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A Framework of Decision Support System based on Integrated Data for Electricity Management in Campus

Suwit Somsuphaprungyos[1*], Marut Buranaruch[2] and Salin Boonbrahm[1]

[1] School of Informatics, Walailak University, Nakhon Si Thammarat, Thailand

[2] National Electronics and Computer Technology Center (NECTEC), Pathumthani, Thailand

*E-mail: ss.rungyos@gmail.com

Abstract

This work presents a framework to support management plan in a university using sensor data and static data. The focused study is a student usage of a campus library. As data to reveal happenings for planning, data from several types of sensors including RFID, push sensor, light sensor and voltage sensor are used to detect students' behavior in a library without interfering students' privacy. The obtained sensor data is processed with ontological inference to infer students' activity as additional information. All gathered data are processed and summarized with various aspects such as location, time, day and activity to inform planners of library usage statistic. From testing, enriched information with ontological inference can reveal more details than raw data of headcount. The results were more insight with student activity. A set of rules to manage facility is designed to suggest closing an area in specific date and time based on the headcount and inferred activity. From testing, the result showed that the suggested plan can help in reducing electricity cost smartly based on the statistic data of usage in the area.

Keywords: integrated data, ontological inference, sensor detection, smart campus, decision support system

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1. Introduction

In management, planning is the most crucial part concerned for future direction and determining on the missions and resources to achieve the target [1]. Planning is a task for those with high authorities, and the plan will affect entire organization. In fact, planning requires analysis from actual circumstances, environment, involved personal in which are different from place to place. To plan, data from the past are used for understanding actual circumstances. Hence, the plan is able to directly improve as expected.

However, there are remaining problems to acquire actual data. First, some significant data are not collected properly. This normally comes from the several sources. For example, some types of data are difficult to obtain, such as usage of specific property and human movement. This leads to the lack of data to analyze. Thus, these types of data are commonly estimated from the point of view of planners. Moreover, planners, who normally are higher-ups, may miss an actual detail since they are usually busy in their tasks and receive more privilege to prevent hardship in their activity. Second, data are in various data formats from several sources. This gives difficulty in gathering and making into statistics without spending time in cleansing and integrating. Without proper data integration, some data may be omitted in which could be a major factor pointing to a cause of a problem.

In a university campus, there are several data to use for management, but they are the same as abovementioned issues which are a lacking of significant data and data in various formats. Moreover, most of the commonly existing data are static data, such as personal information, and academic related results. These data are useful for planning in improving students' quality, but rarely useful to manage efficacy of campus usage. To solve or improve a specific issue such as electricity consumption, additional types of data are required for empirical analysis. Such data are necessary and can be obtained from monitoring or observing as there are several research studies aiming to gain actual information of resource usage [2] [3] [4]. Unfortunately, manual observation is one of the costly tasks and possibly contains human errors. The use of sensors hence becomes more recommended to capture this hard-earned information [5] [6].

Facility management and energy saving in a campus is one of the factors in optimizing campus resources. Energy saving is also one of key performance indicators (KPI) in most of Thai universities aiming to fully use existing resources and reduce wasting in energy such as electricity. In a campus, a library is a common facility to provide extra studying environment for students as it offers workstations, multimedia stations, study space, and collection of various kinds of books. However, since it is a closed room, electricity spending can come from several sources such as air conditioner and light. In this work, we aim to manage a campus library using data from sensors to support planning for reducing electricity uses with the least effect to students. The obtained data will be used to decision-support for planning regarding to library users' behavior. Inference using an ontology will also be applied to enrich semantic of an activity in a library from raw sensor data. With data and inferred activity, we expect these to serve as data for decision-support for efficient library planning.

2. Background

2.1 Ontology and Inference Engine

Ontology [7] is a knowledge representation that represents a logical structure of related concepts in domain knowledge. It is well known as explicit formal specifications of the terms in the domain and relations among them [8]. An ontology defines a common vocabulary for users who need to share information [9] and provides machine-interpretable definitions of concepts and their relations. Hence, ontology schema becomes a good resource to represent a network of concepts.

In ontology, a schema of concepts in a domain is constructed and linked to each other by a relation. Types of relation are as follows.

- Is-a relation: This relation forms hypernym-hyponym (supertype-subtype) relationship between concepts to define a taxonomic hierarchy. As taxonomic hierarchical structure, all qualifications of a supertype must inherit into its subtype.
- Property relation: This relation forms holonym-meronym (whole-part) relationship to define a possession or composition. For linking a concept with other concepts, Object property or Part-of (P/o) is called while Data property or Attribute-of (A/o) is used to mention a link between a concept and data.

With these relations, concepts are linked to each other with specification and semantic constraint. In the usage, ontology is given in a computational logic-based language called OWL (web ontology language) designed by W3C [10]. OWL is built upon a W3C XML standard for objects called the Resource Description Framework (RDF) [11]. It is designed to represent rich and complex knowledge as a base for a machine to interpret and understand knowledge of things and their network.

An ontological inference engine is a system that applies logical rules to the ontology knowledge base to deduce new information [12] from the given logical rules and ontological instances. The logic used in an inference engine is represented as IF-THEN rules (production rules). The general format of the rules is IF <logical expression> THEN <logical expression>.

In most of expert systems, an inference engine is applied to deduce new information with the help of a knowledge base such as ontology. This process would iterate as each new fact in the knowledge base could trigger additional rules in the inference engine. Inference engines work primarily in one of two modes either special rule or facts: forward chaining and backward chaining. Forward chaining starts with the known facts and asserts new facts. Backward chaining starts with goals, and works backward to determine what facts must be asserted so that the goals can be achieved.

There are several open sources for inference engine such as JENA [13] and Prova [14]. Jena is an open-source semantic-web framework for Java which includes a number of different semantic-reasoning modules. Prova is a semantic-web rule engine supporting data integration via SPARQL queries and type systems such as RDFS and OWL ontologies. With the abovementioned open source inference engines, a developer needs only an ontology as a semantic knowledge base and rules for inferring regarding to syntax of the engine.

2.2 Related Work

There are several publications mentioning about recognizing activity in a certain area. Their work is summarized in Table 1. These work projects applied different technology to accomplish their goal. Most of them used sensor data to imply human action or movement while some exploited knowledge representation such as ontology to assist in determination or represent data schema. However, their objective mostly is to recognize human activity, but rarely applies the found activity to use. In this work, we aim to use the sensor data with activities for decision-support in management of a university campus.

Table 1 Comparison of Related Projects

Publication	Data Input	Technology	Targeted Environment	Objective
An ontology based framework of modeling movement on a smart campus [15]	- Enrollment Database	- Ontology	Campus	Analyzing and visualizing human movement
Building A Smart University using RFID Technology [16]	- RFID reader	- RFID	Building	Development of Smart University model
The smart University experience : A NFC-based ubiquitous environment [17]	-NFC : (near field communication) sensor	-Wireless proximity communication -Mobile phone	Campus	Development of Smart University model
Activity recognition using context-aware infrastructure ontology in smart home domain [18]	- Home sensor Network - Body sensor Network - Wireless sensor - RFID reader	- Ontology	Home	Recognition of activity in home
Inferring Students' Activity Using RFID and Ontology [19]	- RFID sensor - Enrollment Database	- Ontology	Campus	Recognition of activity in campus
This work	- RFID - Push sensor - Barcode reader - WIFI login - Voltage sensor	- Ontology	Library in campus	Campus management

3. Decision Support System for Management in Campus

The proposed system consists of three main parts: data collection, inferring students' activity, and decision supporting. An overview of the system is drowned in Fig. 1. In this work, we focus on studying of usage in a campus library for supporting in a campus management in terms of electricity reduction.

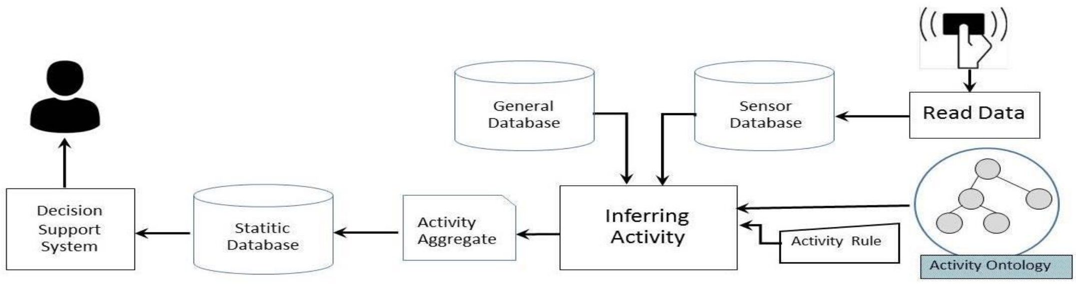

Figure 1 An overview of a framework of decision support system for Electricity Management in Campus

3.1 Data Collection

In this work, we apply sensors such as RFID [20], voltage sensor, motion sensor and push sensor [21], to collect actual data in a campus library. These data will inform us identity (who), location (where), and time (when). Static data will be used to expand information in details such as room details (about available seat, size and available facilitated tools). With these two data combined, we can have a round view of circumstances with details.

Each sensor type gathers different kind of data; thus, a location and activation for each type is assigned as exemplified in Table 2.

Table 2 Examples of Sensor types and their Details

Sensor Type	Location	Activation Condition	Gathered Data
RFID	In front of each door on both side	Required to activate to entry	Identification and Time
Push sensor	Under each chair seat	Sitting on a chair	Duration
Barcode reader	Next to exit of a book shelf room	Automatic reading if book passing by	Amount of book brought out
Voltage sensor	Attached to Desktop PC	Turning on the PC	Using the PC
Wi-Fi access	Each Wi-Fi hotspot in library	Logging into Wi-Fi hotspot	Duration

The collected data are stored in a database. Despite being raw actual data, they alone cannot be interpreted much as they are person ID (who), time (when and how long) and location (where). These data may lead to head counting and plotting a visiting duration, but it is better to understand an activity (what) from the data for more concrete decision supporting.

3.2 Inferring students' activity

From the previous section, raw data from a library can be collected. However, an activity is still needed to sufficiently inform on users' behavior. There is an existing ontology representing knowledge of an activity in a campus [19]. The ontology was designed for representing concepts and their relations relevant to students, course, building and activities. The main tree of the ontology is activity concept that has properties such as location, time and person. However, the ontology focused on general activity concepts and still lacks activities in a library. Some parts of the ontology are shown in Fig. 2.

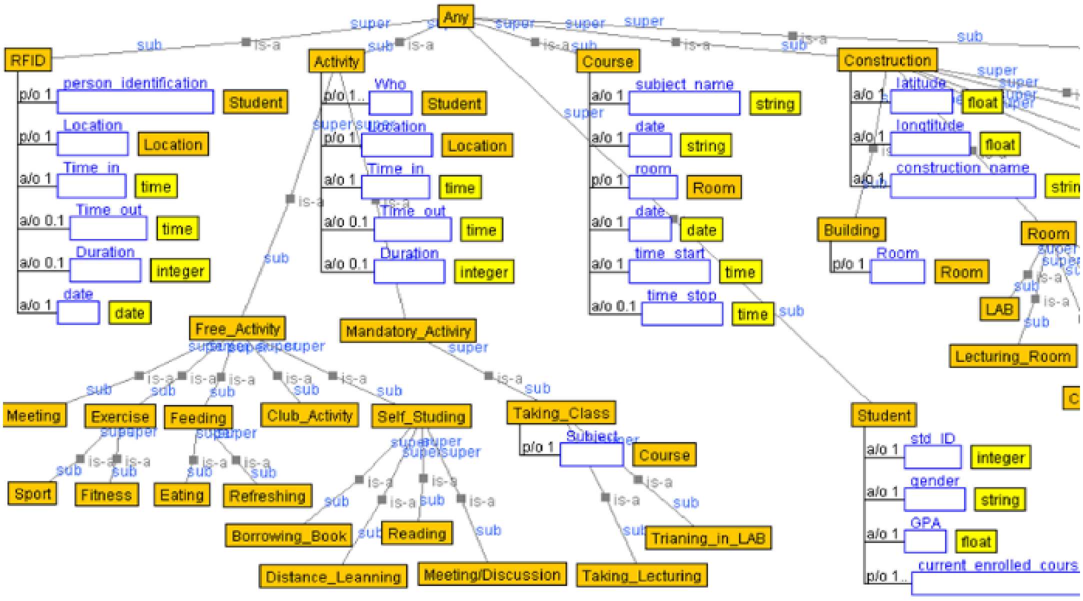

Figure 2 The ontology for activity in campus [19]

In this work, we expand the ontology using Hozo ontology editor [22] to include activities in a campus library. The expansion focuses on activities happened in a library and sensor data.

To estimate an activity from instance, inference engine is needed to give a conclusion on the basis of evidence and reasoning. In this work, we applied OAM [23] in which having Jena inference engine [13] plugged in. With the power of OAM, we can create a rule to determine an activity from instances in spreadsheet [24] without knowing syntax of JENA.

To explain from Table 3, the first rule is to check 'if students have their RFID read before entering a library' and the result is to realize that a timestamp for entering a library. This rule will be used with the exit rule to calculate for total time spending for a single student. With all the rules, we can record student's behavior in usage of a campus library without interrupting their action. Moreover, students can preserve their privacy since the designed method does not record identity of the student or capture their actions in video or image.

3.3 Electricity Saving Plan for Campus

With the output from previous methods, we gain a statistical amount of students and their activities of specified date and time. The statistic is used as a reference to make decision for planning. It can be sorted or viewed to find trend of student headcount and activity for campus locations. This is used for making plan aiming for saving electricity usage in a campus.

To create a plan, criteria are based on the headcount and activity in the past. Since the amount is a collection based on date/time in the past, average and standard deviation of headcount are used as representatives. The main idea in electricity saving plan is to find place in date/time that students rarely participate and to turn off electronic devices in the area. The designed rules for planning with the library blueprint given in Fig. 3 are exemplified as follows.

- IF {[@location] has_headcount_AVG lower than 5 AND has_headcount_SD-Norm greater than 50} THEN {[Electronic_Devices] in [@location] is_recommended [close]}
- IF {[@reading_area] has_headcount_AVG in range of 5-20} THEN {[Room_R1] is_recommended [open] and [Room_R2] is_recommended [close]}
- IF {[@reading_area] has_headcount_AVG in range of 21-30} THEN {[Room_R1] is_recommended [close] and [Room_R2] is_recommended [open]}
- IF {[@reading] has_headcount_AVG greater than 30} THEN {[Room_R1] is_recommended [open] and [Room_R2] is_recommended [open]}
- IF {[@selfstudy_room] has_headcount_AVG in range of 5-9} THEN {[Room_S1] is_recommended [open] and [Room_S2] is_recommended [close]}
- IF {[@selfstudy_room] has_headcount_AVG in range of 9-18} THEN {[Room_S1] is_recommended [open] and [Room_S2] is_recommended [open]}
- IF {[@return_book_area] has_headcount_AVG lower than 5} THEN {1 of [Air_conditioner] in [L1] is_recommended [close]}

With the rules exemplified for library campus, predictably unused areas will be planned to shut down to reduce the electricity cost.

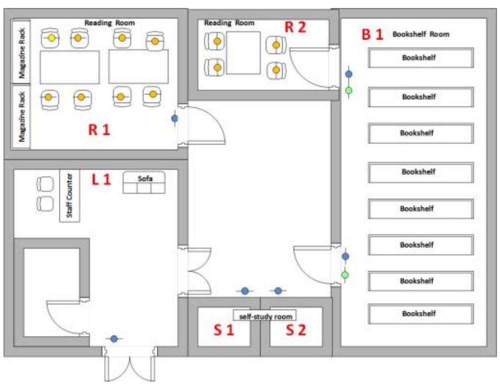

Figure 3 The setup library model

4. Results and Discussion

To show potential of the proposed framework, we test the framework with collected data. We collected students' usage of campus library for 2 months. Then, we inferred their activity and summarized the data. Since there are a large amount of data, we show only Monday' results separated by inferred activity as given in Table 3. In Table 3, columns indicate time periods in Monday, and roles represent activities in campus. The average amount of students is given based on period and activity.

Usually, open hours of the demonstrated library are in between eight o'clock to twenty o'clock for everyday. All facilities in the library are fully open without turning off electronic devices in open hours. The details of room and its electronic devices in the library are given in Table 4.

Table 3 Monday' results separated by inferred activity

Time / Activity	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	18:00-19.00	19:00-20:00
Borrowing	1.17	7.42	3.49	5.48	24.37	4.02	2.96	6.71	17.91	14.34	1.64	0.99
Searching	13.50	11.73	11.04	15.32	29.47	20.85	17.97	31.82	29.71	15.61	13.00	12.16
Reading	10.76	14.05	21.00	22.34	27.31	30.06	29.33	31.25	30.32	30.33	22.66	0.67
Self-Study	0.08	19.92	13.05	18.66	23.35	12.46	11.41	14.55	19.51	25.64	7.39	16.37

In Thailand, electricity cost is calculated by (1) [25].

$$Cost = \frac{Watt * Hour * 0.8}{1000} \quad (1)$$

Based on the recommended plans shown in Section 3.3, the results of recommendation led to action given in Fig. 4. From Figure 4, the plan recommended to close 5 hours for Room_B1, and 3 hours and 6 hours for Room_R1 and Room_R2 respectively. The recommendation plan to close facility by considering past statistical number of less usage can reduce the cost as given in Table 4.

Room	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	18:00-19.00	19:00-20:00
B1	Close	Open	Close	Open	Open	Close	Close	Close	Open	Open	Close	Close
R1	Close	Close	Close	Close	Open	Open	Close	Open	Close	Close	Close	Close
R2	Close	Close	Close	Open	Open	Close	Close	Open	Open	Open	Open	Close
S1	Close	Close	Close	Open	Open	Open	Open	Open	Open	Open	Close	Close
S2	Close	Close	Close	Open	Open	Open	Open	Open	Close	Open	Close	Close

Figure 4 Results of plan recommendations based on rules and inferred activities.

Table 4 The details of room and its electronic devices in the library

Room	Room size(m^2)	BTU	Air condition	Light
B1	576	576000	(53,000)x11	60x40w
L1	144	144000	(32,800)x4	40x40w
R1	288	288000	(38,000)x6	60x4ow
R2	96	96000	(22,000x)4	38x40w
S1	12	12000	(12,000)x1	9x40w
S1	12	12000	(12,000)x1	9x40w

Table 5 Costs comparison between usual open hour and generated recommendation hour

Room	Watt Used	Usual hour	Plan hour	usual cost	Recommended plan cost
B1	51089.77	12	7	490.46	286.10
L1	13772.44	12	-	132.21	73.79
R1	26744.89	12	9	256.75	192.56
R2	9634.96	12	6	92.49	46.25
S1	1374.37	12	5	13.19	5.50
S1	1374.37	12	6	13.19	6.60
SUM				**1091.75**	**704.23**

From cost results, we found that the daily cost from the recommended plan reduced significantly from the usual daily cost. Since we made decision based on statistics in the past, the closing of facility in the specific date/time rarely affects students' usage. We expect this to help to understand students behavior based on actual data in which differentiates from place to place.

5. Conclusions

This paper presents a framework for advancing the saving electricity usage in campus Plan's recommendations using actual data. The sensors such as RFID are used to collect data of students in facility usage based on date/time/area. With ontological inference, activity can be assigned to help in scoping action in specific area. The recommendation plan is designed as a set of rules to help making decision to turn-off electrical appliances devices or to close an area.

From testing of a library usage in a campus, we found that the recommended plan suggested closing several areas in a specific hour. This can help in reducing an electricity cost relatively to additional closing hours.

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