Evolving Personality of a Genetic Robot in Ubiquitous Environment

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Abstract—This paper discusses the personality of Genetic Robot and its evolving algorithm within the purview of the broader Ubiquitous Robot framework. Ubiquitous robot systems blends mobile robot technology (Mobot) with distributed sensor systems (Embot) and overseeing software intelligence (Sobot), for various integrated services. The Sobot is a critical question since it performs the dual purpose of overseeing intelligence as well as user interface. The Sobot is hence modelled as an Artificial Creature with autonomously driven behavior. The artificial creature has its own genome and in which each chromosome consists of many genes that contribute to defining its personality. This paper proposes evolving the personality of an artificial creature. A genome population is evolved such that it customized the genome satisfying a set of personality traits desired by the user. Evaluation procedure for each genome of the population is carried out in a virtual environment. Effectiveness of this scheme is demonstrated by using an artificial creature, Rity in the virtual 3D world created in a PC.

I. INTRODUCTION

Ubiquitous Technology is poised to radically change our lives. In this coming era, it is not difficult to envision highly advanced robot systems, providing us with a variety of services, at any place, by any device, and whenever needed. Ubiquitous robotic systems are emerging and hold great promise for offering integrated services [1]. These ubiquitous robotic systems negate the necessity for the conventional notion of a stand-alone robot platform by effectively incorporating three forms of robots, i.e. the software robot (Sobot), embedded robot (Embot) and mobile robot (Mobot) as defined by Kim [2]. This tripartite decomposition is the key to harnessing this new paradigm.

Brady defined robotics as the 'Intelligent connection of perception to action' [3]. Ubiquitous robotics however, redefines the connection of the three components, intelligence, perception and action by manifesting them individually as the Sobot, Embot and Mobot, respectively. The interconnection is therefore created through the network and the integration is carried out using the middleware in the ubiquitous space (u-space). This can be conceptualized as a networked cooperative robot system. The core intelligence of this system is constituted by software robots. Distributed embedded robot sensors ensure that the Sobot possess context aware perceptive capabilities. Lastly, Mobots act upon the service requests in the physical domain. Networking technology such as the IPv6 format and Broadband wireless systems shall constitute the key leveraging these advancements.

Ubiquitous robots will thus be able to understand what the user needs, even without the issuance of a direct command, and be able to supply continuous and seamless service. The Ubiquitous Robot system, the Ubibot has been under development at the Robot Intelligence Technology Lab at KAIST since 2003. It is designed to be seamless, calm, and context aware. The Ubibot system incorporates three forms of robots, the Sobot, Mobot and the Embot as detailed earlier. The Sobot Rity, visualized as a 3D virtual pet, can connect to and be transmitted to any device, at any time and, at any place within the u-space, by maintaining its own unique IP address. Embots collect and synthesize sensory information through the detection, recognition and authentication of users and other robots. Mobots proceed to act by providing the general users with integrated services. Middleware enables the Ubibot to interact and manage data communication reliably without disrupting the protocols in the u-space [4].

The complexity inherent in the system demand a completely new approach especially in the design of the intelligence component of the Sobot. Its intriguing inherent properties seem to redefine the essence of what it means to be a robot in the third generation of robotics. This brings us to the discussion of the essence of the robot as an artificial creature, which transcends conventional domains and barriers. These domains have until now limited researches to devote their attentions to the development and improvement of functionalities of robots.

Evolution is a widely accepted concept world over since the publication of Darwin’s ‘The Origin of Species’ in 1859. The Ubibot being the third generation of robotics thus represent a stage in evolution of ‘The Origin of Artificial Species.’ This species is typified by the Genetic Robot utilizing artificial chromosomes, which is the essence defining its personality and allowing it to pass on its traits to the
next generation. This essence of computerized genetic code dictates the robot’s personality by determining its propensity to feel emotions. This radical new concept was implemented within the Sobot Rity testing the robotic chromosomes which is a set of computerized DNA (Deoxyribonucleic acid) code for creating genetic robots that can think, feel, express intention and desire, and could ultimately reproduce their kind and evolve their species.

This paper focuses on evolving artificial creature’s personality as desired by using its computer-coded genome in a virtual environment. The primary application is that of providing a believable and interactive agent for a personal usage. The genome is composed of multiple artificial chromosomes each of which consists of many genes that contribute to defining the creature’s personality. The large number of genes also allows for a highly complex system. However, it is difficult and time-consuming to manually assign values to them for ensuring reliability, variability and consistency for the artificial creature’s personality. The evolving an artificial creature’s personality effectively deals with these issues providing a powerful tool for artificial creature personality generation and evolution. This paper describes the architecture and issues in the implementation of a Genetic robot as the virtual pet Sobot within the UbiBot system with an aim of enhancing its capabilities in providing integrated services.

This paper is organized as follows. Section II presents a brief overview on the concepts of the ubiquitous robots, and its component sobots, mobots, embots and the middle layer. Section III details the architecture of the Sobot Rity, while Section IV covers the algorithm for the evolution of a believable personality. The results on the algorithm are presented in Section V followed by the concluding remarks in Section VI.

II. UBIQUITOUS ROBOT SYSTEM

The ubiquitous robot system as defined earlier comprises of networked and integrated cooperative robot systems existing in the ubiquitous world. It includes Sobots, Embots and Mobots in their various forms. The ubiquitous robot is created and exists within a u-space which provides both its physical and virtual environment. It is anticipated that in the years to come the world will consist of many such u-spaces, each being based on the IPv6 protocol or a similar system and be interconnected through wired or wireless broadband network in real time.

The primary advantage of the Ubiquitous robot system is that they permit abstraction of intelligence from the real-world by decoupling it from perception and action capabilities. Sensory information is standardized along with motor or action information and this permits, the abstract intelligence to proceed with the task of providing services in a seamless, calm and context aware manner. The abstraction from reality shall later enable us to seek an artificially evolved solution for generating a believable creature.

As mentioned earlier, the ubiquitous robot system incorporates three kinds of robot systems: Sobots, Embots and Mobots under the ambit of its broader definition provided earlier.

A. Software Robot: Sobot

Sobots are the intelligent component of the Ubibot system whose domain lies wholly within the software realm of the network. It can easily traverse through the network to connect with other systems irrespective of temporal and geographical limitations. Sobots are capable of operating as intelligent entities without help from other Ubiquitous robots and are typically characterized by self-learning, context-aware intelligence and seamless interaction abilities. Within the u-space, Sobots try and recognize the prevalent situation and often make decisions on the course of action and implement them without directly consulting the user each time. They are proactive and demonstrate rational behavior and show capabilities to learn new skills. It is also totally pervasive in its scope and thus is able to provide seamless services throughout the network.

B. Embedded Robot: Embot

The embedded robots as the name implies are implanted within the environment or upon Mobots. They together comprise the perceptive components of the ubiquitous robot system. Utilizing a wide variety of sensors in a sensor network, Embots can detect and monitor the location of a user or a Mobot, authenticating them and also integrate assorted sensory information thus comprehending the current environmental situation. Embots are also networked and equipped with processing capabilities and thus may deliver information directly or under the Sobot’s instructions to the user. Embots are characterized by their calm sensing, information processing and information communication capabilities. Embots offer great functionality by being able to sense features such as human behavior, status, relationships and also environmental conditions impacting human behavior. They also possess abilities to perform data mining, which can enhance information search processes.

C. Mobile Robot: Mobot

Mobots offer a broad range of services for general users specifically within the physical domain of the u-space. Mobility is a key property of Mobots, as well as the general capacity to provide services in conjunction with Embots and Sobots. The mobot is usually in continuous communication with the Sobot in order to provide practical services based on information given by the Embot. Alternately, Mobots serve Embots as a platform for data gathering. Mobots are typically multi-purpose service robots with functionalities extending to home, office and public facilities.

D. Middleware

Middleware allows communication within and among ubiquitous robots using a variety of network interfaces and protocols. Middleware usually varies from one vendor to the next depending upon a variety of factors. The selected middleware allows conversion of the constituent entities of
the ubiquitous robot system into specific components with respect to the developer, thereby making it convenient to update functions, maintain resources and perform power management. The Middleware utilizes a broker which enables the system to make an offer of service irrespective of the operating structure, position and type of interface. This thus enables Sobot to receive information from a wide variety of Embots and to communicate with the Mbots.

III. Sobot as an Artificial Creature

This section introduces a Sobot as an artificial creature, Rity in a 3D virtual world, its internal control architecture and genome composed of a set of chromosomes [5].

A. Artificial Creature, Rity

An artificial creature is defined as an agent which behaves autonomously driven by its internal states such as motivation, homeostasis, and emotion [6] [7]. It should be able to interact with humans and its environment in real-time. Rity is designed to fulfill the requirements for an artificial creature. It is visually depicted on the screen as a dog and can interact with humans based on stimuli through a mouse, a camera or a microphone. This depiction naturally allows users to form a master-pet relation with the artificial creature. Rity can be seen in the screen capture in Fig. 1(b).

A number of different techniques have been tried out by researchers to develop suitable reactive control architectures for robots [7] [8]. In this regard, considering the requirement to incorporate internal states onto Rity, it cannot be considered as a simple stimulus response system with behaviors being mapped to perceptions. The architecture employed in Rity follows up from work by Kim et al [5] [9]. The parameters of this architecture naturally lend themselves to optimization and as a result, the creature’s personality may be artificially evolved as described in this paper. The internal control architecture in this paper is composed of four primary modules, that is, perception module, internal state module, behavior selection module and motor module. The complete internal architecture can be seen in Fig. 1(a).

1) Perception module: The perception module can recognize and assess the virtual environment and subsequently send the information to the internal state module. Rity has several virtual sensors for light, sound, temperature, touch, vision, orientation and time making a total of 47 types of stimulus information.

2) Internal state module: The internal state module defines the creature’s internal state with the motivation unit, the homeostasis unit and the emotion unit. In Rity, motivation is composed of six states: curiosity, intimacy, monotony, avoidance, greed and the desire to control. Homeostasis includes three states: hunger, fatigue and drawiness. Emotion includes five states: happiness, sadness, anger, fear and neutral. In general, the number of internal states depends on an artificial creature’s architecture.

Each internal state is updated by its own weights, which connect the stimulus vector to itself and are also represented as a vector. For instance, motivation vector M is defined as

$$M(t) = [m_1(t), m_2(t), \ldots, m_6(t)]^T$$

(1)

where $m_k(t)$ is kth state in the internal state module and the number of motivation states is 6. Each motivation state is updated by

$$m_k(t + 1) = m_k(t) + \left(\lambda_k (m_k - \bar{m}_k(t)) + S_k \cdot W_{mk}^M(t)\right)$$

(2)

where S is the stimulus vector, $W_{mk}^M$ is a weight matrix connecting S to kth state in the internal state module, $\bar{m}_k$ is the constant to which the internal state converge without any stimuli, and $\lambda_k$ is the difference gain. Similar update equations are defined for the homeostasis unit using state vector H(t) and weight matrix $W_{mk}^H$, and also the emotion unit using state vector E(t) and weight matrix $W_{mk}^E$, respectively.

3) Behavior selection module: The behavior selection module is used to choose a proper behavior based on Rity’s internal state, which is influenced by stimuli. According to the internal state, various reasonable behaviors can be selected probabilistically by introducing a voting mechanism, where each behavior has its own voting value. The procedure of behavior selection is as follows:

1) Determine the temporal voting vector, Vtemp using M and H.
2) Calculate voting vector V by applying attention and emotion masks to Vtemp.
3) Calculate a behavior selection probability, \( p(b) \), using \( V \).
4) Select a proper behavior \( b \) with \( p(b) \) among various behaviors.

**Motor module**
The motor module incorporates virtual actuators to execute the selected behavior in the virtual 3D environment.

**B. Genetic Representation**
The genetic representation aims to create an artificial creature that would be capable of animal-style evolution. Due to the existence of the pleiotropic and polygenic nature of the genotype, a single gene influences multiple phenotypic characters (pleiotropic nature) and a single phenotypic character is directly inspired by multiple genes (polygenic nature). The complexity of Rity's internal cognition and the internal architecture ensures the diversity in personality.

An artificial creature is made up of genome, a set of chromosomes, \( C_k \), \( k = 1, 2, \ldots, c \), which has the capability of passing its traits to its offspring. Each chromosome \( C_k \) is composed of three gene vectors: the Fundamental gene vector (F-gene vector), \( X^F_k \), the Internal state related gene vector (I-gene vector), \( X^I_k \), and the Behavior related gene vector (B-gene vector), \( X^B_k \), and is defined as

\[
C_k = \begin{bmatrix} X^F_k \\ X^I_k \\ X^B_k \end{bmatrix}, \quad k = 1, 2, \ldots, c
\]

with

\[
X^F_k = \begin{bmatrix} x^F_{1k} \\ x^F_{2k} \\ \vdots \\ x^F_{mk} \end{bmatrix}, \quad X^I_k = \begin{bmatrix} x^I_{1k} \\ x^I_{2k} \\ \vdots \\ x^I_{pk} \end{bmatrix}, \quad X^B_k = \begin{bmatrix} x^B_{1k} \\ x^B_{2k} \\ \vdots \\ x^B_{nk} \end{bmatrix}
\]

where \( m, p, \) and \( n \) are the sizes of the F-gene vector, I-gene vector, and B-gene vector, respectively.

An artificial genome, \( G \), composed of a chromosomal set, is defined as

\[
G = [ C_1 \mid C_2 \mid \ldots \mid C_c ],
\]

where \( c \) is the number of chromosomes in the genome.

Rity is implemented with \( w = 4, y = 47, z = 77 \), and \( c = 6 + 3 + 5 = 14 \). These values are equivalent to the ability of perceiving 47 different types of perceptions and of outputting 77 different behaviors as responses.

**IV. EVOLUTION OF THE PERSONALITY OF ARTIFICIAL CREATURE**

**A. Personality Model**

Big Five personality dimensions are employed and Rity's internal traits are classified for the corresponding personality dimension. They are classified as follows: extroverted (as opposed to introverted), agreeable (as opposed to antagonistic), conscientious (as opposed to negligent), openness (as opposed to closedness), and neuroticism (as opposed to emotional stability) [10]. From these, in this chapter agreeable and antagonistic personalities are engineered for Rity to demonstrate the feasibility of proposed algorithm. By comparing the

**TABLE I**

| Personality Values for the Agreeable and Antagonistic Personalities |
|-------------------------|----------------|----------------|
| Mode | Internal State | Assigned Preference Values | Antagonistic |
| | | \( \psi^A_k \) | \( \psi^A_k \) | \( \psi^A_k \) | \( \psi^A_k \) |
| Motivation | Intimacy | 0.5 | 0.5 | 0.5 | 0.5 |
| | Motivity | 0.5 | 0.5 | 0.5 | 0.5 |
| | Appeal | 0.5 | 0.5 | 0.5 | 0.5 |
| | Greed | 0.5 | 0.5 | 0.5 | 0.5 |
| | Control | 0.5 | 0.5 | 0.5 | 0.5 |
| Humanitarianism | Suffering | 0.5 | 0.5 | 0.5 | 0.5 |
| | Happiness | 0.5 | 0.5 | 0.5 | 0.5 |
| | Surprise | 0.5 | 0.5 | 0.5 | 0.5 |
| | Sadness | 0.5 | 0.5 | 0.5 | 0.5 |
| | Anger | 0.5 | 0.5 | 0.5 | 0.5 |
| | Fear | 0.5 | 0.5 | 0.5 | 0.5 |
| | Neutral | 0.5 | 0.5 | 0.5 | 0.5 |

Considering the personality traits, the preference values of the agreeable and the antagonistic personality models are assigned in between 0 and 1 as in Table I, where \( \psi^A_k \) and \( \psi^B_k \) are preference values for \( k \)th internal state and behavior group, respectively. These values mean user's desired preference and will be used for defining the fitness function. Preference values in the table are denoted by

\[
\Psi = \begin{bmatrix} \psi^A_1 & \psi^A_2 & \ldots & \psi^A_n \\
\psi^B_1 & \psi^B_2 & \ldots & \psi^B_n \end{bmatrix}
\]  

**B. Procedure of Evolutionary Algorithm**

This paper includes an evolutionary algorithm, which maintains a population of genomes, \( G^t_s \), \( s = 1, 2, \ldots, n \), with the form of a two-dimensional matrix, \( P(t) = \{ G^t_1, G^t_2, \ldots, G^t_n \} \) at generation \( t \), where \( n \) is the size of the population.
Procedure EA
begin
  \( t \leftarrow 0 \)
  i) initialize \( P(t) \)
  ii) gene-mask \( P(t) \)
  iii) evaluate \( P(t) \)
  iv) store the best genome \( b(t) \) among \( P(t) \)
  v) while (not termination-condition) do
begin
  \( t \leftarrow t + 1 \)
  vi) select \( P(t) \) from \( P(t - 1) \)
  vii) alter \( P(t) \)
  viii) gene-mask \( P(t) \)
  ix) evaluate \( P(t) \)
  x) store the best genome \( b(t) \)
end

Fig. 3. Procedure of evolutionary algorithm for an artificial creature’s personality.

C. Gene Masking

To build a truly believable one with a specific personality, it is required for the artificial creature to have a proper genome which leads to generate plausible internal states and behaviors. In this regard, a gene masking process is needed to isolate unnecessary genes.

D. Perception Scenario

A series of randomly generated perceptions is applied to the artificial creature and its internal states and behaviors are observed. The perception scenario is designed using stimuli from the environment. Perception scenario 1 is used for evaluating genomes and perception scenario 2 is for verifying the selected genome.

E. Fitness Function

Considering the diverse range of personalities, a well-designed fitness function is needed to evaluate genomes for a specific personality. The procedure of evaluation has the following three steps:

- Step 1: A genome is imported to the artificial creature.
- Step 2: A series of random stimuli in a perception scenario is applied to the artificial creature in a virtual environment.
- Step 3: A fitness is calculated by evaluating its internal states and behaviors.

In Step 2, according to the imported genome it generates internal states and relevant behaviors in response to stimuli. The fitness function can be designed by using the difference between the user’s preference and the following two evaluation functions: one is to evaluate internal states and the other is to evaluate behaviors (see (6)).

**Evaluation function for internal states**

For a fitness one evaluates the possession ratio of each internal state in response to stimuli in a perception scenario for perception scenario time \( t_s \). The possession ratio of the \( k \)th \((k = 1, 2, \ldots, c)\) internal state for \( t_s \), \( \Phi_{p_{ik}}(t_s, G) \), is defined as

\[
\Phi_{p_{ik}}(t_s, G) = \left( \sum_{j=1}^{n} \alpha_j(T_s, G) \right) / \Phi_p(t_s, G), \quad (4)
\]

where \( \Phi_p(t_s, G) \) is the sum of possession value of all internal states defined by

\[
\Phi_p(t_s, G) = \sum_{j=1}^{n} \sum_{k=1}^{c} \alpha_j(T_s, G), \quad (4.\alpha)
\]

**Evaluation function for behaviors**

Given a set of behavior groups \( B_c = [\beta_1, \beta_2, \ldots, \beta_c] \), one examines the frequency of each behavior group for \( t_s \). The frequency of the \( k \)th behavior group for \( t_s \) is defined as

\[
\Phi_{f_k}^{BG}(T_s, G) = f_k^{BG}(T_s, G) / n_{BG}, \quad (5)
\]

where the data set consists of \( n_{BG} = \sum_{k=1}^{c} f_k^{BG}(T_s, G) \) observations, with the behavior group \( \beta_k \) appearing \( f_k^{BG}(T_s, G) \) times for \( k \) \((k = 1, 2, \ldots, c)\).

User sets the relevant preference values \( \psi_k^B \) and \( \psi_k^p \) in (3) for Riry’s personality by his/her preference (Table 1), where each preference value is assigned in between 0 and 1. Since the user’s preference corresponds to the desired personality, the I-genes and B-genes are found to meet the preference by utilizing the preference in the fitness function.

Using (4) and (5), the fitness function is defined as

\[
\Phi(T_s, G) = N \times \left[ \sum_{k=1}^{c} \left( 1 / \psi_k^B \right) \left| \psi_k^p - \Phi_{f_k}^{BG}(T_s, G) \right| \right]
\]

with the normalized preference value, \( \psi_k^I \) and \( \psi_k^B \), defined as

\[
\psi_k^I = \psi_k^I / \sum_{l=1}^{c} \psi_l^I, \quad \psi_k^B = \psi_k^B / \sum_{l=1}^{c} \psi_l^B \quad (6.\alpha)
\]

where \( \Phi_{f_k}^{BG}(T_s, G) \) is the possession ratio of the \( k \)th internal state, \( \Phi_{f_k}^{BG}(T_s, G) \) is the frequency of the \( k \)th behavior group in \( B_c \). \( N \) is a constant number and \( \rho \) a scale factor for the difference terms.

V. EXPERIMENTS

The agreeable and antagonistic personality models were chosen to validate the proposed algorithm and the obtained fittest genome was implanted to Riry to verify the feasibility. The parameter settings were applied equally in both cases of agreeable and antagonistic personalities. The population size was 20 and the number of generations was 1,000.
A. Verification of Evolved Genomes

This section verifies the effectiveness of the algorithm by implanting the agreeable genome A and the antagonistic genome B into two artificial creatures, Rity A and Rity B, respectively, and by observing their internal states and behaviors when perception scenario 2 is applied to them.

Figures 4 and 5 show the experimental results on internal state responses when the perception scenario 2 was applied to agreeable Rity A and antagonistic Rity B, respectively. Figure 4(a) shows a histogram of normalized possession ratios calculated in (4) for the perception scenario 2. The horizontal axis represents the index of 14 internal states and the vertical axis represents the normalized possession ratios of internal states. The 1st, 2nd, and 10th internal states have high possession ratios which indicate strong states of curiosity and intimacy in motivation and happiness in emotion, while the 4th, 5th, 6th, 12th and 13th internal states have low possession ratios which indicate weak states of avoidance, greed, and desire to control in motivation, and of anger and fear in emotion. In contrast, Figure 4(b), '4-Avoidance,' '5-Greed,' '12-Anger,' and '13-Fear' have high possession ratios, while '1-Curiosity,' '2-Intimacy,' '3-Monotony,' '10-Happiness,' and '14-Neutral' have low possession ratios.

Verification on behavior responses

Figure 5(a) shows that the frequencies of the behaviors belonging to the groups such as '1-Curiosity,' '2-Intimacy,' and '10-Happiness' are high. In contrast, Figure 5(b) shows that the frequencies of the groups such as '4-Avoidance,' '5-Greed,' '12-Anger,' and '13-Fear' are high.

For both agreeable and antagonistic genomes, plausible artificial creatures, Rities were observed for all internal states and behaviors simultaneously for the prescribed perception scenario.

VI. CONCLUSIONS AND FUTURE WORKS

This paper presented an overview of the state of the art in ubiquitous robot technology, in the form of the Genetic robot. First the Ubiquitous robot system was presented, and its component subsystems of the Embot, Mobot and Mobots were presented. The function and characteristics of Embots and Mobots were described. The Sobot Rity, which is an artificial creature to implement artificial chromosomes, was presented, and the technique for artificial evolution of personality based on user preferences was briefly. The artificial evolution of personality holds great promise to generate believable artificial creatures which can seamlessly interact with humans in the form of pets. It can therefore be concluded that this technology is poised to completely transform our lives, permanently for the better in the years to come. The future belongs to artificially evolved creatures.

REFERENCES