Considering Safety and Feature Interactions for Integrated Services of Home Network System

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Abstract. Assuring safety in the home network system (HNS) is a crucial issue to guarantee high quality of life. In this position paper, we first review our previous work, formulating three kinds of safety for the HNS integrated services: local safety, global safety, and environment safety. We then present a method that validates safety for integrated service. Finally, we discuss a perspective in how the safety can be assured when considering the feature interaction problem.

1 Formalizing Safety in Home Network System

The home network system (HNS, for short) is comprised of networked home appliances and sensors, which is one of the most promising applications of the emerging ubiquitous computing technologies. The HNS enables flexible integration (or orchestration) of different home appliances and sensors through the network, which achieves value-added integrated services [5].

In developing and providing the HNS integrated services, the service provider must guarantee that the service is safe for inhabitants, house properties and their surrounding environment. That is, a service is free from any condition that can cause [injury or death to home users and neighbors], or [damage to or loss of home equipments and the surrounding environment].

Since the service is typically implemented as a software application, appliances are often operated automatically by the application, but not by the human user. Also, one integrated service operates multiple appliances, which yields global dependencies among different appliances. Moreover, since multiple integrated services can be executed, unexpected functional conflicts may occur among the services. Thus, a single fault in the service application can cause serious accidents to the user.

In general, the safety is characterized by some properties to be satisfied by a user (or a system). In our previous work [6], we have formulated three kinds of safety properties in the context of HNS integrated services.

Local Safety Property A safety property \( lp \) is called a *local safety property* iff \( lp \) is defined within a single appliance \( d \) in the HNS. Typically, \( lp \) is derived as a safety instruction for using \( d \). Let \( LocalProp(d) = \{lp_1, lp_2, ..., lp_n\} \) be a set of all local safety properties with respect to the appliance \( d \). For a given integrated service \( s \), let \( App(s) = \{d_1, d_2, ..., d_n\} \) be a set of networked appliances used by \( s \). Then, we define \( LocalProp(s) = \cup_{d \in App(s)} LocalProp(d) \) which is a set of local safety properties with respect the service \( s \). The following property is an example of the local safety property of an electric kettle:
Do not open the lid when the electric kettle is in the boiling mode.

Global Safety Property A safety property $gp$ is called a global safety property iff $gp$ is defined over multiple appliances $d_1, d_2, ..., d_n$. Typically, $gp$ is a safety instruction of an integrated service $s$ that uses $d_1, d_2, ..., d_n$. We denote $GlobalProp(s) = \{gp_1, gp_2, ..., gp_k\}$ to represent a set of all global safety properties for the service $s$. The following is an example of the global safety property for any integrated service that uses a gas valve and kitchen equipments.

[G1] While the gas valve is opened, the ventilator must be turned on.

Environment Safety Property A safety property $ep$ is called an environment safety property iff $ep$ is defined as the environmental or residential constraints, which exist independently of any appliances or services. $EnvProp = \{ep_1, ep_2, ..., ep_l\}$ denote a set of all environment properties given. The following environment property might be derived from the safety guideline of the house:

[E1] The total current used simultaneously must not exceed 30A.

Safety of HNS Integrated Services Let $P$ be a set of safety properties. For a service $s$, we write $s \vdash P$ iff $s$ satisfies all properties contained in $P$. Then, we define the safety of $s$ as follows.

- $s$ is locally safe iff $s \vdash LocalProp(s)$.
- $s$ is globally safe iff $s \vdash GlobalProp(s)$.
- $s$ is environmentally safe iff $s \vdash EnvProp$.
- $s$ is safe iff $s$ is locally, globally and environmentally safe.

Thus, the safety validation problem is defined as follows:

**Input:** An integrated service $s$, $LocalProp(s)$, $GlobalProp(s)$, $EnvProp$.

**Output:** $s$ is safe or not.

2 Safety Validation by Design by Contract

Since any safety flaws in an integrated service $s$ can lead to serious accidents, we consider it crucial to remove the flaws before $s$ is actually deployed in the HNS. In [6], we have proposed a framework of safety validation using object-oriented modeling and design by contract (DbC) [4], which is applied to testing phase of $s$. The framework first introduces an object-oriented modeling technique of HNS to clarify the relationships among the HNS components (i.e., appliances, services and the home) [5]. Fig. 1 shows the overview of the proposed model. The model mainly consists of three kinds of objects (classes): Appliance, Service, and Home. These classes forms the following relationships to match well the intuition of the HNS and integrated services: [R1: a Home has multiple Appliances], [R2: a Home has multiple Services], and [R3: a Service uses multiple Appliances].
Assuming that the HNS is implemented according to the model, we then embed the given safety properties into the source code of appropriate objects. For this, we encode each safety property as a contract of DbC (i.e., a pre-condition, a post-condition, or a class invariant). More specifically, LocalProp(s), GlobalProp(s) and EnvProp are encoded as certain DbC contracts, and are respectively embedded into Appliance, Service and Home objects. The source code with the DbC contracts are compiled into instrumented target code which involves check routines of the contracts. Then, we conduct testing of the instrumented code. While running the testing, if any DbC contract is broken, an exception is thrown and thus the security flaw can be detected. Fig. 2 shows an overview of the safety validation, where the source codes are written in the Java language and the JML (Java Modeling Language) [1, 3] is used for writing the DbC contracts.

3 Feature Interactions and Safety in HNS

The safety validation framework presented above is basically for each individual integrated service, and is executed before the service is deployed in the HNS. However, even if every service is proven to be safe, combined use of multiple services may violate some safety properties, due to feature interactions (FIs) among the services. The safety violation by the FIs can be formulated as follows:

For a given pair of integrated services $s_1$ and $s_2$,  

**FI-(L)(Local Safety Violation):**  
$$ [s_1 \models \text{LocalProp}(s_1)] \land [s_2 \models \text{LocalProp}(s_2)] \Rightarrow [s_1 + s_2 \not\models \text{LocalProp}(s_1) \cup \text{LocalProp}(s_2)].$$

**FI-(G)(Global Safety Violation):**  
$$ [s_1 \models \text{GlobalProp}(s_1)] \land [s_2 \models \text{GlobalProp}(s_2)] \Rightarrow [s_1 + s_2 \not\models \text{GlobalProp}(s_1) \cup \text{GlobalProp}(s_2)].$$

**FI-(E)(Environment Safety Violation):**  
$$ [s_1 \models \text{EnvProp}] \land [s_2 \models \text{EnvProp}] \Rightarrow [s_1 + s_2 \not\models \text{EnvProp}].$$

where the operator $+$ denotes a composition operator of two services $^1$. The above

$^1$ The detailed semantics of the composition are not given here.
definitions the safety violation appear to be quite similar to the definition of the con-
ventional feature interactions in telephony. However, there are some domain-specific issues.
Taking them into account, we are currently developing a method for safety validation
with FIs.

– The three types of the safety violation could be dealt with different methods.
– The safety properties in HNS must be assured at all costs. There is no desirable
interactions with respect to the safety violation.
– The formalization of FIs in HNS, presented by Nakamura et al. [5], would contain
some cases of the safety violations. However, not all interactions cause a safety
violation.
– Our safety validation framework [6] can be used only if both \( s_1 \) and \( s_2 \) are pro-
vided by the same service provider. Otherwise, an alternative online approach is
necessary.
– The online approach would be implemented on the central home server, which
manages all appliances and environment properties.
– The sophisticated execution control of multiple services (e.g., resource locking [2])
would be promising to prevent FIs that leads to the safety violation. The execution
control restricts the semantics of the service composition (i.e., the operator +).

Acknowledgment: This research was partially supported by the Ministry of Education,
Science, Sports and Culture, Grant-in-Aid for Young Scientists (B) (No. 18700062) and
Scientific Research (B) (No. 17300007), and by JSPS and MAE under the Japan-France
Integrated Action Program (SAKURA).

The author thanks to Prof. Masahide Nakamura at Kobe University, Prof. Lydie du
Bousquet at Joseph Fourier University, and Prof. Ken-ichi Matsumoto at Nara Institute
of Science and Technology, for the supervision of my research.

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