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An intelligent synthetic character for smartphone with Bayesian networks and behavior selection networks

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ABSTRACT

As cell phones have become more common, personalized intelligent services in smartphones have become more highly desired. The mobile intelligent synthetic character is an example of one of these desired services. It is hard to apply an intelligent synthetic character to the smartphone environment because of its dynamism and complexity. This paper proposes a method for generating behaviors of a smart synthetic character that infers user contexts with Bayesian networks. In order to generate more realistic behaviors, the OCC model is utilized to create the character's emotion. Behaviors are produced through large-scale modular behavior networks with inferred contexts. A working progress is the mobile log collected with a Samsung SPH-M4650 smartphone that is used to verify the naturalness and flexibility of the generated behaviors.

1. Introduction

High-end devices on mobile networks, smartphones, have been developed to include both functions of a PDA (personal digital assistant) and those of a cell phone. As smartphones have become more common, demand for personalized intelligent services will increase. The intelligent synthetic character we focus on is an autonomous agent that can interact with a user in real-time. The character provides information to users or interacts with them based on their facial expressions, behaviors, and simple dialogs. The intelligent synthetic character can also be used by entertainment and service robots (Kim, Kim, Kim, & Lim, 2002). Many researchers have attempted to apply this intelligent synthetic character to smartphones.

The main issue when implementing a synthetic character is how to make the character realistic and believable. Many researchers have aimed to designate character that seems to think, feel and live. To achieve this goal, the characters should have their own perceptional, behavioral and motor mechanisms (Pan, Yang, Xu, & Zhang, 2005).

The intelligent synthetic character should provide suitable services for various situations. To this end, there are three general required functions of an intelligent synthetic character. First of all, the character should recognize the contexts around the user. Not only low-level contexts gained directly from sensors but also high-level contexts inferred from various low-level contexts can be used. Secondly, the character should generate suitable behaviors for various situations by considering the inferred contexts. Moreover, to make the character more believable, it should behave according to its own internal state, since humans have a wide variety of expressive actions in their personalities, emotions, and communicational needs (Canamero, 1998; Cassell, 1999).

However, since the mobile environment is often complex and changes dynamically, the mobile intelligent synthetic character should be able to handle the mobile environment and its structure. For example, the character should produce reliable information and be aware of contexts in the presence of uncertain, rapidly changing, and partially true data from multiple heterogeneous sources (Korpipaa, Mantyjarvi, Kela, Keranen, & Malm, 2003). The character should also generate behaviors as fast as possible in real-time by considering recognized contexts, since the mobile environment changes rapidly. In this paper, we propose a mobile intelligent synthetic character that considers problems which can occur in the mobile environment.

The proposed mobile intelligent synthetic character was designed to integrate Bayesian networks, the OCC model and the behavior network. To solve the problem of context inference in the mobile environment, we used a Bayesian network, are presentative probabilistic approach. Also, the behavior network was used to quickly generate behaviors suitable for various situations. Finally, the OCC model was used to generate the emotional state of the character in order to make it more realistic.

2. Related work

2.1. Intelligent services on smartphones

In order to support smartphone users, many studies have been proposed. The researchers have mainly focused on situational

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awareness of the smartphone and its ability to provide suitable services to the user. Schiaffino and Amandi (2002) designed the software structure of the personalized schedule manager agent and proposed a case-based reasoning method using Bayesian networks. Cho, Kim, Hwang, and Song (2007) summarized a given user's daily life with a cartoon-style diary using Bayesian networks based on information collected from mobile devices like smartphones. Siewiorek et al. (2003) designed SenSay, the context-aware mobile phone which recognizes current contexts by analyzing the data from various sensors.

Synthetic-character-based intelligent services have received attention because of their usefulness in interactions between the user and the agent. Kim, Kim, and Kim (2004) proposed an intelligent agent that selects behavior using its internal state and learns through interactions with the user. Berg, Taylor, and Harper (2003) helped users to recognize the owner of specific contact information at a glance. Moreover, SK Telecom, Korea's leading mobile phone operator, provided 1 mm service which includes character-based intelligent services for the mobile phone platform in 2005. The character interacts with the user and provides services that consider the contexts around the mobile phone.

However, previous works have proposed intelligent services which provide a limited number of services by considering only a few contexts. To provide more intelligent services, the system should consider a broader environment around the user. Additionally, the synthetic character should look realistic. In the structure of the character proposed in this paper, the limitations addressed above can be overcome using a combination of the Bayesian network, the behavior network and the OCC model.

2.2. Behavior network-based system

Researchers in intelligent behavior generation consider how behavior is generated within an environment. They propose behavior generation structures which generate human-like behaviors in a variety of environments.

Contrary to traditional methods in artificial intelligence, which represent precise knowledge, a behavior-based system generates behaviors through direct interactions between environments and agents. The behavior network (Maes, 1989) proposed by Maes generates behavior autonomously by attaching goals to the behavior-based system. The network was inspired by animal behaviors observed by robotics researchers and ecologists. The behavior network generates the most suitable behavior for an environment using sensory information and established goals.

Many studies for generating behavior have adopted a behavior network as their behavior generation method. Nicolescu and Mataric (2000) proposed an extended behavior network system and designed a hierarchical behavior network system that adapted to the behavior of a mobile robot (Nicolescu & Mataric, 2002). Khoo and Zubek (2002) generated behaviors for a computer game character using behavior networks, and Weigel, Gutmann, Dietl, Kleiner, and Nebel (2002) adopted behavior networks for soccer robots. The concept of a behavior network can be applied to a mobile intelligent synthetic character since it can generate behaviors flexibly in a complex environment. In this paper, we integrate the behavior network into a Bayesian network and the OCC model in order to create suitable character behavior. Additionally, we tested the behavior network in a larger, more complex network.

3. Mobile intelligent synthetic character

In order to design a mobile intelligent synthetic character, three challenges should be considered.

- The contexts should be inferred successfully in a dynamic, complex environment by considering the uncertainties of the sources in the smartphone.
- The appropriate internal states of the character should be generated for recognized situations.
- The behaviors suitable for the recognized situations and the state of the character should be generated as quickly as possible.

The structure of the proposed mobile intelligent synthetic character is designed to address these challenges. The intelligent synthetic character consists of five components: a perception system, a user context recognition system, a character emotion system, a motivation system and a behavior generation system. The character can generate suitable behaviors for various situations within the limitations of the mobile environment. The perception system simply gathers information about the user from the smartphone. The user context recognition system produces high-level contexts about the user based on the collected information. The Bayesian network is used in the system to deal with the complex mobile environment and the uncertainties of the information sources. The character emotion system produces an emotional state for the character using the OCC model, and the motivation system generates the goal states of the character according to the situation. Finally, the behavior generation system is designed to generate 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. Fig. 1 shows an architecture for the proposed mobile intelligent synthetic character.

3.1. Perception system

The perception system gathers information available in smartphones such as contact information, schedules, call logs, and device states. When a user stores contact information in the address book, the perception system can collect information about the people whom the user contacts. The information can be used with call logs to identify frequent contacts. It is also exceedingly useful to infer the user's situation. With schedule information, the character can infer what the user is doing and what the user is going to do. Call logs are useful information that can be gathered easily. Whenever the user makes a call, the smartphone records logs including the name of the caller/receiver, phone number, call type, and duration. Finally, the perception system gathers the internal states of a smartphone. Table 1 shows some of the information sources available in a smartphone. The gathered information is necessary for the emotional system and the behavior selection system.

3.2. User context recognition system

To indirectly interact with the user, the character should be able to reason higher-level contexts using gathered information. The user context recognition system infers the user's emotion and the business state using Bayesian networks. The Bayesian network is a representative model to infer states with insufficient information and uncertain situations. We design two types of Bayesian networks: one infers valence and arousal states of the user and the other infers the business state of the user.

In order to infer the emotional state of the user, we apply the Valence–Arousal (V–A) space model, which represents emotion as a given position in a two-dimensional space. This method has been commonly used in previous studies on emotion recognition (Picard, 1995). The user's emotion is determined using two variables, valence and arousal, which are inferred from the Bayesian networks. Valence and arousal values are discretized into five levels: very high, high, medium, low, or very low.