Software Robot in a PDA for Human Interaction and Seamless Service

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Abstract— In this paper, a new architecture is proposed for the efficient human interaction with software robot (Sobot) in a PDA and the Sobot transmission between PDAs. Sobot can move to any mobile device through a wireless communication network. This ability is required to follow its user by moving itself to a device in his/her new location. Sobot as an artificial creature, has genetic code which is a set of computerized codes representing the personality. It has an internal state which consists of motivation, homeostasis, and emotion. The data set of genetic code and current internal state are transmitted through the network when it moves to the other device. A main server manages IP addresses of registered devices, Sobot’s data set, and Sobot’s location for the transmission. To demonstrate the effectiveness of the proposed scheme, Sobot is implemented in windows mobile environment of PDA such that it can interact with a human being and move to the other mobile device without spatial limitation.

I. INTRODUCTION

The ubiquitous robot, Ubibot, is being developed based on the fusion of Ubiquitous Computing (UC) [1], [2] and robot technology [3]. The operation of Ubibot will be seamless, calm, context-aware and networked. Ubibot consists of three types of robot: Software robot (Sobot), Embedded robot (Embot) and Mobile robot (Mobot) [4]-[6]. Sobot can move to any device through a network and provides seamless interaction with the user. Embot is embedded within the environment or within a Mobot. It detects the location of the robot or the human, recognizes and authenticates them, and collects and synthesizes the various sensing information [7], [8]. Mobot has a mobility and provide a broad range of services in cooperation with Sobot and Embot. Sobot’s behaviors in the virtual environment can be realized by Mobot’s behaviors in the real environment for physical services [9].

Sobot can be described variously as artificial creature, interactive creature, autonomous agent, synthetic character, or 3D avatar. Sobot, as an artificial creature, imitates animal or human which has an ability to perform a proper behavior selection and to adapt to the environment [10], [11]. It can become an interactive creature or a friend for humans. Sobot, as an autonomous agent, can determine and control its behavior automatically without external commands [12]. In the ubiquitous system, Sobots control or cooperate with Embots and Mobots. It can be also transmitted into any device as well as other robots as a core system.

Each Sobot has their own personality [13] and can reproduce their kind, or even evolve as a distinct species [14]. Evolving the Sobot’s personality as desired by using its computer-coded genome in a virtual environment was proposed in [15]. The robot genome is composed of multiple artificial chromosomes each of which consists of many genes that contribute to defining the creature’s personality. It provides primary advantages for artificial reproduction, the ability to evolve, and reusability among Sobots. Since genome data can be utilized for various individuals in networked environment, it is required to manage the genome database in the main server.

In the previous work, studies on Sobot were focused on behavior selection and learning mechanisms [16], [17] to improve its output performance, or on its artificial genome in the personal computer environment. However, Sobot is needed to be in mobile devices such as Pocket PC, PDA (Personal Digital Assistance) and mobile phone, as these devices have an advantage that user can utilize them more frequently and easily than others. In the ubiquitous environment, the transmission of Sobot between devices should be also needed so that it can interact with user by any device at any place and any time.

This paper proposes a new architecture for the implementation of Sobot in a PDA for human interaction and the Sobot transmission between PDAs. The architecture consists of five subsystems: virtual environment subsystem, memory allocation subsystem, data communication subsystem, user interface subsystem, and Sobot subsystem. The internal architecture of Sobot is designed and artificial genome is defined to identify its personality. Buttons and stylus are used to give stimuli to Sobot for interaction. Considering the communication efficiency, instead of all the software system of Sobot, its genome is sent to the other device via a main server (UbiServer). By transmitting the genome along with current internal state, Sobot can maintain its consistent personality in the other device. In the experiment, bitmap images are utilized to generate Sobot’s motion animation. Star topology is employed for communication among UbiServer and PDAs. The procedure of transmission is provided in the test setup comprising of three PDAs and UbiServer.

This paper is organized as follows. Section II presents the architecture of PDA-Sobot system and internal architecture of Sobot. Genetic representation for Sobot is described in Section III. Section IV presents how Sobot is implemented in a PDA and how user interacts with Sobot. The procedure of transmission among UbiServer and PDAs is also described. Finally, concluding remarks follow in Section V.
II. PDA-SOFTWARE ROBOT SYSTEM

Geney is designed to fulfill the requirements for Sobot. The name comes from genes, since Geney’s personality is based on its artificial genome. Also, it is originated from Genie in the fable of Aladin and magic lamp from the Arabian nights. As Aladin could call or interact with Genie at any place and whenever needed, Sobot in a PDA represents itself visually on the screen and interacts with user. In this section, a new architecture for implementation of Sobot in the PDA is proposed and the internal architecture of Sobot is described.

A. PDA-Software Robot System Architecture

The PDA-Sobot system depicted in Fig. 1 comprises of the following subsystems: virtual environment subsystem, memory allocation subsystem, data communication subsystem, user interface subsystem, and Sobot subsystem. Virtual environment subsystem consists of objects such as food, ball, and other Sobots. By sensor information, Sobot can recognize environment and then it decides a proper behavior. Memory allocation subsystem ensures the memory in the device that Sobot can be created and activated. Data communication subsystem connects the device to the main server (UbiServer) for the transmission of Sobot to the other device. Considering communication efficiency, its genetic code and internal state are transmitted instead of entire software system. Since the main server notifies Sobot’s location to all the connected devices, its current location can be monitored by each device. User interface subsystem is to deal with user’s input information such as user stimuli and communication signals through buttons or stylus for interaction. Sobot subsystem includes Sobot itself and its internal architecture is described in the next section.

B. Internal Architecture of Sobot

The internal architecture of Sobot (Fig. 2) is composed of four primary modules [11], [18]: perception module, internal state module [19]-[21], behavior module [22], [23], and motor module. The perception module processes virtual and physical sensor information to update Sobot’s internal state and behavior. Considering user interface of PDA, in this paper six percepts such as dandled, shaken, patted, hit, noisy, and loud noisy are considered (see Fig. 6). These are given by the stimuli of PDA buttons or stylus. It means the buttons and stylus are used as sensor system in the implementation. Sobot has an adaptation mechanism for the stimuli such that if it receives the same stimulus continuously, it becomes insensitive to the stimulus.

The internal state module defines the Sobot's internal state with three units: motivation unit, homeostasis unit and emotion unit. Motivation is composed of six states: curiosity, intimacy, monotony, avoidance, greed and the desire to control. Homeostasis includes three states: fatigue, hunger and drowsiness. Emotion includes five states: happiness, sadness, anger, fear and neutral. Sobot as an artificial creature can behave autonomously driven by its internal state. Each internal state is updated by its own weights, which connect the stimulus vector to itself (W in Fig. 2). Motivation vector M, homeostasis vector H, and emotion vector E are defined as [18]

\[
M(t) = [m_1(t), m_2(t), \cdots, m_k(t)]^T \quad (1)
\]
\[
H(t) = [h_1(t), h_2(t), h_3(t)]^T \quad (2)
\]
\[
E(t) = [e_1(t), e_2(t), \cdots, e_k(t)]^T \quad (3)
\]

where \(m_k(t), h_k(t), \) and \(e_k(t)\) are \(k\)th state in the internal state module. Each state is updated by

\[
m_k(t+1) = m_k(t) + \lambda_k (\tilde{m}_k - m_k(t)) + S^T \cdot W^M_k(t) \quad (4)
\]
\[
h_k(t+1) = h_k(t) + \lambda_k (\tilde{h}_k - h_k(t)) + S^T \cdot W^H_k(t) \quad (5)
\]
\[
e_k(t+1) = e_k(t) + \lambda_k (\tilde{e}_k - e_k(t)) + S^T \cdot W^E_k(t) \quad (6)
\]

where S is the stimulus vector, \(W^M_k, W^H_k, W^E_k\) are weight matrices connecting S to \(k\)th state in the internal state module, \(\tilde{m}_k, \tilde{h}_k, \) and \(\tilde{e}_k\) are constant values to which the internal state converge when no stimuli are applied, and \(\lambda_k\) is the difference gain.

The behavior selection module chooses a proper behavior based on internal state [11]. According to the current internal state, various behaviors are selected probabilistically by voting mechanism, where each behavior has its own voting value [24], [25]. The voting values and internal state are related by \(W_2\) in Fig. 2.
The motor module incorporates virtual actuators to execute the selected behavior in the virtual environment. The virtual environment can be expressed by 2D or 3D graphical display. In the PDA, 2D virtual environment is used because of limited hardware resources.

III. ARTIFICIAL GENOME

Artificial genome of Sobot is to represent its personality and to pass its traits to its offspring. The genome is composed of a set of chromosomes, $C_k, k = 1, \cdots, c$. Each $C_k$ consists of three gene vectors: the Fundamental gene vector (F-gene), $x^F_k$, the Internal state related gene vector (I-gene), $x^I_k$, and the Behavior related gene vector (B-gene), $x^B_k$, and is defined as [14]

$$ C_k = \begin{bmatrix} x^F_k \\ x^I_k \\ x^B_k \end{bmatrix}, \quad k = 1, 2, \cdots, c \tag{7} $$

where $w$, $y$, and $z$ are the sizes of the F-gene vector, I-gene vector, and B-gene vector, respectively. F-genes represent fundamental characteristics of Sobot, including volatility, initial values, constant values ($\bar{m}_k$ in (4), $\bar{r}_k$ in (5) and $\bar{r}_k$ in (6)), and the difference gain ($\lambda_k$). I-genes includes genetic codes representing its internal preference by setting the weights of $W^M_k(t)$ in (4), $W^B_k(t)$ in (5), and $W^F_k(t)$ in (6).

B-genes include genetic codes related to output behavior by setting the weights of $W_2$ in Fig. 2. In other words, the weight values of weighting systems, $W$, and $W_2$, in internal state module and behavior module (see Fig. 2) are encoded as I-genes and B-genes, respectively [14].

A genome, $G$, composed of a chromosomal set, is defined as

$$ G = [C_1 | C_2 | \cdots | C_c], $$

where $c$ is the number of chromosomes in the genome.

The parameter values, $w$, $y$, and $z$ are equivalent to the number of fundamental features, the ability of perceiving different types of stimuli and of outputting different behaviors as response, respectively. Fig. 3 shows 14 chromosomes of Geney where $w = 4, y = 6, z = 77$, and $c = 6 + 3 + 5 = 14$. First six $C_1$-$C_6$ are related to motivation: curiosity, intimacy, monotony, avoidance, greed, and desire to control. The next three $C_7$-$C_9$ are to homeostasis: fatigue, drowsiness, and hunger. The last five $C_{10}$-$C_{14}$ are to emotion: happiness, sadness, anger, fear, and neutral. As each chromosome is represented by 4 F-genes, 6 I-genes, and 77 B-genes, Geney has 1218 genes in total.

The genes in Fig. 3 are originally represented by real numbers: values of F-genes range from 1 to 500, I-genes from -500 to 500, and B-genes from 1 to 1000. F- and B-genes are normalized to brightness values from 0 to 255, which are expressed as black-and-white rectangles. The darker color is, the higher its value is. I-genes may have negative values and are normalized as red-and-black rectangles in the same manner.

The 2D genetic representation has advantages of representing essential characteristics of three types of genes intuitively, reproducing the evolutionary characteristics of living creatures, and enabling users to easily insert or delete other types of chromosomes and genes related to Sobot’s personality and other information.

IV. IMPLEMENTATION OF SOBOT IN A PDA

This section describes implementation of Sobot in a PDA for human interaction by using buttons and stylus. Also, Sobot transmission mechanism of transferring the robot genome and internal state files is presented.

A. Interaction with Sobot

Sobot was implemented in the PDA (SPH-M4300) of Samsung Electronics Co., which had 57.03 MB as a total main memory. Due to the other application programs, only about 30 MB out of the total memory could be used for running a Sobot program. As a programming tool Embedded Visual C++ 4.0 was used. Initially, Geney was developed in a desktop computer by using 3DS MAX to design a character and Cal3D software to generate motion animation. In the PDA, however, considering the limited memory consecutive bitmap images of Geney were used by capturing the motion animation.

Fig. 4(a) shows Sobot simulator based on the overall system architecture of Fig. 1 and the internal architecture of Sobot of Fig. 2. Four Sobots with different personality can be simultaneously simulated with six stimulus buttons. They respond to the applied stimulus according to their personality encoded by the genome. It shows a selected facial expression and behavior of each Sobot as a text output, respectively, to the applied stimulus. It can be incorporated with the computer graphical animation to show the output behavior visually for natural interaction with user.

![Fig. 3. Artificial genome of Geney.](image-url)
Selected one out of four Sobots, named Geney, is shown in Fig. 4(b). Since the size of each behavior bitmap image file was around 2~5 MB, seven representative behaviors with 17.5 MB were provided in this paper. It means that the original 77 behaviors provided in the Sobot simulator were classified into 7 representative ones. Each representative one is shown in Fig. 5. For instance, Shrinking-back behavior represents original behaviors such as moving backward, resisting, hiding a head, flinching, covering eyes, and blocking. It should be noted that if an embedded processor in mobile device is improved to that of a PC in the near future, more natural behaviors of 3D animation will be shown.

Fig. 6(a) shows available nine user inputs, to have interactions with Geney as shown in Fig. 6(b). Connect button was used to register the IP address of the PDA to the main server and Call button was used to call Sobot from the main server or other device. Provided stimuli are dandling, shaking, shouting, shouting loudly, hitting and patting by buttons, and patting by stylus. Each stimulus directly generates its corresponding perception, which influences Geney’s internal state (Fig. 2). It should be noted that because of limited inputting mechanism in a PDA environment, only six user’s inputs were utilized as stimuli, but combination of six buttons or other buttons can be used for diverse stimuli.

B. Transmission of Software Robot

Fig. 7 shows overall configuration of network system connecting various devices to main server (UbiServer) by star topology. UbiServer is located in the center of the network system and manages efficient transmission of Sobot between devices. Users can select and download a Sobot to his/her device from UbiServer which maintains various genomes for Sobots.

When Sobot traverses connected devices through the network, UbiServer manages IP addresses of registered devices, data set of Sobot, and Sobot’s location, that is, IP address of the device where Sobot is located. When a Sobot moves to the other device, the data set comprising of its genome and current internal state are sent. The transmission of the Sobot is essentially transfer of this data set. As the genome data keep its personality, it generates its unique responses to external stimuli even in the new device. Also the internal state data in the previous device are to maintain the continuity of the states of motivation, homeostasis, and emotion in the new device.

As Fig. 8 shows, IP addresses of all the connected devices were registered in UbiServer. If a new device is added to the network, its IP address is registered to UbiServer, which broadcasts a new list of IP addresses of devices to all. Also, since it broadcasts Sobot’s location to all devices, each de-
vice can keep track of its location in real-time.

A standard packet is required for the transfer of Sobot. The composition of packet for communication is depicted in Fig. 9. ‘STX’ indicates the begin of packet and ‘ETX’ indicates the end of packet. ‘COMMAND’ includes control instruction and ‘DATA’ includes IP address. Table I shows command and data information of control packet developed for the experiment.

A network router was used for wireless data links. Data upload and download were done by FTP server. An example of transmission of a Sobot between three devices is shown in Fig. 10. Arrows between PDAs and UbiServer indicate actual data communication and dotted arrows represent the conceptual transmission of Sobot. Fig. 11(a) shows the test setup comprising of three PDAs and UbiServer running on a tablet PC. In this experiment, only one Sobot was considered for transmission between PDAs via UbiServer.

<table>
<thead>
<tr>
<th>COMMAND</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADDR</td>
<td>Register IP address to UbiServer</td>
</tr>
<tr>
<td>MOVE</td>
<td>Move Sobot to IP address</td>
</tr>
<tr>
<td>DELE</td>
<td>Remove IP address in UbiServer</td>
</tr>
<tr>
<td>CALL</td>
<td>Call Sobot to IP address</td>
</tr>
<tr>
<td>SOBOT</td>
<td>Current Sobot’s location</td>
</tr>
<tr>
<td>EXIT</td>
<td>Terminate the device operation</td>
</tr>
</tbody>
</table>

TABLE I
 COMMAND AND DATA INFORMATION OF CONTROL PACKET

i) PDA-Sobot system was running on each device. All the devices registered their own IP address to UbiServer using control packet (e.g. STXADDR192.168.3.100ETX) of Connect button. Registered IP addresses are shown in Fig 11(b).

ii) Firstly, device A transmitted control packet (STXCALL192.168.3.100ETX) of Call button to UbiServer in order to download Sobot (Fig 11(c)).

iii) Once it downloaded the data set of Sobot, it transmitted control packet (STXSOBOT192.168.3.100ETX) to UbiServer. Then UbiServer broadcasted the control packet to all devices to notify Sobot’s new location. By this broadcasting, all devices updated Sobot’s current location.

iv) Secondly, device B transmitted control packet (STXCALL192.168.3.102ETX) of Call button to UbiServer in order to call the Sobot. UbiServer broadcasted the control packet to all devices.

v) According to the request of device B, device A sent the Sobot’s data set to UbiServer by control packet (STXMOVE 192.168.3.102ETX). Then, UbiServer broadcasted the received control packet to all devices.

vi) Since IP address of device B matched the received IP address, device B downloaded the data files and transmitted control packet (STXSOBOT192.168.3.102ETX) to UbiServer in order to notify Sobot’s new location (Fig 11(d)).

vii) Thirdly, in the same way as iv)-vi) Sobot could move to device C (Fig. 11(e)).

viii) When the system was disconnected, UbiServer deleted its IP address in the list and finally it presented a message that there was no Sobot in any devices (Fig. 11(f)).
Video clips of two successful experiments on human interaction and transmission are available in ‘Software Robot, Geney’ at http://rit.kaist.ac.kr/home/Geney.

V. CONCLUSIONS

This paper proposed a new architecture for the Sobot in a PDA for the interaction with human and the transmission of Sobot between PDAs in the wireless network environment. The interaction was demonstrated to be effective by buttons and stylus of mobile devices. For the transmission of Sobot to the other device, only two data files instead of the entire software system were transmitted because the Sobot sub-system in each device had been already installed. This could lead to reduce the network overhead. Since present PDAs have resource limitations such as memory size and limited graphic library, 2D graphical representation of Sobot was implemented using bitmap images. Since user always carries mobile devices with him/her, he/she will be able to interact with Sobot in his/her mobile device for ubiquitous services without any limitation of time and place by the proposed scheme.

VI. REFERENCES
