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Interactive Genetic Algorithm for Designing the Appearance of Software Robot using Homologous Chromosome Representation

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Abstract: A software robot requires plausible external features for intimate interaction with humans. The various appearance designs effectively contribute to provide him/her with an opportunity to select a preferable robot among them. This paper proposes genetic representation for the appearance of software robot, which is inspired by homologous chromosomes. User selection scheme is based on the interactive genetic algorithm. As user evaluates the preference of external features of software robot, proposed algorithm converges to the most preferable appearance to user's choice. The effectiveness of the proposed scheme is demonstrated through experiments.

1. INTRODUCTION

Software robot is called interactive creature, autonomous agent, synthetic character or 3D avatar. It imitates animal or human which has an ability to perform a proper behavior selection and to adapt to the environment (M. Wooldridge [1997] and Y.-D. Kim et al. [2004]). It can become an interactive creature or a friend for human beings. Until now, the software robots have been researched in many directions. Previous most works concentrated on the behavior selection and learning mechanism for a better performance. In general, most works have mainly focused on how to make software robot more intelligent and interactive with humans.

Recently, evolutionary schemes based on biological genetics to imitate natural evolution were applied to the software robot, which possesses an ability to decide a proper behavior and to adapt to the new environment. The software robot was designed with its own genome, where each chromosome consists of many genes. The mechanism of evolution was established with the genome as the essence to define the personality of the software robot and to pass on its traits to the next generation (J.-H. Kim et al. [2005], J.-H. Kim et al. [2006] and J.-H. Kim and C.-H. Lee [2008])

Lots of research is being conducted for the development of software robot in virtual environment to provide interactions with user. In this point of view, the design as well as the personality of software robot is an important issue for its naturalness. The naturalness can be enhanced if external features can be represented with more diversity (Cynthia Breazeal [2004]). One of main reasons why human may not feel a robot as a living creature may be a uniform design. The dog, naturally, is unique because it is similar with others, yet, still different with others. Similarly, if all robots are recognized differently and have their own characteristics, people may feel a robot more like a real creature.

Every creature has been evolved for a very long time for survival. All species should preserve their own variety. Otherwise, they cannot survive anymore because the environment always changes. The variety does not mean various behaviors of one individual, but it means there are various individuals in one species group. The fundamental component in which most species can preserve their own variety is homologous chromosomes. The homologous chromosomes make it possible to inherit various combination of genetic information (Neial A. Campbell [2002]). This is what genetic variability contributes. Software robot can be also various by adopting the homologous chromosome representation.

Interactive GA has been used in a wide variety of artistic applications, engineering applications and edutainment applications (S.-B. Cho [2002]). In artistic applications, interactive GA has been applied to generating montage of face images (C. Caldwell and V.S. Johnston [1991]), creating 3-D CG lighting (K. Aoki and D. Takagi [1997]), creating 3D designs with structured directed graph (H.-J. Min and S.-B. Cho [2000]), and for the design of clothes (H.-S. Kim and S.-B. Cho [2000]).

This paper proposes a scheme for generating a software robot with the most preferable design by interactive genetic algorithm based on homologous chromosome representation. In order to converge to the most favorable one, user selects or evaluates the degree of preference to the generated robots with various appearances at each generation. Additionally, a novel crossover technique, which can be utilized in the proposed genetic representation, is introduced to have various individuals.

This paper is organized as follows. Section II presents homologous chromosomes, genetic variability and phenotype characteristics. Section III introduces the interactive genetic algorithm and proposes appearance genes of homologous

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chromosome structure. Section IV describes experimental results and concluding remarks follow in Section V.

2. HOMOLOGOUS CHROMOSOMES

In humans, a typical body cell has 46 chromosomes. Each duplicated chromosome has a twin that is always identical in length and centromere position during metaphase of mitosis. Altogether, three are 23 such matched pairs of duplicated chromosomes in human. Other species have different numbers of chromosomes, but these, too, are usually matched pairs. The two chromosomes of such a pair are called homologous chromosomes because they both carry genes controlling the same inherited characteristics.

Every species is grouped various individuals. They look similar, but not the same. The process of meiosis and the crossing over of homologous chromosomes contribute genetic variability. Fig. 1 shows how the arrangement of homologous chromosome pairs at meiosis affects the result. In this case, there are two possible ways for varied offspring. Crossing over is the exchange of corresponding segments between two homologous chromosomes. Fig. 2 illustrates how crossing over can produce new combination of genes. If there were no crossing over, meiosis could produce only two genetic types of gametes. Most chromosomes contain thousands of genes and that multiple crossovers can occur in each homologous pair, it is no wonder that gametes and the offspring that result from them can be so varied (Neial A. Campbell [2002]).
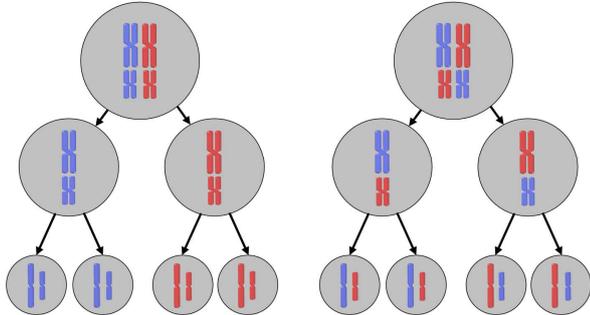

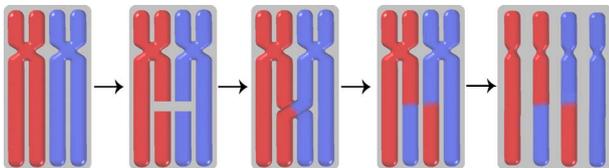Fig. 1. Results of the independent orientation of chromosomes at meiosis.

Fig. 2. Crossing over

An organism's appearance does not always reveal its genetic composition. The geneticists distinguish between an organism's expressed characteristic, called its phenotype, and its genetic makeup, called its genotype (Neial A. Campbell [2002]). The homologous chromosomes have genes for the same characteristics located at the same positions along their lengths. If the two genes of a pair are different alleles then one is fully expressed while the other has unnoticeable effect on the organism's appearance. In this case, the expressed one is called the dominant allele and the other is called the

recessive allele (Fig. 3a). Other than some characteristics, the hybrids have an appearance in between the phenotypes of the two parental varieties and an effect called incomplete dominance (Fig. 3b).

Fig. 3. Phenotype characteristics

However, many genes have multiple alleles. Although each individual carries, at most, two different alleles for a particular gene, in cases of multiple alleles, more than two possible alleles exist in the population. The ABO blood groups in humans are one example of multiple alleles. Moreover, a single gene may affect many phenotypic characteristics or a single characteristic may be influenced by many genes (Neial A. Campbell [2002]).

3. INTERACTIVE GENETIC ALGORITHM

Interactive genetic algorithm (Interactive GA) is almost the same as GA except the fitness evaluation method. GA calculates a fitness function to evaluate the fitness, but in interactive GA user decides the fitness for each individual. Thus, the outcome is subjective to the user. The procedure of a simple interactive genetic algorithm is as follows (H.-S. Kim and S.-B. Cho [2000] and M. Shibuya et al. [1999]):

$t = 0$
Initialize population $P(t)$
Evaluate $P(t)$
While(terminal condition is not satisfied)
    $t = t + 1$
    $P'(t)$ = Select parents $P(t)$
    Recombine $P'(t)$
    Crossover $P'(t)$
    Mutate $P'(t)$
    Evaluate $P'(t)$
    $P(t)$ = Survive $P'(t)$
End While

3.1 Appearance Genes

The genes determining the appearance of the software robot are known as appearance genes. Essential features of the software robot should be initially selected in order to define the appearance genes. They are expressed as numerical values, where these values are encoded in the form of homologous chromosomes consisting of appearance genes. The appearance genes are utilized for inheriting external features of software robot. Appearance elements can be distinguished into specific shapes, i.e. size, color, thickness, etc. If the robot mimics a dog, these specific features are defined by standard features of breeds in the American Kennel Club, i.e. head, neck, body, legs, tail, coat and so on.

Appearance genes are provided for a software robot Rity, modeling a dog, designed in RIT Lab of KAIST (J.-H. Kim et al. [2005]). Nine external features of Rity are shown in Fig. 4. The chromosome consisting of appearance genes includes nine external features representing body, leg, head, eyes, pupil, eyebrow, ear, nose, and tail. Each external feature is composed of color and part size rate of original software robot's size by real number. Fig. 5 shows one example of homologous chromosomes consisting of appearance genes. In this case, the brightness of each gene signs its value. The color of each external feature is formed with red, green, and blue elements which take a decimal value between 0 and 1.

The size of external feature is generated between 0.8 and 1.2, which is the relative standard size rate. There are physical constraints between external features based on the linkages (Fig. 6). For balanced external features, the size of the child part depends on the size of the parent part. For example, when body size is 0.9 and leg size is 0.8, then represented leg size is 0.72.
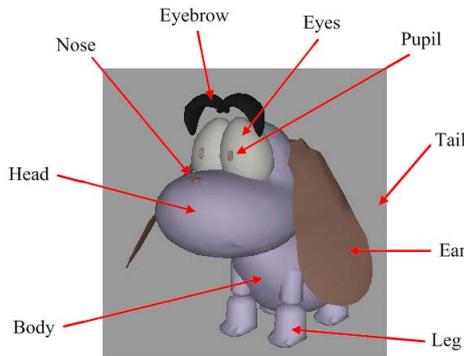

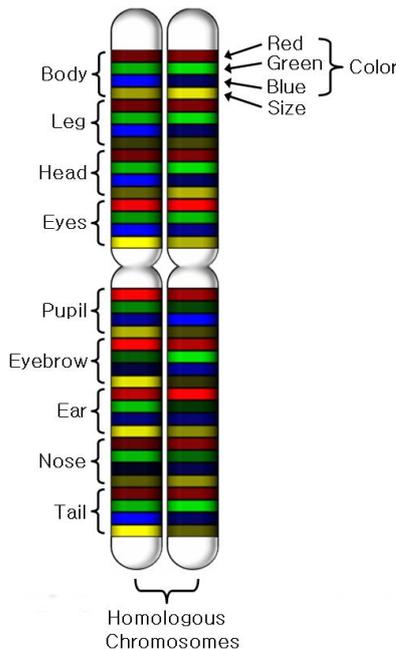Fig. 4. External features of Rity

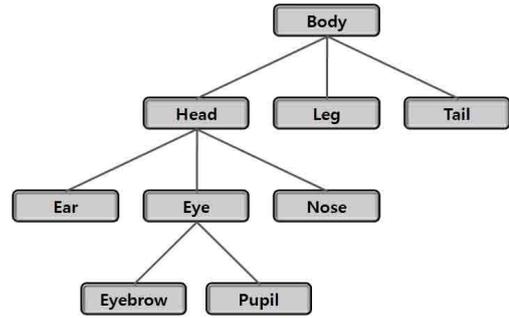Fig. 5. Homologous chromosome consisting of appearance genes

Fig. 6. Physical linkage of external features of Rity

3.2 Inheritance Process

The inheriting process of the software robot defined by appearance genes is based on four steps: crossover occurring in homologous chromosomes, mutation wherein one gene is changed onto a new gene, meiosis determining chromosome delivered to a descendant and generating inherited offspring.

Crossover occurs when the value, generated by random decimal number generation between 0 and 1, is less than crossover rate. Chiasma points are determined by randomly generated integer number between 1 and 35 as shown in Fig. 7. N point crossover algorithm for appearance genes is as follows:

```
IF ( RandomRealNumber(0,1) < Crossover Rate )
    LOOP n = 1 to N
        p = RandomIntegerNumber(1,35)
        Swap two sides of all genetic value after pth one
        END LOOP
END IF
```
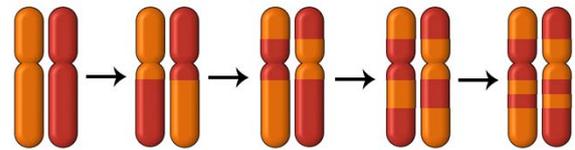

Fig. 7. 4 point crossover of homologous chromosomes

Mutation occurs when the value, randomly generated decimal value between 0 and 1, is less than the mutation rate. Mutating gene and side are determined by randomly generated integer numbers between 1 to 36 for a location of gene and 0 or 1 for side. The mutation algorithm is as follows:

```
IF ( RandomRealNumber(0, 1) < Mutation Rate )
    p = RandomIntegerNumber(1,36)
    side = RandomIntegerNumber(1,2)
    IF (side == 1)
        Mutate pth value in LEFT SIDE of chromosome
    ELSE
        Mutate pth value in RIGHT SIDE of chromosome
    END IF
END IF
```

In meiosis, one strand of the chromosome is selected. In the next step, the strand mates with the other one and forms completed homologous chromosomes. Impartially a selection rate is one half.

The last step is generating new offspring. Two parents are needed in order to generate the offspring. Each parent inherits his/her single strand of the chromosome, which is selected through meiosis, to new robot designs. Fig. 8 illustrates these four overall steps.
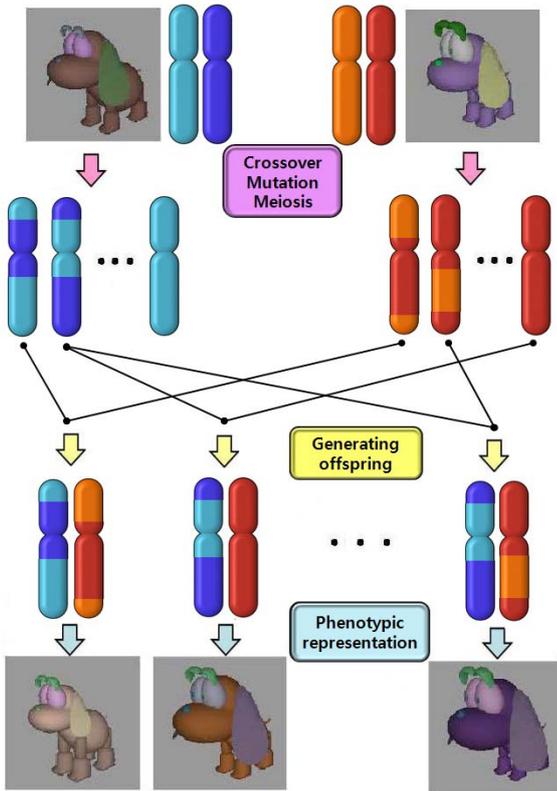

Fig. 8. Inheritance of Rity

3.3 Phenotypic Representation

The appearance genes are initially generated by random. Thus, infinite number of alleles in appearance gene, i.e. size and color, can exist unlike humans who possess only three alleles of blood type. In order to pursuit a diversity of offspring, every allele takes incomplete dominance with each other. Therefore, each software robot's appearance design is represented by its phenotype, which is determined by taking the average of a pair of corresponding appearance gene.

4. EXPERIMENTS

Software robot, Rity, which was used in this experiment, was modeling a dog with 3D studio MAX. In the experiment, 36 genes representing the size and color of the external features of software robot were initially defined. The population of one generation was composed of 10 individuals. The initial population was randomly generated in a specific domain of each gene. Once the user selects two individuals which catch

his or her preference, then program creates next generation of appearance gene using these two selected individuals. We used four point crossover, crossover rate of 0.4 and mutation rate of 0.05. Crossover point and mutation gene were decided probabilistic algorithm discussed in previous section. Each experiment was carried out until the user could not distinguish any differences in 10 individuals (Fig. 9).

It took 10 experiments to obtain an individual suitable for the user's preference. Appearance gene of each part was encoded by numerical number. The average of standard deviations of each part, M in (1), was used as convergence measurement, which is shown as follow:

$$GSD_p = \sqrt{\frac{\sum_{i=1}^{10}(AGV_p - GV_p^i)^2}{10}} \quad (p = 1,2,\cdots,36)$$

$$M = \frac{\sum_{j=1}^{36}GSD_j}{9}$$

(1)

where $GSDp$ is a standard deviation of the pth phenotype values of 10 individuals, $AGVp$ is an average of 10 individual's pth phenotype values, and $GVpi$ is a pth phenotype value of ith individual

Fig. 10 represents that individuals of each generation are converging. Generating a preferable software robot from randomly initialized group proved that the proposed homologous chromosome structure successfully generated various individuals. Nevertheless, several experiments did not converge well due to the influence of certain crossover condition. For example, when the user selects a middle sized robot design, often the values of size genes were set as big or small values. In this case, subsequently generated offspring were also created as big or small sized ones along with medium ones. Moreover, as the termination time of the experiment was decided by the user, the experiment might be concluded even when all 10 individuals did not converge. This resulted in the discrepancy in the results.

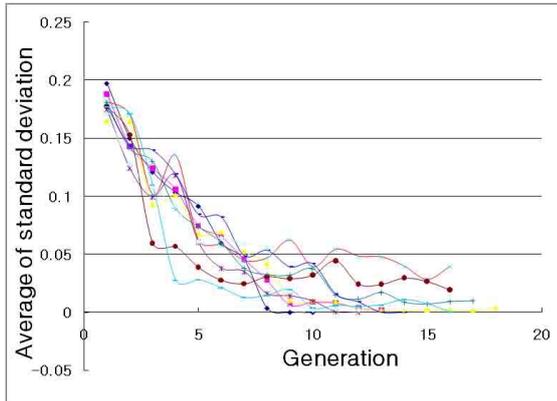Fig. 9. Experiment result (1st, 5th and 10th generations)

Fig. 10. The average of standard deviations for nine

5. CONCLUSION

This paper proposed homologous chromosome structure with appearance genes of software robot, Rity. The software robot with the most preferable design was selected using the interactive genetic algorithm. This technique was successfully applied in the appearance design of the software robot, Rity, which was modeled as a virtual dog. The application of this technique resulted in the generation of a multitude of physical forms of the software robot. The interactive genetic algorithm further refined this process allowing us to choose a desired robot appearance from the plethora of possible choices.

Even though the homologous chromosome structure was only applied for appearance genes, it can also be applied to genes defining character or behavioral characteristics of the software robot. A possible future works is to attempt a law of dominance, wherein one gene could affect many characteristics of inheritance or alternately many genes that could affect only one characteristic of inheritance. Also, the chromosome structure can be extended as an algorithm in order to construct a creature using parameterized values.

It is said that "Variety is the spice of life." The immense promise shown by this method in the generation of different appearances can definitely add the spice to the development of interactive software robots in the near future leading to a more comfortable human-software robot interaction.

REFERENCES

C. Caldwell and V.S. Johnston (1991). Tracking a criminal suspect through "face-space" with a genetic algorithm. *4th Int'l Conf. on Genetic Algo-rithms (ICGA '91)*, San Diego, CA, July, pp.416~421.

Cynthia Breazeal (2004). Social Interactions in HRI: The Robot View. In: *IEEE Transactions on System, Man, Cybernetics Part C, Applications and Reviews*, vol. 34, no. 2, pp. 181-186, May.

H.-J. Min and S.-B. Cho (2004). Creative 3D Designs Using Interactive Ge-netic Algorithm with Structured Directed Graph. In: *Proceedings of 8th Pacific Rim International Conference on Artificial Intelligence*, vol. 3157, Aug., pp. 391-400.

H.-S. Kim, S.-B. Cho (2000). Application of interactive genetic algorithm to fashion design. *Engineering Applications of Artificial Intelligence*, vol . 13, issue 6, Dec., pp. 635-644.

J.-H. Kim, C.-H. Lee (2008). Multi-objective evolutionary generation process for specific personalities of artificial creature. In: *Computational Intelligence Magazine*, IEEE, vol. 3, issue 1, Feb., pp. 43-53

J.-H. Kim, K.-H. Lee and Y.-D. Kim (2005). The origin of artificial species: genetic robot. In: *International Journal of Control, Automation, and Systems*, vol. 3, no. 4, pp. 564-570, Dec.

J.-H. Kim, K.-H. Lee, Y.-D. Kim, and I.-W. Park (2006). Genetic representation for evolvable artificial creature. In: *Proceedings IEEE of the Congress on Evolutionary Computation*, Vancouver, Canada, pp. 6838-6843, Jul.

K. Aoki, D. Takagi (1997). 3-D CG Lighting with an Interactive GA. In: *Proceedings of First International Conference on Knowledge-Based Intelligent Electronic Systems*, vol. 1, May, pp. 296-301.

M. Shibuya, H. Kita and S. Kobayashi (1999). Integration of Multi-objective and Interactive Genetic Algorithms and its Application to Animation Design. In: *Proceedings of IEEE International Conference on System, Man, and Cybernetics*, vol. 3, Oct., pp 646-651.

M. Wooldridge (1997). Agent-based Software Engineering. *IEE Proc. Software Eng.*, vol. 144, no. 1, Feb., pp. 26-37.

Neil A. Campbell, Jane B. Reece, Lawrence G. Mitchell, Martha R. Taylor (2002). *BIOLOGY Concepts & Connections*. Fourth Edition, Benjamin Cummings.

S.-B. Cho (2002). Towards Creative Evolutionary Systems with Interactive Genetic Algorithm. *Applied Intelligence*, vol. 6, no. 2, Mar., pp 129-138.

Y.-D. Kim, J.-H. Kim and Y.-J. Kim (2004). Behavior selection and learning for synthetic character. In: *Proceedings IEEE of the Congress on Evolutionary Computation*, Portland, USA, Jun., pp. 898-903