) How many hours did my son play computer games last week? Which day did he play the longest?
- Detect important events or change points using spacelog for prompt reactions
  Examples: (1) What's the problem with the facility which consumed too much electricity in a certain period as compared to its previous working condition? (2) Is it necessary to send a message to parents if their child has not returned home for unusual long time after school? (3) What advice/action will be given when someone's medical measured readings become abnormal? (4) What medicines/foods have expired dates?

Furthermore, the spacelog can also be used by other systems and applications, e.g.,

- Used as context history data for smart spaces and other context-aware devices/systems
  The spacelog includes the space-related past information, i.e., context history, can be used as references for some smart environments to take response decisions. For examples: (1) Check if an item (e.g., an umbrella) has been brought back since it was brought out. Give a message if it's not yet returned; (2) Give an advice if a child played games too much, recently.
- Used as modeling/learning/training data for some intelligent algorithms in AI, GA, etc.
  In many context-aware systems, the intelligent algorithms will be applied to process context information. The spacelog can be used to model some intelligent algorithms and further used as learning/training data to determine the algorithms related parameters.

Two prototype systems of HomeLog and LabLog are under development to offer several representative novel services/applications including automatic management of u-goods in a home, robots-based mobile measurement of sound/temperature distribution, semantic summarization of kid's activity after school, etc.

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