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Context-Awareness Modeling For Intelligent Building Energy Aware

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Abstrak

Pemerintah Indonesia menerbitkan banyak peraturan pemerintah terkait manajemen pengunaan energi Listrik pada bangunan kantor miliknya, dengan harapan terjadinya optimalisasi penggunaan energi Listrik disana. Namun sesungguhnya, kemajuan dibidang Pervasive Technology, telah memungkinkan dibuatkannya sistem control otomatis berbasis context-awareness. Pemerintah Indonesia dapat menggunakan teknologi tersebut untuk mengelola sistem kelistrikan pada gedung kantornya. Penelitian ini mengusulkan pendekatan context-awareness untuk pengembangan bangunan kantor cerdas penggunaan Listrik melalui eksplorasi regulasi Pemerintah Indonesia di bidang konservasi dan manajemen energi untuk sistem perkantoran di Indonesia. Berdasarkan peraturan-peraturan tesebut, kemudian dikembangkanlah pemodelan context-awareness sebagai sistem cerdas penggunaan Listrik. Kecerdasan bangunan kantor ditunjukkan oleh kemampuannya didalam mengelola penggunaan peralatan Listrik secara otomatis.

Kata kunci: *Context-Awareness System, Bangunan Kantor Cerdas, Manajemen Energi*

Abstract

The Government of Indonesia issued many governmental regulations related to the management of the electrical equipment usage in the government office buildings. These regulations aim to realize the optimal energy consumption in those buildings. Indeed, nowadays, advances in pervasive technology have enabled the development of a context-based building automation system. The government of Indonesia can apply these technologies to manage electrical systems in their office buildings. This study proposes context-based approach as a tool for the development of Intelligent Office Building. Through exploration of Indonesian Government regulations in the area of energy conservation and management for their office buildings, context-awareness modeling of intelligent energy aware is developed. The intelligence is shown by the building ability to manage electrical equipment usage based on context-awareness.

Keywords *: Context-Awareness System, Intelligent Office Building, Energy Management*

1. Introduction

Energy consumption for building operation increases every year, for example, about 70% of energy in US is consumed by buildings[1]. The same problem also occurs in Indonesia, where electrical energy usage increases constantly, which is distributed for industries (34.6%), commercial buildings (17,8%), and residential (41.5%)[2]. In general, energy is consumed by electrical devices for artificial lightings, air conditioners, and other electrical devices [3]. Therefore, nowadays, it becomes an important focus for many countries. One solution for this problem is applying energy management, which refers to the managing of electrical devices in the building.

Effort in building energy management had been widely done. Indonesian government moreover has actively participated in supporting building energy management by setting some related regulations. The government had issued some standard, namely *Standar Nasional Indonesia* (SNI) to govern lighting[4] and air flow systems[5] within buildings, make use of achieving optimal operational cost. These standards aim to gain efficient building energy usage without reducing or altering building function, comfort, and productivity.

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The president of Indonesia also plays important part by issuing a presidential instruction of energy and water savings in 2008[6]. The president instructs official government to perform innovations in order to reduce energy and water consumption while maintains its main functions. Management of electricity usage involves air conditioners, lightings, computers, and other electrical devices.

Afterward, in 2009, the Indonesian government issues policies about energy conservation that is defined as a systematic and integrated plan to conserve national energy resources and increase its efficiency. Energy conservation becomes national responsibility, including government, corporations, and communities. Further, the minister of energy (ESDM) acts upon this responsibility by establishing a national energy conservation plan. The minister issues a regulation of electricity usage by creating a framework of air, lighting, and official equipment management for official buildings in 2012[7]. This regulation targets 20% of saving in energy usage within official building all over the country.

All those policies and regulations are formulated in order to govern energy savings, and hope that electricity is used efficiently and rationally without reducing safety, comfort, and work productivity. The regulations determine plans of electricity from the early stages of building up to the operation of the building. However, from the results of Weng's research, et al., There are many cases that electrical equipment is left alive (on) when it has not been used by occupants [1]. The indifferent nature of occupant to electricity consumption in building contributes waste of electricity usage by one-third of the total electricity usage [3], consequently it should be well managed. Therefore, energy management becomes one of the main focuses of many researchers, including experts in Information Technology (IT).

Advances in IT have opened opportunity to build an intelligent systems that has capabilities to sense environment using integration of embedded devices[8]. The intelligent system i.e. intelligent building is considered to have the capability to sense their physical environment, aware to its context (so called *context-awareness*), and adapt their behaviour accordingly[9]. The waste of energy usage due to neglect or forgetting of occupants can be overcome through IT, based on context-awareness approach. In this case, the context-awareness system is applied to control and manage electricity devices so that energy savings can be created without reducing occupant comfort in carrying out their activities.

Context-awareness system is an application that adopts some defined context in its computation hence does not require any explicit interaction with human [10]. This system makes use of occupants as the main focus and has automatic functionality for electrical appliances adaptation. This approach gives some flexibility in space and time to the occupants because building understands inhabitants need and perform environment adaptation according to its awareness.

IT tries to contribute solution in term management of electricity usage within office buildings by make-used of context-aware computing approach [11]. This model is a new paradigm in energy management. Awareness of intelligent building to contexts that effects of electricity usage enable occupants' comfort and efficient energy usage at the same time. Therefore, this study aims to develop a model of context-based electricity system due to the office buildings of Indonesian government. We call this intelligent system as Intelligent Building Energy Aware (IBEA).

2. Methodology

IBEA is a context-awareness based management system with a primary focus on management and automation in electrical system of Indonesian government office buildings. IBEA utilizes pervasive technology as a platform and applies context-aware computation in its intelligence. IBEA is built by make used of a context-aware method that is a programmable controlling method based on awareness of particular contexts. In this case, IBEA applies occupancy within the office buildings as the main contexts to activate the automation system. The system will activate the electrical equipment automatically when aware of the presence of the employees in environment, and will immediately disable all electrical appliances when the employees are no longer active in the environment.

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IBEA utilizes pervasive technology because this technology have integrated sensors, actuators, microprocessors, and wireless network[12], such that it can perform services as required by inhabitants [13]. Sensors sense and collect data according to the contexts of application, and then microprocessors process those data. Furthermore, microprocessor sends instructions to actuator in case of some adaptations are required. In general, pervasive system applies wireless network to perform communication between devices that might be distributed in space[14].

Model of IBEA which is developed in this research consists of three main components; they are sensor, reasoner and actuator. Sensor components are used to sense and to collect environmental data due to the built electrical system contexts, reasoner component is used for reasoning and management mechanism of the collected contexts. Output of the reasoner component is contextual information. Actuator components make adaptation of electrical equipment based on value of contextual information.

Sensor components consist of user sensor, physical sensor and virtual sensor that serve to sense and collect context value around office buildings. For example, the IBEA may know the presence of employees using a PIR (Passive Infra-Red). IBEA can also get the temperature value of the sensor temperature [8] and the amount of illumination obtained from the light sensor. All of these sensor values are inputs for reasoner component.

Reasoner component is assigned to execute management of context with its main function is to process reasoning, perception and interpretation of building environment semantics in relation to the needs of electrical equipment. Reasoner component output is in the form of contextual information that can be used as the basis of decision-making related to artificial temperature adaptation, artificial lighting adaptation, and other activity appliance adaptation[15].

Function of actuator component is enables or disables electrical equipment. Actuator executes this function based on contextual information provided by the reasoner component. For example, when a reasoner component gives contextual information that the environment is dark and requires artificial lighting, the actuator must switch-on artificial lighting, adapted to the commands of reasoner component.

Applying context-aware computing to build adaptive application requires some comprehension knowledge about the environment of the electrical system in the office building of Indonesian Government. The application adapts to the environment if it understands the surrounding context, For example, Bhardwaj, S. et.al. develop an application to control artificial lighting by sensing light intensity from nature[16]. The application considers inhabitants as the main object. When someone enters one particular room without adequate light from nature, then it activates artificial lighting.

Development of IBEA requires defining contexts of electrical system environment explicitly inside the application. The step of the IBEA development are as follows:

1. First, do the general patterns definitions of electrical system in the Indonesian government office buildings to obtain an initial perspective of the system. Then the abstraction is carried out hence that it gets context entity and context attributes of electrical system.
2. Second, studying and identifying the characteristics and behaviours of the context entity defined in the first activity. Further, the definition of context intelligence and awareness for IBEA is developed based on the results of this activity.
3. Third, to study interaction between electrical system in the buildings and defined environment context entity. This activity produces interaction scenario model. IBEA make use of this model to test its context awareness engine.

3. Analysis of Real-world Electrical System in the Office Building

The model of IBEA is built based on the result of the real-world environment abstraction of electrical system in the Indonesian government office building. The abstraction process generates a description of the most influential factors on electricity usage in Government of Indonesia office buildings. It had been published at the International Conference on Smart Green Technology in Electrical and Information Systems[17]. These results are then used as main objects for creating model of context-awareness system and context-aware reasoning algorithms.

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Context and system definition based on[17], there were two types of context entities in the IBEA namely Officer entity and Room entity. Furthermore, IBEA had one entity that was manage based on context-aware computation namely Plug-Load Appliances. The values of attribute contexts in these context entities must explicitly be stated within IBEA because they will be adopted for context awareness of electricity usage management. Hence, IBEA poses behaviours as an adaptive electricity usage since it aware to the contextual information of occupants and building electricity environment.

The most influential factors on electricity consumption in Government of Indonesia office buildings are then defined as context cues that perceived by IBEA. Context cues are contextual data that will be used to obtain contextual information required by IBEA. IBEA uses contextual information to be aware of the state of the office building environment and make adaptation decisions on electrical equipment based on that awareness. Context cues used by IBEA are:

$$\begin{aligned} &C_1 \equiv \text{occupancy} \\ &C_2 \equiv \text{roomLightIntensity} \\ &C_3 \equiv \text{roomTemperature} \\ &C_4 \equiv \text{roomType} \\ &C_5 \equiv \text{officerFunction} \\ &C_6 \equiv \text{roomFunction} \\ &C_7 \equiv \text{timeSetting} \end{aligned} \tag{1}$$

Where, elements of context cue attached to Officer entity are:

$$\text{Officer} = \{C_1, C_5\} \tag{2}$$

$$\text{Officer} \equiv \text{Person} \cap \text{hasFunction.FunctionInOffice}$$

Officer is the main context entity for IBEA to activate context-aware computation. Moreover, context cue elements attached to Room entity are:

$$\text{Room} = \{C_2, C_3, C_4, C_6\} \tag{3}$$

$$\text{Room} \equiv \text{RoomInOficeBuilding} \cap \forall\text{hasFunction.Room} \cap \forall\text{hasType.Room} \cap \forall\text{hasLightIntensity.Room} \cap \forall\text{hasTemperature.Room}$$

Room is a context entity where electrical appliances are placed and where the officer's activities are adjusted to the function of the officer in the office and the room. When the value of context entity is occupied by the officer, then IBEA will activate the indoor space sensing in the office building. And one time context cues:

$$\text{Time} = \{C_7\} \tag{4}$$

Those context cues are applied to obtain contextual information. IBEA make use of contextual information to decide electrical appliances adaptation. The values of context cues elements are adopted by IBEA as filters hereafter activate awareness to office building environment. Only instantaneous values that match the IBEA context value activate context-aware reasoning.

The main elements to apply context-aware computing is context value and context states[18]. Context value is a value that explicitly predefined in the IBEA. Here is refer to the standard in the regulation of Indonesian government. Context state is every possible of current context value in the office building. Cross-correlation between those contexts activates context-aware reasoning, provide output in the form as contextual information, and finally act adaptation according to that awareness. For example, when a room is occupied and recognized context state of ambient light intensity not match its context value, then IBEA defines the room need lighting hence automatically switch-on artificial lighting.

IBEA adopts standard values defined within the regulation of Indonesian government. Standard values are used as predefine context cues values and rule set definition to obtain contextual

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information. Contextual information (CI) is required by IBEA to decide electricity system adaptation as shown by the formulation below:

$$
\begin{aligned}
CI_1 &\equiv \text{occupancy}\\
CI_2 &\equiv \text{ambientLightIntensity}\\
CI_3 &\equiv \text{ambientTemperature}\\
CI_4 &\equiv \text{roomType}\\
CI_5 &\equiv \text{authority}\\
CI_6 &\equiv \text{roomFunction}\\
CI_7 &\equiv \text{timeSetting}
\end{aligned} \tag{5}
$$

All contextual information is adopted by IBEA to understand the state of the office building environment. IBEA will adjust the switch-on/switch-off adaptation of electrical equipment based on the value of the contextual information. IBEA awareness in a person's presence will activate the context-aware computation process. IBEA uses composition of contextual information to run context-awareness and decide adaptation in the use of electrical equipment in the office building as a consequence. However, not all contextual information must be activated simultaneously in the context-aware computation process. Even so, activation of contextual information is adapted to the functions and needs of the Indonesian government office building space. Model of IBEA can be seen in Figure 1.

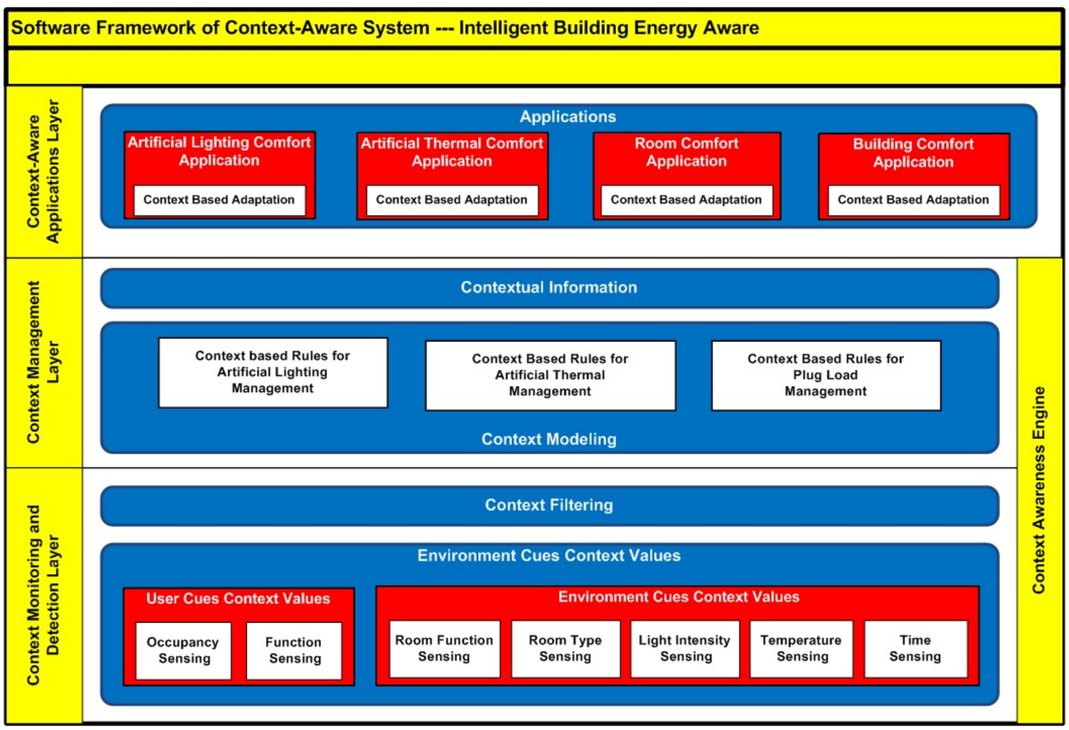

Figure 1. Context-Awareness System for IBEA

As can be seen from Figure 1, context-awareness modeling of IBEA is categorized into three main layers, namely context monitoring and detection layer, context management layer, and context-aware application layer. The first two layers are the main layer of context-awareness engine, functioning to produce contextual information. The context-aware application layer will consume contextual information raised by context-awareness engine and then context-based adaptation is decided.

The first layer of context-awareness system is context monitoring and detection layer that functions to act as context acquisition. This layer consists of 2 main modules; they are module sensor used to collect environment cues context values and module context filtering used to filter

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raw context data so that data in accordance with the data format requirements of the layer management context could be obtained.

Context monitoring and detection layer has seven main sensor modules that work for sensing environment cues context value. Two sensors are applied for sensing user cues context value, four sensors for sensing room cues context value and one for time cues context value. In general, IBEA can utilize physical sensors capable of sensing or scanning to collect contextual data from the user occupancy, room light intensity, and room temperature contexts. Virtual sensors in the form of queries can IBEA apply to collect contextual data from user function context, room type, room function and time setting. Then, context filtering components remove headers and redundant packets, extract important data and then send them to the context management layer.

Second layer of context awareness system is context management layer that works for reasoning by using pre-define context modeling. It consists of two modules, namely context modeling module and contextual information module. Context modeling module is a pattern or context composition that represent context-aware algorithm whereas awareness implies reasoning of context based on that pattern. Output of this component is contextual information that can be adopted by context-aware application layer as context-based Building Automation Systems.

Context modeling module in context management layer is categorized into three, namely context composition for artificial lighting management, artificial thermal management, and plug-load management. They act as reasoner to do reasoning and provide output in the form of contextual information about the state of building environment as the basis for mechanism of awareness for decision of electrical system adaptation over there.

Management of context is built based on context composition. Context composition of IBEA can be classified for the needs of management context on context based automatic lighting system, context based automatic AC system, context based automatic support appliances system, intelligent room energy aware system and intelligent building energy aware system. The definition of the system is shown by the following equation:

$$f(x) \equiv \text{Context Based Automatic Lighting System} \tag{6}$$
$$f(y) \equiv \text{Context Based Automatic AC System} \tag{7}$$
$$f(z) \equiv \text{Context Based Automatic Plug-Load System} \tag{8}$$

Where the three systems are commonly in a room of an office building, with equation:

$$f(r) \equiv \text{Intelligent Room Energy Aware System}$$
$$f(r) = f(x) \cap f(y) \cap f(z) \tag{9}$$

IBEA manages electrical system within a building that uses context awareness approach:

$$f(b) = \bigcap_{r=1}^{n} f(r) \tag{10}$$

Where,
$f(b) \equiv$ Intelligent Building Energy Aware (IBEA) System
$n \equiv$ number of Room in the Building

Third layer of context awareness system is context-aware application layer as context-based Building Automation System. This layer uses contextual information resulted by context awareness engine. This model is modular and independent between one module and others so that developer may choose particular modules in the model adjusted with the needs for application. For example, in figure 1, there are four application models that can be developed based on this model, namely Context Based Automatic Lighting System, Context Based Automatic AC System, Intelligent Room Energy Aware Application, and Intelligent Building Energy Aware Application.

4. Context awareness Application Based on IBEA Model

Context-aware computing is applied as engine of IBEA to develop smart energy environment. Smartness is referred to the building functionality that aware to its embedded context, such as

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occupancy of inhabitants, physical environment contexts, and virtual environment contexts. Those contexts are set up in the form of context composition that will be acted as manager of electricity usage in the IBEA. two examples of system models that refer to figure 1 is tried to develop.

4.1. Composition of Contextual Information (CI) for Intelligent Room Energy Aware

Intelligent room energy aware system in IBEA aims to provide comfortable room according to room functionality. This system applies and manages automatic lighting system, automatic AC system and automatic support appliances system based on the context-awareness. The IBEA aware to officer (or guests) presence, determines the decision of adaptation electricity devices in a room. In other words, electrical devices are activated only when room is occupied. The activeness of electrical devices is determined by the output of the three context-aware system embedded to it. Contextual information used by this system is:

CI_1 ≡ occupancy
CI_2 ≡ ambientLightIntensity
CI_3 ≡ ambientTemperature
CI_7 ≡ timeSetting
in,
f(x) ≡ Context Based Automatic Lighting System
f(y) ≡ Context Based Automatic AC System
f(z) ≡ Context Based Automatic Plug-Load System
So, the result:
f(r) ≡ Intelligent Room Energy Aware System
$f(r) = f(x) \cap f(y) \cap f(z)$
r = room in the office building

The reasoning algorithm of intelligent room energy aware system is presented below.

```
intelligentOfficeRoomAdaptation( )
  CI1← getContext(occupancy)
  IF (CI1 = occupied) THEN
    SWITCH-ON appliances( )
    CI2← getContext(ambientLightIntensity)
    CI3← getContext(ambientTemperature)
    IF (CI2Dark = true) THEN
      SWITCH-ON artificialLighting( )
    IF (CI3Hot = true) THEN
      SWITCH-ON AC( )
    ENDIF
  ELSE
   CALL timeDelay(  )
```

```
timeDelay( )
  CI7 ← getContext(timeSetting)
  IF ((CI1 = occupied) ∩ (CI7 ≤ timeSetting)) THEN
    SET Lighting(lastConditionValue)
    SET AC(lastConditionValue)
    SET plug-loadAppliances(lastConditionValue)
  ELSE
    SWITCH_OFF lighting(  )
    SWITCH_OFF AC(  )
   SWITCH_OFF Plug-loadAppliances(  )
```

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4.5. Composition of Contextual Information for Intelligent Building Energy Aware

Intelligent building energy aware system aims to provide comfortable rooms according to its functionality within office building of Indonesian government. The IBEA aware to officer (or guests) presence, determines the decision of adaptation electricity devices in rooms of office building. This system utilizes of intelligent room energy aware system. Electrical devices only active when someone in the rooms of office building. Contextual information used by this system is:

CI_1 ≡ occupancy
CI_2 ≡ ambientLightIntensity
CI_3 ≡ ambientTemperature
CI_4 ≡ roomType
CI_5 ≡ authority
CI_6 ≡ roomFunction
CI_7 ≡ timeSetting

in

f(r) ≡ Intelligent Room Energy Aware System

So, the result:

f(b) ≡ Intelligent Building Energy Aware System

$$f(b) = \bigcap_{r=1}^{n} f(r)$$

n = number of room in the office building

The reasoning process in IBEA determines electrical equipment adaptation decision in office building as shown by pseudocode of intelligent building energy aware system presented below:

1. When IBEA is aware with the presence of a person in the office building, it will activate context-aware of roomTypeIdentification( ).

```
intelligentOfficeBuildingAdaptation( )
  CI1 ← getContext(occupancy)
  IF(C1 = occupied) THEN
    CALL roomTypeIdentification(  )
  ENDIF
```

2. Government of Indonesia distinguish type of room in the office building into three main types, they are public room, private room, and transit room. Public rooms are rooms provided by institutions for carry out their functions and duties. Private rooms are provided for officials, functional teams and administration teams in order to support their jobs. Transit rooms function as connecting room both in public or private rooms.

   A public room is accessible to both guests and officers freely since the room is designed to give service to public. However, a private room has only limited access, and it is only accessible to particular persons. Transit room depends on its place in the office building. If it is in a public room, it is accessible to anyone. However, if it is in a private room, it will be accessible to all staff having activity in the private room. IBEA treats the transit room as behaviour of public room.

   Formal definition of room types in IBEA is as in the following equation:

   CI_4 ≡ roomType

   Value of CI_4 is obtained by using rule set:

   Rule set 1 ← $CI_{4Publik}$ =
   iff (Value(C_4) ≡ publicRoom)
   Rule set 2 ← $CI_{4Privat}$ =
   iff (Value(C_4) ≡ privateRoom)

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Rule set 3 $\leftarrow CI_{4Transit}$ =
iff (Value(C_4) $\equiv$ transitRoom)

Reasoning algorithm to identify the type of room as shown by pseudocode below:

```
roomTypeIdentification()
  CI4 ← getContext(roomType)
  IF (CI4Public= true)THEN
    CALL roomFunctionIdentification( )
  ELSE IF (CI4Privat = true)THEN
    CALL OfficerAuthorityIdentification( )
  ELSE IF (CI4Transit = true)THEN
    CALL roomFunctionIdentification( )
  ENDIF
```

3. IBEA is obliged to understand the authority of a person in a room of the office building. This awareness is used by IBEA for the management of electrical equipment in a room. However, this awareness will be only activated in a private type of office room because this room has special privileges for their employees.

   The formal definition is as follows:

   $CI_5 \equiv$ authority

   Value from CI_5 is obtained by using rule set:

   Rule set 1 $\leftarrow CI_{5FullAuthority}$ =
   iff (Value(C_5) $\equiv$ Value(C6))
   Rule set 2 $\leftarrow CI_{5ParcialAuthority}$ =
   iff (Value(C_5) $\neq$ Value(C6))
   Rule set 3 $\leftarrow CI_{5NoAuthority}$ =
   iff (Value(C_5) $\neq$ Value(C6))

   Where,
   $C_5 \equiv$ officerFunction
   $C_6 \equiv$ roomFunction

Reasoning algorithm to identify officer's authority (guest as well) as shown by pseudocode below:

```
OfficerAuthorityIdentification( )
  CI5 ← getContext(authority)
  If (CI5FullAuthority = true) THEN
    CALL roomFunctionIdentification( )
  ELSE IF (CI5ParcialAuthority=true) THEN
    SWITCH-ON artificial_Ligthing_based_on_roomRules( )
    SWITCH-ON AC_based_on_roomRules( )
    SWITCH-ON appliances_based_on_roomRules( )
  ELSE
  CALL timeDelay( )
```

4. Generally, the use of electrical equipment for the office activities is influenced by the function and the needs of a room. The environment of the room must meet the demands of each functional activity carried out in the room. Things to note are:

   - Good room lighting.
   - Good air circulation.

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- Appropriate equipment for the functional activities in the room.

Thus, the IBEA encapsulates the management of electrical devices in the room function. Reasoning algorithm for identification of room function is shown by pseudocode below:

```
roomFunctionIdentification( )
  CI6 ← getContext(roomFunction)
  IF (CI6SenseValue= C6StandardValue)THEN
    SWITCH-ON appliances_based_on_roomRule( )
    CI2 ← getContext(ambientLightIntensity)
    IF (CI2Dark = true) THEN
      SWITCH-ON_artificialLighting( )
    CI3 ← getContext(ambientTemperature)
    IF (CI3Hot = true) THEN
      SWITCH-ON_AC( )
  ELSE
      CALL timeDelay( )
```

```
timeDelay( )
  CI7 ← getContext(timeSeting)
  IF ((CI1 = occupied) ∩ (CI7 ≤ timeSetting)) THEN
    SET lighting(lastConditionValue)
    SET AC(lastConditionValue)
    SET plug-load_appliances(lastConditionValue)
  ELSE
    SWITCH_OFF lighting( )
    SWITCH_OFF AC( )
   SWITCH_OFF Plug-load_appliances( )
```

5. Conclusions

This paper introduced context-aware computing for intelligent energy aware in office building of Indonesian Government namely Intelligent Building Energy Aware (IBEA). Context awareness system of IBEA is classified into three layers namely context monitoring and detection layer, context management layer and context-aware application layer.

IBEA manages electrical system based on context-awareness by utilized of context cues in the office building, i.e., occupancy, room light intensity, room temperature, room type, officer function, room function and time setting to produce contextual informations. Furthermore, Contextual Informations are applied by IBEA to decide electrical devices adaptation. Context based management in the form of context compositions are applied to control electrical system in the office building of Indonesian Government.

This model has been already being able to execute general functions that apply equally in the office building rooms. Further research on the management context is needed to operate specific cases in a room so that it can be served by IBEA as well.

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