A SENSOR BASED CONTEXT-AWARE INFECTION ALGORITHM FOR
UBIQUITOUS RESIDENTIAL ENVIRONMENTS

JUHYUN LEE AND HYUNSOO LEE
Dept. of Housing and interior Design, Yonsei University, South Korea
{imkyo, hyunsl}@yonsei.ac.kr

Abstract. As the development of a computer and the internet have changed social and
economic activities related with the human life style. According to these changes, ubiquitous
residential environments have been discussed. This paper presents ways of interpreting
the situation in association with human interaction with residential environments. This
paper deals with various operations of architectural components based on a sensor based
context awareness. The methods adopted in this paper for suitable services corresponding
to residents’ requirements are Pattern Driven Inference (PDI), Rule Driven Inference (RDI)
and Case Driven Inference (CDI). In summary, this paper describes processes how services
are provided. And Context based residential management is main research issue.

Keywords. Context-Aware: Algorithm; Ubiquitous Residential Environments; Ubiquitous
Computing; Case-based Reasoning.

1. Introduction

In order to provide appropriate services of ubiquitous residential environments (UREs) for
residents, we should understand residents and the situation surrounding them, and then try to
cope with the situation.

This study has a uniqueness both in explaining the UREs through residential environments
aspect not from a computer science perspective, and in proposing reasoning algorithm
considering the main requirement based on residents’ behavior patterns. Even though the
context supporting ubiquitous computing system is one of important factors to develop
the concept of the UREs, it is hard to find researches which are related with context or context-
aware focusing on quality of the residents’ life since most of previous researches were based
only on technology development. Moreover, the UREs should be organized to optimize service
regarding residential needs, which is the starting point of this research.

Context (Sensor data) only requires the information related with this service. In order for the
environment to evolve with the residents, human behavior could be deduced and learned
from the environments. Rule-induction algorithm and Case-based reasoning, which are the
representative reasoning methods (Chen, 2007; Golding, 1996; Madhusudan, 2004; Mchserry,
2001; Tsuchiya, 1996), have a limit to predict and cope with the intricate human behavior.
Therefore, multiple approaches of reasoning methods based on context, behavior and service
are required. This research focuses on complementing technology centred residential
environment study area since the main contribution of this research is to develop technological context-aware inference algorithm based on the needs of the residents and their housing behavior. Three different methods are used for the Inference algorithm in this research. The first method is Rule Driven Inference (RDI) based on basic service needs, the second one is Case Driven Inference (CDI) based on learning residents and Bayesian thesis, and the third one is Pattern Driven Inference (PDI) based on reasoning residents’ behavior patterns. This research aims to explain the valuable communication of human and their living environment by eliminating negative feelings of residents in the technological aspect through hierarchical reasoning algorithm.

2. Context-Aware Inference

2.1 CONTEXT

In this study, the context is the Sets of Sensor data which URE references to properly provide the service and information about the residents and residential environments. In addition, it is the method of communication which connects the environment and residents since it interacts with the physical environments. In this sense, the UREs can be interpreted as the set of the context. In other words, understanding the contexts effectively means understanding the human environments and needs.

Context originates in the physical surroundings of a device, is captured through sensors, and finally results from analysis of sensor data. Devices may have direct or indirect awareness of context (Gellersen, Schmidt and Beigl, 2002). Liberman (2000) described that context was everything but the explicit input and output. In detail, it was state of the user, the physical environment, the computational environment and history of user-computer-environment interaction. In our study, context related with the explicit input and output as well as its history is also importantly considered and gives effects to the inference computation.

Schilit (1994) explained that the important aspect of the computing which occurred in the UREs and could be thought as the context was the constantly changing execution environment. We will consider importantly the changes over time and place for the context nodes to connect the residents’ service. Furthermore, our inference algorithm adopts their basic concept of the significant aspect of context; where you are, who you are with, and what resources are nearby.

Context is any information that can be used to characterize the situation of an entity. Location, identity, time, and activity are context types for characterizing the situation of a particular entity (Dey, 2000). Of course, the type of context is a kind of distinctive element but it is hard to explain how the context is connected to the service. In this study, we adopt the context as the Mapping information to match the service in the end. In our inference algorithm, context is the set of Sensor data and it is the set of entity which mapped with the behavior. In other words, context is the information which gives effects to the behavior and the behavior can correspond to the services, and so it becomes the basic entity which provides the customizing service. In the next section, this concept will be explained with the Context Node. In order to provide service it is necessary to connect the Context Node to the Service node. This process is operated by the Context–Aware Inference.

2.2 CONTEXT-AWARE INFERENCEx

In order to use the context in the UREs, it needs to communicate with application providing service (Henricksen, 2002). The role of interpreting the context and connecting to the special service is the Context-Aware Inference. In other words, the UREs using the Context–Aware
Inference understands the context and responds to it. Finally, the residents have an interaction with residential environments.

There was a method of interpreting the inference method as the 5W1H (Schilit, 1994; Dey, 2000; Ha, 2006) with these backgrounds. There were studies of understanding the behavior itself through the various sensors and sensor pattern (Nakauchi, 2003; MacDorman, 2004; Hara, 2002). However, there must be problems of serious private exposure and the accuracy of interpretation to understand the residents’ various behavior based on the sensor. The Context-Aware Inference is difficult to consider unconventional sensors, multiple distributed and heterogeneous sources, constant changes (Salber, 1999). For the purpose of the ideal inference method, this study focuses on the typical behavior which can be supported by only matching service, and use the mixture of reasoning methods and inference through hierarchal layers.

Context is any measurable and relevant information that can affect the behavior (Meyer, 2003). The kernel of our study lies in the reasoning of the residential behavior. The reasoning effectiveness is higher through the consideration of the continuity of time and the direct control of residents. When the behavior occurs continuously, the one Behavior node itself acts as the important condition and the Behavior node has tree-like pattern which has a tree structure with root and more children for some nodes and root. This ordering from root to leaf in sequence is looked at from case-based reasoning.

From the characteristics of fixed and dynamic Context (Henricksen, 2002), it can be considered that the context has the ordering of past, future and present. This continuous characteristics in sequence is considered importantly because our the Case Driven Inference and the Pattern Driven Inference provide reasoning based on the past behavior pattern.

3. Structure of Context Aware Inference

Providing proper service with of context-aware is an important issue. Related works have adopted various reasoning methods. In this study, we use both the rule-induction algorithm and case-based reasoning algorithm, and provide the Pattern Driven Inference systemizing the behavior pattern.

![Figure 1. Three Nodes of Context-Aware Inference](image)

The Context-Aware Inference Algorithm composes the three nodes which are the structural flowing of context, behavior and service. The reciprocal mapping of these nodes is performed. This concept has differences in application by the method of reasoning, but the integrated definition is as follows.
1. Context constitutes with one or more sensor data.
2. Sensing data have some hierarchical tree structure or not.
3. The Sensor Set over two sensor make up the behavior node.
4. Behaviors have the sequential Pattern.
5. Most of Service nodes customizing by residential needs match behavior nodes.

The UREs is related with the environments composing of three nodes. The context node, behavior node and service node form the hierarchical layer in Figure 1. In other words, context nodes create the behavior node through certain sensor set, the behavior node inferences service node considering the Behavioral continuity. Behavior node is deduced form the context node composing of the Sensor data and induces the service node providing the customizing service for the residents. As shown in Figure 1, various combinations of context node correspond to one behavior node and match the service node. As the contrary concept of this flow, the customized service node make up the behavior node which the reasoning algorithm can calculate and compose the hardware constitution in the UREs. In this method these nodes support the suitable service, because these are performed effectively to make up sensor framework according to the service node which the users select. Sensing data related with service except for the useless Behavior information from the UREs, it is of advantage to keep the personal privacy. These three Nodes are the basic entities which are discussed in this study and the basic principles of the UREs.

Context node created by one or more sensor data constitutes a combination of sensors. As the sensor data create one context node, it can be considered as the concept of Cue (Gellersen, 2002). The combination of sensors can have hierarchical tree structure and be in certain sequence, because the housing Behavior can be deduced from the sequence which the sensor information is percept.

Behavior node is deduced from more than two sensor Set. The distinctive point is that this Behavior node has some patterns in the general housing environment. In other words, one Behavior node makes it possible to predict another Behavior node ordering in sequence. Behavior node which is the core of the algorithm can directly connected to the service node.

Service node is the contact point to connect the service. In this study, the service node is formed by the residents’ service customized needs. Service node is inferred from two different methods. One case is reasoned with the behavior node and the other case is deduced from the context node that constitutes with 1Set.

The reasoning method applied to the 1Set context node is Rule Driven Inference (RDI) and uses rule-induction algorithm. As reasoning out the behavior node to the context node, we use the Case Driven Inference (CDI) and Pattern Driven Inference (PDI) according to the situation changes. For the connection of the three node which is important in the reasoning, there are the mapping tables between the there nodes in Figure 1. The explanation about the RDI, CDI and PDI is as following.

4. Rule Driven Inference

The RDI is the method which is applied to the device without the user or location if the condition of the sensor is matched. This reasoning method is similar to the home automation system which was studied commercially before the houses become cleverer. The RDI which is discussed in this study is applied to the context node which has the structure of connection from the context node to the service node. This is the method which make up of sensor data of the 1Set structure and is applied if the condition (IF, THEN) is satisfied without predicting and reasoning. In case of the RDI, environmental, fixed and passive sensor is discussed. Also, in the service aspect the RDI deal with environmental service like HVAC and Illumination which is for the Indoor Comfort and the Emergency, the Security Service.
Though the context in the RDI is made up of the 1Set construction, there is the case that we refer other sensor data condition in the course of context searching for the current situation. The sensor data which is referenced in this case can conform the additional condition in the other sensor which is connected to the context node, and is explained the 1set structure because it deals with in one device. In other words, the service trigger is the context node which is constructed with the 1Set and is making up with the reference context.

Context node A (Figure 2) without the searching for the mapping table can refer the context node A’ value in executing the service S₁. And the B executes the service S₂ without the reference value but it explains the use of the Mapping Table (Service Rule DB).

The distinctive point which we should consider is that 1Set of context all can not use the RDI method. 1Set of Context may be considered for other reasoning method in case of the residents’ controls. In this study the method of the RDI is only presented because the 1Set of Context do not have the learning element in the UREs which is analyzed in the limited experiment.

If not the method of directly executing the device, there are the DB searching for the corresponding service and executing the device. In Service Rule DB the Emergency Rule DB is included and related to the Safeness.

The simplest process is as follows; New Values in Context node is perceived to the Sensor A of Device A (1.1), the information is delivered to the Trigger corresponding to initial setting condition (1.4) and the service is executed (5). If the Sensor A refer to other Sensor A’ information (1.3), transaction is conducted in the Device A and the service is executed.

If it refers to another condition except Device A, the reasoning method is requested through the Inference Operating System (2). The RDI method is adopted and the service Rule DB is retrieved (3) and mapped. If the Device A is searched, the Trigger is executed (1.4) and serviced (5). If other Device B is searched, the trigger of the Device B is executed (4.2) and serviced (5). The Last is that the log of the new value in context is saved for other reasoning.
5. Case Driven Inference

User, space and time in the CDI unlike the RDI are the important elements to provide service. Namely, suitable service is possible to be served considering various user, other location and time. The core of the CDI method is learning and probability.

The CDI is the inference method which makes the house learn the situation if operation action of the user is the custom way over again. It means that there is regular rule in the device operation. The high probability means that the user wants the service.

The first characteristic of the CDI is that it has behavior node. Context node consists of more than 2Set sensors and sometimes continual sensor data with tree-like structure. These sensor set create the behavior node. Namely, behavior node is combination set of context node.

The second characteristic is to consider the time and have each node order in sequence. The Behavior node and the service node have particular pattern and sequence within 24 hours. This means that the following service can expect and find the continuity from the small sensor unit of the context node to the service node.

The third characteristic is that the CDI evolves continuously. Continuously accumulating the reasoning frequency and the time of service execution make inference probability. This information and the probability value triggering service are accumulated to the Service Case DB and the service is mapped. In this way, the Service Case DB is created automatically and as the houses are operated the user’s habit is learned.

In Service Case DB there is information on the time, location, user, behavior. Service is extracted with the information which same time, place, and user executed. As the frequency information is calculated, the service is provided according to the service execution probability. The reasoning frequency of the behavior and service node in sequence and the service reasoning make it possible to learning the service and expecting it. In this study, the service expectation probability is calculated here:

\[
P(S_k) = \frac{O_k}{F_k} \times P(B_k | B_j) \times \frac{T_{kon}}{T_{koff}}
\]

- \(O_k\) : Frequency of Operating Service node \(S_k\)
- \(F_k\) : Frequency of deducing \(S_k\) from Context node \(C_k\)
- \(P(B_k | B_j)\) : Conditional probability of generating Behavior node \(B_k\), \(B_j\) is the root node of \(B_k\)
- \(T_{kon}\) : Frequency of direct trigger
- \(T_{koff}\) : Frequency of direct termination
- *Default value of Frequency: 1

The service execution accuracy rate can be higher when using the service reasoning frequency and verifying the continuity of the behavior pattern. As the \(P(B_k | B_j)\) can be expressed as the root-children node in the behavior sequence aspect, it is the expected value which the case-base reasoning is introduced. Service execution probability can be improved by learning the resident’s direct control frequency. As the control frequency occurs which the residents are terminated \((T_{koff})\), the service is not taken place and the execution probability is higher as the residents directly trigger \((T_{kon})\). With this method CDI learns the changing process as the residents adapt to the environment and the UREs gradually deletes the unwelcome attention of resident and evolves together.

If the New Values of Context node is perceived (1), the Inference Operating System retrieves the Profile DB (2) to decide the reasoning method, extract the CDI method (3) and transmit the information to the Context Mixture (4). Context Mixture search for the context which is
related to the context node transmitted (5) and construct the context Set (6). The constructed Context Set is saved on the Working Memory (7) and transmitted to the behavior Detector (8) and search for the behavior (9) and extracts (10), and then transmits the behavior node to the Inference Engine (11). Inference Engine search for the service Case DB (12), and acquires the service information and Case frequency information (14), and calculates the probability of service. If the probability of service is calculated more than the resident’s setting up probability, the execution command is transmitted to the Device (14.1) and the service is executed (15). If not the service is not executed and the service reasoning frequency is saved in the Service Case DB (14.2). In Figure5, the Process about the User’s direct control appears. User’s explicit control (16) executes the service (15) and save the frequency in the Service Case DB (17) and make it used for the later inference.

6. Pattern Driven Inference

In this study, as a result of observing behaviors of five families in five days excluding the weekend, we could get the constant behavior pattern set for initial mapping table of the PDI. Our sample families have the life cycle of nursing preschoolers and live the apartment. Basically the behavior pattern set consists of more than 2Set and can be 12Set mostly. Surprisingly, the housing behavior showed constant pattern on weekdays. Following with the study, it is enough to expect to get life patterns of residents according to life cycles and housing types.

The PDI is similar to reasoning structure of the CDI. In a strict meaning the PDI is one kind of the CDI. Only one different point with the Case Driven operating method is that it connects the user, time, space, behavior, service. Accordingly, this method is a more favorable method in providing the customizing service. This method comes from the idea that the ubiquitous houses should be thought to focus on human, not technology, though it is the houses which uses the digital technology. Sensor just exists to know residents’ behaviors related to service. A ubiquitous house is made to response if the human beings activity occurs. As explaining the aspect of the CDI in Figure 4, it constructs as the pattern which the service execution probability is 1. The information which the value is 1 by the CDI is saved in the Life Pattern DB. The mapping table which provides the accurate service to the residents is created.

Pattern Drive Inference Process can be considered as shown in Figure 5. As explaining the difference from the CDI, Inference Engine searches for the Life Pattern DB (12) to look up the service and execute the service which was looked up in the Life Pattern DB without the service execution probability calculation; the Life Pattern DB is consist of the values which the service execution probability is 1. Because the life Pattern DB is made from the CDI, it
can not be created at the first setting in the URE. But the method of setting the important and
general housing behavior pattern in a generalized way can be considered for the care of the
dependent persons like elderly. In this study the high frequency pattern from behavior pattern
in observation research for the initial setting is applied.

7. Application of Context-Aware Inference

The context awareness accomplishes in three reasoning methods. The inference Operating
System performs the role of selecting the reasoning method and based on the reasoning method
the service extraction is reasoned using the Service Rule DB (RDI), Service Case DB (CDI)
and Life Pattern DB (PDI). In using the three reasoning method as some context occurs, only
one service and reasoning method may not be searched. As one context node execute the
Inference Operating System and search for the Profile DB, a lot of Service and the reasoning
method can be searched. In this case the reasoning is done as order (RDI → PDI → CDI) and
the service is executed based on the sequence. In this aspect the service operation method can
be constructed for each reasoning method.
The Example of Context awareness is as following:

Monitor Agent check out the Sensor value (PIR1=yes) at the bedroom from the Working
Memory (1). Inference Operating System retrieves the Profile DB (2) and gets the data (3).

1) RDI Process
As the visitor monitoring system is the method of the Rule Driven Inference, we can get
the results searching for the Service Rule DB (6). Visitor monitor Service’s sensor setting is
not corresponded so it is excluded.
2) PDI Process
As the illumination system is the Pattern Driven inference method, we can get the results
searching for the Life Pattern DB (9). The residents Pattern of place-user-time-behavior-
service is searched for the illumination service bedroom1-husband-a.m.- get up - Lighting
service 1(10).
3) CDI Process
Searching for the service Case DB, we can get results (13). Auto lighting service is the PDI
which the service execution probability is 1 and accordingly the Schedule management service
is searched but the service is not executed because the probability is under 0.8(the initial
setting value).

Service which was searched from the three reasoning methods that were looked up in the
Inference Operating System is executed and the device operation status is saved as the Log
Data.

As the Example of Context Awareness, three reasoning methods are complementary and
provide service in an independent way. Accordingly if the reasoning method which was
suggested in this study is consisted in residents customizing form, the UREs excluding the
negative feelings can be presented.

8. Discussion and Conclusion

The Context-aware inference algorithm for Ubiquitous Residential Environments (UREs)
discussed in this research is an important issue. The method of how further ubiquitous computing
supports residential environment in a positive way is a further research problem. This research
has a contribution that the Context awareness has the humane approach to the learning of
residents and the UREs makes complex ubiquitous environments understand more easily using
three inference algorithms. In order to apply reasoning system, which discussed in this research, into reality, more following researches are needed. Probability calculation of behavior continuity, distribution system, sensor and device composition are major key components.

The means of generalizing residential behavior could be interpreted in various ways, and residential values, which have been made for a long time according to social hierarchy, could also be applied in it. In case of the Case Driven Inference (CDI), which is a main issue of this research, the point of continuation probability of behavior pattern and the method of the service execution probability have originality compared with the other researches. In order to develop reasoning algorithm with the residents suggested in this research, more detailed supplementation is needed through these researches.

The UREs in this research can be explained as environment constituting three layers of Context Node, Behavior Node and Service Node, and three layers systematically express residential computing environment. Reasoning system suggests the way of blending the Rule Driven Inference (RDI), the Case Driven Inference (CDI) and the Pattern Driven Inference (PDI).

The Behavior Node especially acts as an important reasoning factor in the Case Driven Inference and the Pattern Driven Inference which happens around continuation of behavior. For this, service execution probability is applied, and then character trait of service execution probability, which resident behavior forms regular patterns in the method of the Pattern Driven Inference for single, is explained.

Even though customized services for residents are considered in a whole process, this reasoning method could also be applied selectively. In other words, we can select either only the RDI applied environment or both the RDI and the PDI applied environment according to residents. In case of the aged or the disabled, who need high level of assistance, it is effective to constitute the residential environment as applying the RDI, the PDI, and the CDI, and it is better to apply only the RDI and the PDI in case of the users, who are sensitive to unless reasoning and information monitor. This research has the advantage in uniting and applying of reasoning method to make the suitable service possible according to not only various residential environment but also residents’ needs.

Though the reasoning method suggested in this research is verified its efficiency through observation and experiment, further researches for investigating the reasoning method applying into real environment are needed.

References


