Mobile Intelligent Synthetic Character in Smartphone
Using Behavior Selection Network

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Abstract—Since smartphones have become popular, intelligent adaptive services were more highly demanded. The intelligent synthetic character on a mobile phone is one of the promising services. It is difficult to develop an intelligent synthetic character on the mobile environment due to its dynamism and complexity. This paper proposes a method to generate a synthetic character’s behaviors using contexts inferred with Bayesian networks. To make more realistic character, the OCC model creates the character’s emotion. Large-scale modular behavior networks generate the character’s behaviors with inferred contexts. In order to verify the naturalness and flexibility of the generated behaviors, a simulation is conducted with the mobile log collected with a Samsung SPH-M4650 smartphone.

Keywords- intelligent synthetic character; behavior-based agent; smartphones; ubiquitous computing

I. INTRODUCTION
As high performance mobile devices become more common, intelligent adaptive services have been increasing. The synthetic character is one of the intelligent services, and it is a mobile agent interacting with user in real-time. The character can interact with the user through their facial expressions, behaviors, and simple dialogues. The intelligent synthetic character can be also used as an interface for a specific service. To implement a more realistic synthetic character, the character should have its own perceptual, behavioral and motor mechanisms [1].

The intelligent synthetic character must be able to react to various situations. To generate appropriate actions, three functions such as context awareness, behavior generation, and maintenance of the character’s internal states are required. Context-awareness is required to recognize the situation around a user. Secondly, the character has to generate suitable reactions for the recognized situations. In addition, it is necessary to consider the character’s own internal state such as its own personalities and emotions [2, 3].

The character should extract reliable information from uncertain, rapidly changing, and partially true data from multiple heterogeneous sources [4]. The character should also generate behaviors in real-time according to dynamically changing mobile environment.

The proposed mobile intelligent synthetic character contains three modules: Bayesian networks to recognize context in the mobile environment, the OCC model to represent the emotional state of the character and the behavior network to make quick and suitable reactions for various situations.

II. RELATED WORKS
A. Intelligent Services on Smartphones
Many researchers have studied context aware services on the smartphone. Cho et al. [5] developed a system to generate a cartoon-style diary to summarize a user’s daily life. The system used Bayesian networks to recognize a user’s activities from information collected in a mobile device. Daniel et al. [6] developed a mobile context-aware system which collected personal data from diverse sensors and recognized current contexts. Kim et al. [7] proposed an intelligent agent that selected behavior using its internal state and learned through interactions with the user. Berg et al. [8] helped users to recognize the owner of specific contact information at a glance. Moreover, SK Telecom, one of Korea’s mobile phone operators, launched character-based intelligent services named as 1mm service in 2005.

However, previous works have a limitation to consider only a few contexts. To handle more contexts reliably, the proposed system includes a probabilistic model like Bayesian network. Additionally, it also contains behavior network and OCC model to make the synthetic character realistic.

B. Behavior Network-based System
Behavior network, proposed by Maes [9], can generate the most suitable behavior for an environment using sensory information to achieve given goals. The model consists of relationships between behaviors, goals, and external environments. Each behavior contains preconditions, an add list, a delete list and an activation. There are three types of links between behavioral entities: predecessor link, successor link and conflictor link. Each link from the i-th behavioral entity to the j-th behavioral entity can be defined as follows (p is the current condition):
• Predecessor: \((p = false)\) and \((p e preconditi0n of B_i)\) and \((p e add list of B_i)\)
• Successor: \((p = false)\) and \((p e add list of B_i)\) and \((B_i is executable)\) and \((p e preconditi0n of B_i)\)
• Conflictor: \((p = true)\) and \((p e preconditi0n of B_i)\) and \((p e delete list of B_i)\)

The activation energies of behaviors firstly induced from external environments and goals. The activation of the \(i\)th behavior \(A_i\) can be presented as follows:

\[
A_i = A_i + \sum_{n} w_p E_{i,n} + \sum_{m} w_g G_{i,m} (E_{i,n}, G_{i,m} = 0,1)
\]

where \(w_p\) and \(w_g\) are the weights to induce activation energies from environments and goals, respectively. \(E_{i,n}\) and \(G_{i,m}\) represent whether the \(n\)th environment element and the \(m\)th goal are connected with the \(i\)th behavior or not respectively.

After the first induction, the activation energies are propagated to other behaviors. The propagation can be presented as follows:

\[
A_i = A_i + \sum_{j} (w_p P_{i,j} + w_s S_{i,j} - w_c C_{i,j}) (i \neq j; P_{i,j}, S_{i,j}, C_{i,j} = 0,1)
\]

where \(w_p\), \(w_s\), and \(w_c\) are the weights to exchange activation energies through predecessor, successor, and conflictor links respectively, and \(P_{i,j}\), \(S_{i,j}\), and \(C_{i,j}\) whether the \(i\)th and \(j\)th behavior are connected by each type of links respectively.

Many studies for generating behavior have adopted a behavior network as their behavior generation method. Nicolescu et al. [10] proposed a hierarchical behavior network to control the behavior of a mobile robot [11]. Khoo and Zubek [12] used behavior networks for a character’s behavior in a computer game, and Weigel et al. [13] controlled soccer robots using behavior networks. This paper also uses the behavior network to create an intelligent synthetic character’s behaviors.

### III. MOBILE INTELLIGENT SYNTHETIC CHARACTER

The intelligent synthetic character consists of four components: mobile data collection, context recognition, emotional state and goal setting, and behavior generation. The character can generate suitable behaviors for various situations within the limitations of the mobile environment. The data collection part simply gathers raw data from the smartphone. The context recognition produces semantic information about the user from the collected raw data. It uses Bayesian network to handle the uncertain and incomplete data in mobile environment. The system produces an emotional state and goal states using the OCC model and rule-based system. Behavior generation is a process to select suitable behaviors for the situation by considering gathered information and the emotional states of the character, inferring high-level contexts for the user, using behavior networks to reflect both external situations and internal states, and generating behaviors quickly. Figure 1 shows an overview for the proposed mobile intelligent synthetic character.

### A. Data Collection

The system collects raw personal data such as contact information, schedules, call logs, and device states. The contact information can be used with call logs to identify frequent contacts. Schedule can be fundamental to infer the user’s activities. Call logs include the name of the caller/receiver, phone number, call type, and duration. Table I summarizes the information.

<table>
<thead>
<tr>
<th>Class</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>User information</td>
<td>Address book</td>
</tr>
<tr>
<td></td>
<td>Name, group, phone number, E-mail, address, homepage</td>
</tr>
<tr>
<td>Schedule</td>
<td>Subject, location, category, start time, end time</td>
</tr>
<tr>
<td>Call logs</td>
<td>Name, phone number, call type, start time, duration</td>
</tr>
<tr>
<td>Smartphone device states</td>
<td>Battery state, memory state, touchpad input, screen complexity, executing programs, time</td>
</tr>
</tbody>
</table>

### B. Context Recognition System

The context recognition system recognizes the user’s emotion and the business using Bayesian networks. The Bayesian network is a probabilistic model to estimate a user’s state with incomplete and uncertain information. There are two types of Bayesian networks. They are designed to recognize the user’s valence and arousal states, and business.

Figure 2. A part of Bayesian networks for user context recognition
In order to recognize the user’s emotional state, the Valence-Arousal (V-A) space model is applied to design Bayesian network. The model represents the user’s emotion in a two-dimensional space (valence and arousal) [14]. Valence and arousal values are discretized into five levels: very high, high, medium, low, or very low. Figure 2 shows a part of Bayesian network for context recognition.

C. Emotion & Goal Generation System

Emotions are important factors for realistic characters [15]. To generate the character’s emotion, this system uses the OCC model [16] which is based on the cognitive appraisal theory of emotion. This paper uses a modified OCC model with 14 emotional categories (gloating, joy, distress, pity, pride, shame, admiration, reproach, love, hate, gratification, remorse, gratitude, and anger) as shown in Figure 3.

![Figure 3. The modified OCC model with 14 emotional categories](image)

Goals are another important part for an intelligent synthetic character. Goal-oriented behaviors make the character more realistic. The character sets its own goals with information gathered from the smartphone. The goals are used in behavior selection networks to generate appropriate behaviors. Table II shows the goal states for various situations.

TABLE II. GOAL STATES FOR VARIOUS SITUATIONS

<table>
<thead>
<tr>
<th>Goal State</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notice</td>
<td>Before the schedule</td>
</tr>
<tr>
<td>Be in agreement with phone state</td>
<td>Special phone state</td>
</tr>
<tr>
<td>Be in agreement with emotion</td>
<td>Special emotion</td>
</tr>
<tr>
<td>Be in agreement with time</td>
<td>Special time</td>
</tr>
</tbody>
</table>

D. Behavior Generation System

In order to generate suitable behaviors for various situations, behavior network is used because it can overcome problems of classical planning approaches such as brittleness, inflexibility, and slow response [9], and the problem of reactive approaches such as the lack of explicit goals. Moreover, it is easier to design relationships between various behaviors and external factors using the behavior networks.

A large-scale behavior network which includes various external environments, goals and behaviors is required to cover diverse situations for the mobile intelligent synthetic character.

TABLE III. EXECUTABLE BEHAVIORS OF SYNTHETIC CHARACTER

<table>
<thead>
<tr>
<th>Category</th>
<th>Behaviors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active behavior</td>
<td>Appear, Disappear, Dance, Get up, Lie, Roll, Eat, Play, Read, Rest, Stay, Sing</td>
</tr>
<tr>
<td>Emotional behavior</td>
<td>Happy, Laugh, Boring, Annoyed, Cry, Love, Envy, Sleepy, Anger</td>
</tr>
<tr>
<td>Conversational behavior</td>
<td>Console, Cheer up, Notice, Charm, Good night, Good morning</td>
</tr>
<tr>
<td>State transition expression</td>
<td>Hungry, Get fat, Get slim, Get red-faced</td>
</tr>
</tbody>
</table>

The designed behavior network includes 44 external environmental factors and four goal states, and generates 31 behaviors. The behaviors include active behaviors, conversational behaviors, emotional behaviors and the character’s state transition expressions. Table III shows the executable behaviors of the character. Behaviors are generated by considering external environments such as the device state, the user state, the emotional states of the character, etc.

IV. EXPERIMENTAL RESULTS

A. Experimental Settings

The proposed intelligent synthetic character is developed by Microsoft Embedded Visual C++ 4.0 and Pocket PC SDK 2003. The experiment is conducted on the Samsung SPH-M4650 smartphone. Figure 4 shows screen shots of the character’s behaviors.

![Figure 4. Screen shots of an intelligent synthetic character on smartphone](image)

B. Evaluation

For the evaluation of the fitness of the character’s behaviors, eight participants were recruited. In the evaluation, the participants carried out ten scenarios, each of which contained a unique situation. Table VI shows the ten scenarios used for the evaluation.
The participants observed a sequence of five randomly-generated behaviors for every scenario and another sequence of five behaviors generated by the proposed method. After this task, they evaluated the fitness of each behavior in each situation. The fitness ranged from 1 which meant “strongly incongruent” to 5 which meant “strongly suitable.”

<table>
<thead>
<tr>
<th>No</th>
<th>Time</th>
<th>Schedule</th>
<th>Call logs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weekday morning</td>
<td>A lot of business schedules</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Weekday evening</td>
<td>All schedules ended</td>
<td>Frequent, with familiar people</td>
</tr>
<tr>
<td>3</td>
<td>Weekday morning</td>
<td>No schedule</td>
<td>Frequent, with familiar people</td>
</tr>
<tr>
<td>4</td>
<td>Weekend afternoon</td>
<td>All schedules ended</td>
<td>Frequent, with familiar people</td>
</tr>
<tr>
<td>5</td>
<td>Weekday lunchtime</td>
<td>A lot of remaining schedules</td>
<td>None</td>
</tr>
<tr>
<td>6</td>
<td>Weekday night</td>
<td>All schedules ended</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>Weekday forenoon</td>
<td>A lot of business schedules</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>Weekday morning</td>
<td>A lot of business schedules</td>
<td>Frequent</td>
</tr>
<tr>
<td>9</td>
<td>Weekday forenoon</td>
<td>No schedule</td>
<td>Frequent, due to business</td>
</tr>
<tr>
<td>10</td>
<td>Weekday forenoon</td>
<td>A lot of business schedules</td>
<td>Frequent, due to business</td>
</tr>
</tbody>
</table>

Figure 5. Evaluation results

V. CONCLUDING REMARKS

We proposed a mobile intelligent synthetic character which can deal with dynamism and complexity in a mobile environment. A Bayesian network was used to infer high-level contexts from the smartphone, and the OCC model was used to generate the character’s emotional state. To provide numerous behaviors which can be performed in various situations by considering inferred situations and the character’s internal states, we proposed a large-scale behavior network with many behaviors.

In order to provide enhanced intelligent services for smarter phones, it is necessary for the intelligent synthetic character to interact with the user and to evolve independently. To achieve this, we developed algorithms for interaction and evolution, including a learning system that evolves the structure of the Bayesian networks and the behavior selection network using user feedback.

REFERENCES