

Innovative Design and Making of Bionic Robot Rabbit

Hsin-Sheng Lee Kuo-Huang Lin and Yi-Yueh Hsu

Abstract—In order to improve the leaping function of robots, the documented information of bionic robots is collected for the study and analyzed according to existing mechanisms. The ideal design with application of the innovative design theory “TRIZ” was used as a basis of innovative design for bionic robot rabbits, so the plan that complies with the design demand can be allocated. In this study, the intelligent robot by Dr. Bioloid was used as the original mechanism for innovative combination and making of the bionic robot rabbit. Motion editors were used to program the behavior model of the robot rabbit, simulate structures, control and sport skills of rabbit, as well as selecting rabbit movement characteristics and recording the rabbit leaping forms with the motion editor, behavior controller and connection program. The motion smoothness for the innovative plan was also modified, so the behavior model of the bionic robot rabbit can be provided with more bionic, obstruction prevention and remote control functions. The results from this study can be used to verify the feasibility of a bionic robot rabbit, which helps improve the functions of the bionic robot.

Index Terms—Bionic robot rabbit, Innovative design, TRIZ.

I. PREFACE

Electronic pets include categories such as technological toys, motion intelligence, 3C entertainment or home appliances, as well as simulated interaction. In addition to entertainment and being fun, the key element of evolution is the use of technology that allows electronic pets to have technological characteristics such as artificial intelligence, human-machine interaction and emotions. In order to develop the electronic pets with bionic, leaping, obstruction preventive and remote control functions, relevant documents of bionic robots were discussed in this study by application of the innovative design theory TRIZ (Theory of Inventive Problem Solving) to pursuit the innovative solution for the bionic robot rabbit, so it is capable of interaction, obstruction prevention and steady forward leaps, for which the innovative plan can be prototyped.

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II. INNOVATIVE DESIGN THEORY

The acronym “TRIZ” is derived from the Russian phrase “Teoriya Resheniya Izobretatelskikh Zadatch” and translated as “Theory of Inventive Problem Solving” in English, which emphasizes that invention or innovation can be implemented according to certain procedures and steps instead of mere brainstorming that compiles group opinions. “TRIZ” was proposed by Genrich Altshuller, the Russian engineer who analyzed and studied 200,000 technological characteristic patent cases, where he found that the same problems and technique of problem solving co-existed in the innovation and invention of different fields. Genrich Altshuller had compiled 40,000 patents and systematically arranged them into various question modes. The procedures and solving methods of invention and innovation were proposed further to generate a series of concepts on innovative design and effectively shorten the design duration, which was very effective for producing innovative problem solving within a short time [1]-[3].

In this study, the ISQ (Innovation Situation Questionnaire) under the TRIZ theory was used to analyze the definition. The ideal design tool was used as the basis of systemized innovative design for the bionic robot rabbit, which allocated the plan that provides functions of interaction, obstruction prevention and steady forward leaping.

A. ISQ

In this study, the original mechanism of bionic robots was analyzed and defined according to ISQ:

1. Information of the system to be improved

(1)Name of system: Bionic robot.

(2)Main useful functions of the system: Capable of human motion ability and movement.

(3)Structure of the system: Intelligent robot by Dr. Bioloid [4] that consists of a CM-5 controller, a DC servo motor module, a sensor module, a frame set, an external power cable and a rechargeable Ni-H battery. Dr. Bioloid was shown in Fig.1.



Fig.1. Dr. Bioloid [4]

(4)Function of the system: A bi-ped robot in human shape was assembled with the frames of Dr. Bioloid's intelligent robot and bionic actions were added into the control functions of the motion script program. Various actions were linked as a behavior mode by application of a behavior control program. The written program was transmitted to the CM-5 controller in the robot and data was sent data to control the DC servo motor module via external power cable, so the robot can be operated and can execute complete behavior mode.

(5)System environment: laboratory.

2. Available resources

(1)Substance resources: Metals, plastics.

(2)Field resources: Electrical power.

(3)Functional resources: Bionic and intelligent robot.

(4)Informational resources: Position, sound and shape of motor.

(5)Time resources: Duration needed for the motor to complete an action.

(6)Space resources: Space for robot assembly.

3. Information about the problem situation

(1)The drawbacks expected to be improved for the system: Unstable walking of the anthropomorphous robot.

(2)The cause of drawbacks: Since the center of gravity for the bi-ped robot was too high and it could easily lose balance, the robot would tip over whenever it walked into an obstruction.

(3)History of problem development: The mechanism of walking on two pedals was considered during development of the anthropomorphous robot. After completion of assembly and programming, since the height of controller for the bi-pad anthropomorphous robot was too far from the ground, it could easily lose balance.

(4)Other problems to be solved: Insufficient power and output.

4. Changing the system

(1)Allowable changes to the system: Methods of movement and assembly.

(2)Limitations to change the system: Stable movement of the robot that achieves bionic functions.

5. Criteria for selecting solution concepts

(1)Desired technological characteristic: Achievement of bionic functions.

(2)Desired economic characteristic: Mainly based on practicality.

(3)Desired degree of novelty: Bio-simulation.

6. History of attempted solutions to the problem

(1)Previous attempts to solve the problem: 6-pad and 4-pad robot that simulated insects.

(2)Similar problems existed in other systems: Pet robots.

B. Idealization

Altshuller has developed the idealized design to emphasize that within its life cycle, any technical system can become more reliable, simplified and efficient; in other words, more idealized. To improve a technical system, such system is expected to be closer to idealization, which means

that the system requires less cost, space and wastage of resources. In this study, the ideal design method of TRIZ was used to provide rules that brought the solution closer to result of ideal design and achieve the final solution of idealization. The steps and contents are given as follows:

(1)Final objective of the design: To develop a bionic robot that is capable of multi-functional interaction with the user. In case of confronting obstruction, such robot shall be able to avoid, leap, climb stairs or cross over obstructions.

(2)Ideal solution: To develop a multi-functional bionic robot with walking, remote control, voice control, automatic obstruction prevention or capability of mission execution when confronting the obstruction functions. Such a robot must also be able to leap for increasing its dimension and range of movement; moreover, the momentum of leaping must help the robot to avoid danger.

(3)The obstruction to achievement of idealization: At present, the bi-pad anthropomorphous robot walks slowly with an unstable balance and it falls easily. If the leaping movement is added, the robot becomes extremely unstable upon landing and it will bend forward or backward easily.

(4)Result under obstruction: When the bionic robot leaped and landed in case of obstruction, it would bend forward or backward and lose balance. In addition, the walking speed of the bi-pad robot needed to be designed at a slow pace and this would limit the interaction with the user due to speed, which made it impossible to implement more interaction modes and commands from the user.

(5)Condition for eliminating such obstructions: The change of robot assembly will allow it to walk steadily. The program of the interactive mode shall be re-written, so the multi-function modes of walking, remote control, voice control, automatic obstruction prevention or capability of mission execution when confronting the obstruction can be provided.

(6)Applicable resources for creating these conditions: Frames, re-chargeable battery, motor and computer.

From the discussion above for final idealization, two methods were used in this study to propose the solution:

(1)Replacement of components: Since the original mechanism was provided by a bi-pad robot that was unstable and bent forward or backward when landed, the method of assembly must be replaced.

(2)Amendment of the operation principle: The program of interactive mode shall be re-written, to provide the multi-function modes of walking, remote control, voice control, automatic obstruction prevention or mission execution capability when confronting obstructions.

In this study, the assembly method for the original mechanism was replaced from bi-pad robot to 4-pad robot, where the rabbit was taken as a subject of study for writing the behavior control program of motion simulation, interaction, remote control and obstruction prevention


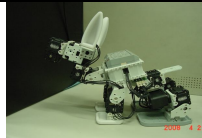
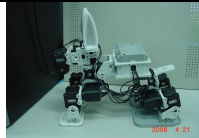
III. ASSEMBLE AND MOTION ANALYSIS OF THE BIONIC ROBOT RABBIT

The assemble, motor analysis and control procedures of the bionic robot rabbit are described below:

A. Robot Rabbit Assembly

Firstly, observe movements and postures of the rabbit and record the form of its leaping motion; then use Dr. Bioloid' s robot [4]-[5] to assemble a 4-pad robot with a similar appearance to a rabbit. In this study, three models (M-01~M-03) of bionic robot rabbits were assembled for comparison of strengths and weaknesses as shown in Table 1. Since bionic robot rabbit M-03 showed most stable landing from leaping, M-03 was adopted as the assembled model of robot rabbit for consequent motion analysis and control.

Table 1. Three assemble models (M-01~M-03) of bionic robot rabbits

M-01	M-02	M-03
		

B. Motion Analysis and Control

For control functions in the motion script program, the movements of a rabbit were imitated for designing the leaping motion of the robot rabbit. The motion script program was then utilized to link various motions into complete behavior mode. The written program was transmitted to the CM-5 controller for operation of the robot rabbit and implementing the bionic behavior thoroughly. For example: The robot rabbit would march forward and leap when a command was placed. By repeating the practical operation and study, the balance and smoothness of the leaping action performed by the bionic robot rabbit can be modified accordingly.

In this study, the program of motion simulation, behavior control and correction of leaping action for the robot rabbit was written:

(1) Motion simulation

The function of motion simulation was added into the control program of motion script (Fig. 2). The postures of the rabbit were observed, recorded and written into the motion script and edited with script numbers. The script included forward, backward, standing, left and right facing motions. The DV was then used to actually film and record the leaping posture of rabbit. The software Sony Vegas 7.0 was used to cut out break-down posture of rabbit leaping and these postures were plotted with Illustrator cs3, so the leaping posture of the bionic robot rabbit can be edited with ease. Lastly, the bionic robot rabbit was operated for observation on balance and stability of its motions, so the improvement can be implemented constantly to achieve the leaping movement required under this study. The editing of leaping postures for robot rabbit M-03 are shown in Table 2.

(2) Behavior control

In this study, the internal actions of controller CM-5 were backup into the computer. The behavior control

program was then applied to link the motions into a behavior mode. The program for bionic robot rabbit was written according to the design requirement for executing the following behavior modes:

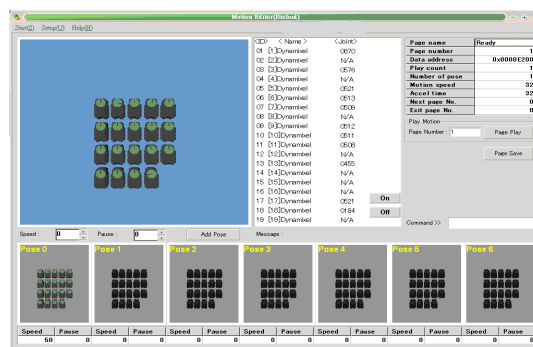


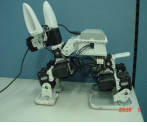


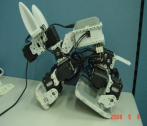


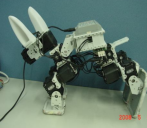





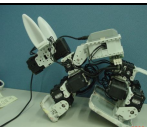


Fig.2. Control program of motion script

Table 2. Editing of leaping postures for robot rabbit M-03

Title	Motion style	Motion record	Motion edit
Step 1. Preparation			
Step 2. Prepare to bounce			
Step 3. Post-leg is bouncing			
Step 4. Pro-leg is touchdown			
Step 5. Touchdown			


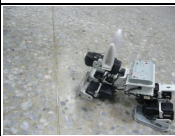
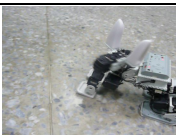






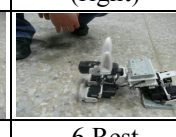


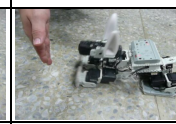






(a) Interaction:

Walking: When the user steps forward, the robot rabbit will sense the user' s direction and step forward along with the user. When the robot rabbit is too close to the user or senses the user in two directions, it will stay stationary and continue with the walking function after confirming the user' s direction.

Sensing: The user can utilize clapping and sensing of palm distance to control the motion mode of the robot rabbit and achieve the interactive effect. The robot rabbit would be under resting status at the beginning. When the user clap hands once, the robot rabbit will sit up and shake its head. When the user claps twice, the robot rabbit will stand up and

shake its head. When the user's palm is sensed at the front, the rabbit will retreat backwards. When the user's palm is sensed at the right hand side, the rabbit will lean left, and vice versa. The interactive mode is shown in Table 3.

Table 3. Interactive mode

Rest	 Rest		
Claps one time	 1. Setting out	 2. Shaking head (left)	 3. Shaking head (right)
Claps two times	 1. Setting out	 2. Standing	 3. Standing and Shaking head (right)
	 4. Standing and Shaking head (left)	 5. Touchdown	 6. Rest
Front sensing	 1. Sensing	 2. Backlash	 3. Backlash
Right sensing	 1. Sensing	 2. Left	 3. Left
Left sensing	 1. Sensing	 2. Right	 3. Right

(b) Remote control:

The user can use a remote controller to control the walking direction and motion mode of the robot rabbit from afar. In this study, the ZIG-100 (ZigBee) module was operated via behavior control, which is used to give commands and further display the communication code of ZigBee [6].

(c) Obstruction prevention:

When the robot rabbit senses an obstruction, it will walk towards the opposite direction of the obstruction or climb over it by leaping, which are shown in Table 4 and 5.

(3) Correcting leaping motion of the robot rabbit

Put the robot rabbit into practical leaping and record the leaping height and motion. If the design requirement is not met, modify the program, moving the angle and speed of the motor, so the leaping height can be increased.

Table 4. Obstruction prevention mode-1

















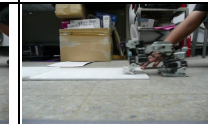




Front sensing (have obstacle)	 1. Sensing	 2. Backlash	 3. Backlash
	 4. Right	 5. Right	 6. Sensing
Front sensing (haven't obstacle)	 1. Advance	 2. Advance	 3. Sensing
Left sensing	 1. Sensing	 2. Right	 3. Sensing

Table 5. Obstruction prevention mode-2

 1. Preparation	 2. Preparation	 3. Leaping
 4. Advance	 5. Touchdown	 6. Preparation
 7. Leaping	 8. Touchdown	 9. Preparation

IV. CONCLUSION

In this study, Dr. Bioloid's intelligent robot was used for re-assembly and manufacturing of the robot rabbit. The motion editor was used to write behavior modes of the robot rabbit. With the motion editor, behavior controller and connection program, the motional smoothness of the robot rabbit were modified from imitating structure, control and sporting skills of the rabbit, selecting motion characteristics of the rabbit and recording the motion form of rabbit leaping, which allowed more bionic, interactive, obstruction preventive and stable leaping forward functions for the

motion mode. The results from this study verified the feasibility of a bionic robot rabbit, which could be helpful to improve the functions of bionic robots and used as a reference case for bionic robot development.

REFERENCES

- [1] Semyon D. Savransky, "Engineering of creativity: introduction to TRIZ methodology of inventive problem solving", CRC Press, New York, 2000.
- [2] John Terninko, Alla Zusman and Boris Zlotin, "Systematic innovation-an introduction to TRIZ (Theory of inventive problem solving)", New York, 1998.
- [3] Ideation International Inc, "Tools of classical TRIZ", 1999.
- [4] Intelligent Data Miner Inc. <http://www.idminer.com.tw/>
- [5] Intelligent Data Miner Inc., "Integrated application of motion communication and robot", 2007.
- [6] W. K. Park, I. Han, K. R. Park, "ZigBee based dynamic control scheme for multiple legacy IR controllable digital consumer devices", *IEEE Transactions on Consumer Electronics*, vol. 53, no. 1, 2007, pp.172-177.