The Development of the Eye-System for the Intelligent Huggable Robot ANTY

K. Goris[1], J. Saldien[1], B. Vanderborght[1], B. Verrelst[1], R. Van Ham[1], D. Lefeber[1]
[1]Vrije Universiteit Brussel, Department of Mechanical Engineering,
Robotics & Multibody Mechanics Research Group,
Pleinlaan 2 – 1050 Brussels – Belgium
kristof.goris@vub.ac.be, jelle.saldien@vub.ac.be,
http://anty.vub.ac.be

Abstract: **The purpose of this study is to design and develop an anthropomorphic based eye-system, used in the intelligent huggable robot ANTY. The intelligent huggable robot ANTY aspires social children-robot interactions relying on face-to-face communication. The anatomy of an anthropomorphic eye and its movements are presented and linked to the design of the artificial robot eye-system.**

Keywords: **huggable robot, artificial eyes, complaint actuation, human robot interaction, emotional communication**

I. Introduction

Two classes of robots that interact with children or humans in general can be considered: those developed by private companies, whose goal is purely commercial, and those developed by universities, focusing on the dynamics of human-robot interactions [1]. Besides that we notice a growing trend in humanoid robotics to reduce the size of robots in order to lower their building costs. By using low cost consumer grade components, we can pave the way for widespread use of humanoid robots in education, health-care, science, and entertainment [2]. As the state of the art among robots developed by private enterprises, we can cite Honda ASIMO [3], Sony QRIO [4], AIST paro [5], HASBRO furby [6], Sega Near Me Cat [7] Among the robots developed by research groups, we can cite WABIAN [8] from the Waseda university in Japan, CLA and KENTA [9], [10] from the Tokyo university, COG [11], Kismet [12] and Leonardo [13] from the MIT, ROBOTA [14] from the EPFL of Suisse or ARMAR [15] from Karlsruhe university.

The purpose of the ANTY project is to develop the intelligent huggable robot ANTY, an interactive communication system that will be devoted to hospitalized children [16]. We aim at developing/building a miniature child-friendly pet-type robot, approximately 60 [cm] tall, build of low cost consumer grade components, that communicate emotionally in an environment where human beings and robots coexists. Currently there are several pet-type robots produced as a real communication medium or as a test bed to investigate the possibility of coexistent with humans [17], [18]. The robot ANTY aims to be both, and will be used as a research platform to investigate the medical, psychological, and social condition and consequences of hospitalized children.

II. The Huggable Robot ANTY

The intelligent huggable robot ANTY aspires social children-robot interactions. Such educational and entertaining applications of robots have created a demand for robots showing a number of social skills. These skills include the capacity to imitate, to interpret gestures, to recognize and to show emotions [19]. Different systems are required to perform these skills, in ANTY's head for example: a couple of eyes and eyelids, a mouth with a trunk, two ears and a neck. The use of the robot ANTY as part of studies with hospitalized children sets a number of constraints on its design. In particular, it requires that the robot bears a living huggable pet likeness. Besides aesthetics, including looks and natural movements, it is fundamental to provide the robot with sensory capabilities, such as speech and vision, which are the basis of child-robot interactions.

The development of a prototype started some months ago. First the head of the robot will be developed, mainly for one reason: in our daily life we rely on face-to-face communication and the face plays a very important role in the expression of character, emotion and/or identity [20]. Mehrabian showed that only 7% of information is transferred by spoken language, that 38% is transferred by paralanguage and 55% of transfer is due to facial expressions. Facial expression is therefore a major modality in human face-to-face communication [21].

Although we aim a pet-type robot, we base the design on natural anthropomorphic behavior. This puts also constraints on its design, and requires the knowledge of anatomy of anthropomorphic eyes and its movements. The imitation of its movements gives the impression of being natural. Besides that eye-gaze based user interfaces is a powerful social cue that people use to determine what interests others. By directing the robot's gaze to the visual target, the person interacting with the robot can accurately use the robot's gaze as an indicator of what the robot is attending to. This greatly facilitates the interpretation and readability of the robot's behavior, since the robot reacts specifically to what it is looking at [22]. The phenomenon that occurs when two people cross their gaze is called eye contact, and it enables communication [23]. The same phenomenon between robot and child will be used.

III. Anthropomorphic Eyes

Within this paragraph we refer to anatomical knowledge of anthropomorphic eyes, and we describe some of its movements. Let's focus on the anatomy of the eye and its support in the skull. In many species, the eyes and its appendages are inset in the portion of the skull known as the orbits or eye sockets. The movements of different body parts are controlled by striated muscles acting around joints. The movements of the eye are no exception. Each eye has six extraocular muscles that control its movements: the *lateral* *rectus*, the *medial rectus*, the *inferior rectus*, the *superior rectus*, the *inferior oblique*, and the *superior oblique*. When the muscles exert different tensions, a torque is exerted on the globe causing it to turn. This is an almost pure rotation, with only about one millimeter of translation [24]. So we can consider that the eye undergoes rotations about a single point in its center. A seventh extraocular muscle, the *levator palpebrae superioris* is the muscle in the orbit that elevates the upper eyelid. Fig.1 shows the eye support in the orbit and the paths of the extraocular muscles. The four *rectus* muscles have their origin in the back of the orbit in a fibrous ring called the *annulus of Zinn*. They course forward through the orbit and insert onto the eye globe in front of the eye's equator at the four main wind directions of a compass-card. The *oblique* muscles follow more complicated paths. The *superior oblique's* origin is at the back of the orbit, and courses through a pulley, turning sharply across the orbit, and inserts the eye globe on the lateral, posterior part. By passing the top of the eye and by going backwards for the last part of its path; it pulls the eye downward and lateral ward. The inferior oblique originates at the lower front, and passes under the eye to insert on the lateral posterior part of the globe; it pulls the eye upward and lateral ward [25].

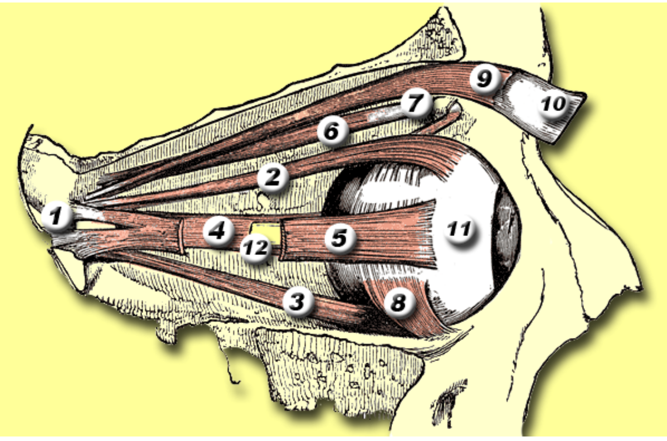

Fig.1 Extraocular muscles and their paths: 1. Anulus tendineus communis, 2. Superior rectus, 3. Inferior rectus, 4. Medial rectus, 5. Lateral rectus, 6. Superior oblique, 7. Trochlea, 8. Inferior oblique, 9. Levator palpebrae superioris, 10. Eyelid, 11. Eyeball, 12. Optic nerve. [26]

Animals with compound eyes have a wide field of vision, allowing them to look in many directions. To see more, they have to move their entire head or even body. Eye movements are very important for visual perception. A small area of the retina, called the fovea, has a very high visual acuity. To get a clear view, the brain must turn the eyes so that the image of the object of regard falls on the fovea. Let's focus now on the anthropomorphic eye movements. Eye movements can be classified different ways. In general eye movements are either *ductions*, *versions* or *vergences*. An eye movement involving only one eye is called a duction. When both eyes move in the same direction we call it a version. When both eyes move in the opposite direction we call it a vergence. The two eyes converge to point to the same object, and maintain single binocular vision. Vergence movements are closely connected to accommodation of the eye. Changing the focus of the eyes to look at an object at different distances will automatically cause vergence and accommodation [24],[25].

More specific literature classifies seven eye movements, as they are: *saccades*, *microsaccades*, *vergence*, *rolling*, *pursuit motion*, *nystagmus*, and *physiological nystagmus* [27],[28]. Saccades are very rapid ballistic simultaneous movements of both eyes in the same direction. Microsaccades occur during fixations and consist of slow drifts followed by very small saccades. Vergence is a motion of both eyes relative to each other that ensures that an object is still foveated by both eyes when its distance from the observer is changed. Rolling is a rotational motion around an axis passing through the fovea and pupil. Pursuit motion acts to keep a moving object foveated, and is a smoother, slower movement. Nystagmus occurs as a response to the turning of the head, or the viewing of a moving, repetitive pattern, i.e. the train window phenomenon. A smooth pursuit motion in one direction to follow a position in the scene is followed by a fast motion in the opposite direction to select a new position. Physiological nystagmus is a high-frequency oscillation of the eye that serves to continuously shift the image on the retina, and that way calling fresh retinal receptors into operation.

With this knowledge we can design an eye-system for the robot ANTY. The knowledge implements some design constraints, which has to be kept in mind. Next part describes a preliminary design.

IV. Preliminary Design Eye-System

The design of ANTY's eye system has been based on an animal or human being. The conceptual idea was to hold the eyes in an orbit as discussed in previous paragraph. A preliminary design is showed in Fig.2.

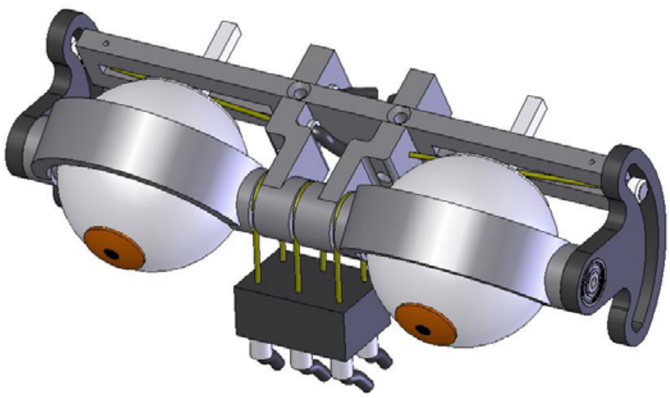

Fig.2 Preliminary design of the eye-system for the intelligent huggable robot ANTY.

The eye-ball is a precision PA6.6 sphere having a diameter of 35 [mm], used in roller bearings. The sphere will be CNC machined to host a commercial CMOS camera. Thanks to the miniaturization and the recent wide use of cameras for cell phones and security applications, it is possible to find a number of cameras compatible with the size of ANTY's eyes. At the front a spherical iris (brown) and pupil covers the camera for aesthetical reasons. The rear flange can support the camera, leads the wires of the camera, and is used to actuate the eye. An exploded eye is showed in Fig.3 (Camera not depicted).

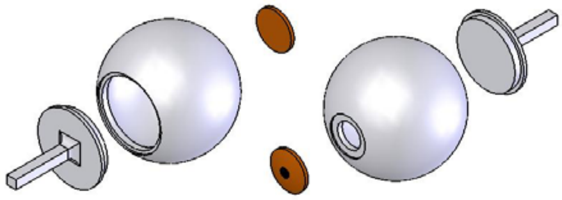

Fig.3 Exploded eye.

Two possible eye-supports are shown in Fig.4. The former holds the eye-ball between two Teflon parts. The two parts are machined with a bulb-shaped milling cutter with the same spherical curvature as the eye-ball. That way the eye has three DOF as in a spherical joint, and allows smooth rotations around the center of the sphere, because of its low friction coefficient. Not one mechanical part intersects the eye-ball. That way the eyes can bulge out of the head. The latter concept consists of two rings and two axes. One rotation axis passes through the center point of the eye and holds the eye in the inner ring, that way the eye can rotate relative to the inner ring. A second rotation axis passes through the inner and outer ring, that way the inner ring (holding the eye) can rotate relative to the outer ring. The eye can thus pan/tilt and has 2 DOF. While panning the eye, the inner ring comes out of the head. That way the eye can not bulge out as far as in the former support, that has a great anthropomorphic eye in orbit likeness. The ring-based support is more complex to build because of the miniaturized parts. These two main disadvantages lead to the rejection of the ring-based eye-support.

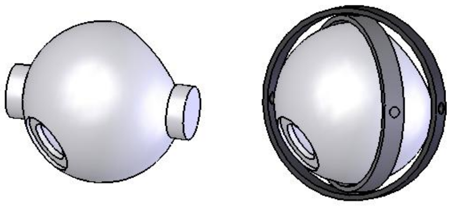

Fig.4 Two possible eye-supports

Hobbyist servo motors are used to actuate the different parts. A Bowden cable based actuation is used. A Bowden cable is a type of flexible cable used to transmit mechanical force or energy by the movement of an inner cable relative to hollow outer cable housing. The linear movement of the inner cable is generally used to transmit a pulling force, although for very light applications over shorter distances a push may also be used. In this design the inner cables are only used to transmit a pulling force. The inner cable is a nylon cable with a diameter of 0,5 [mm] and is moving in a hollow more stiffer outer cable. Fig.5 describes the principle.

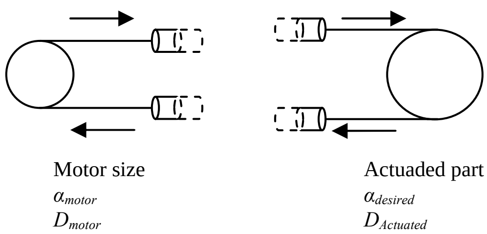

Fig.5 Bowden cable principle with pulleys.

Let‘s consider $\alpha_{desired}$ the desired range of the actuated part. α_{motor} is the range of the servomotor, mostly 180° or 90°. D_{motor} and $D_{actuated}$ are the diameters of the pulleys were the inner cable is rolling over. The relation between the different parameters is:

$$\alpha_{desired} = \alpha_{motor} \cdot \frac{D_{motor}}{D_{actuade}} \quad (1)$$

The eyes can tilt together and each eye can pan. Both movements are decoupled. By pulling the rod on the rear flange we can pan the eye. To tilt the eyes, the bow, leading the rear flange, is actuated. Each eye-lid can move separately. That brings the total DOF of the eye-system up to five. The rolling movement described in paragraph III is not possible in this design. The movement ranges are showed in Table 1.

Movement	**Range $\alpha_{desired}$ [°]**
Left Eye Pan	80
Right Eye Pan	80
Both Eyes Tilt	90
Left Eye-Lid	110
Right Eye-Lid	110

Tabel 1 Eye movements and ranges.

For safety reasons each actuated part is actuated flexible. On the motor size two pretended tension springs are placed. Making use of the Bowden cables, all motors can be grouped, that way the noise of the servos can be reduced on a proper way and the mechanical structure is motor independent. Fig.6 shows a single servo motor with the two pretended springs and the flexible motor-system with twelve servos. The servos are actuated by commercial servo controllers.

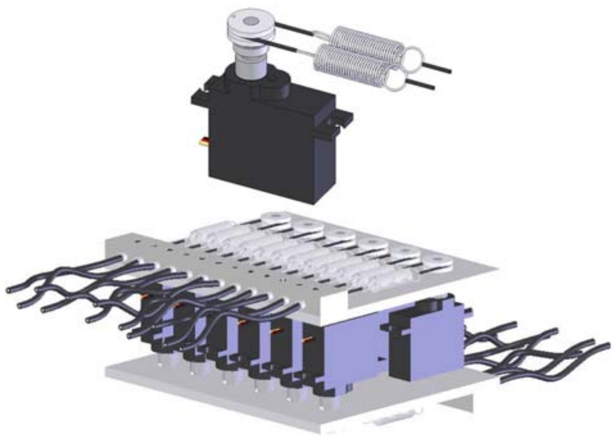

Fig.6 Single servo and flexible motor-system.

V. Summary and Future Work

An eye-system for the huggable robot ANTY is designed, based on an anthropomorphic model, with eyes supported in an orbit. Bowden cables and hobbyist servos are used to actuate the eyes and eye-lids. The eyes can pan separately and tilt together. Pretended tension springs secure an intrinsic safe mechanical design.

The eyes will be equipped with commercial CMOS cameras and move on a natural way, based on the movements described in part III, all with the intentions to communicate emotionally with humans and children in an environment where robots and human beings coexist.

ACKNOWLEDGEMENTS

The ANTY project is financially supported by the Brussels capital-region.

REFERENCES

[1] F. Guenter, L. Roos, A. Guignard and A. G. Billard, "Design of a Biomimetic Upper Body for the Humanoid Robot Robota," in IEEE/RAS Intl Conference on Humanoid Robots, 2005

[2] K. Hyundo, G. York, G. Burton, E. Murphy-Chutorian, and J. Triesch, "Design of an Anthropomorphic Robot Head for Studying Autonomous Development and Learning," in IEEE/ICRA, 2004

[3] Y. Sakagami, R. Watanabe, C. Aoyama, S. Matsunaga, and K. Higaki, N. Fujimura, "The intelligent asimo: System overview and integration," in IEEE/RSJ Intl Conference on Intelligent Robots and Systems, 2002.

[4] M. Fujita, Y. Kuroki, T. Ishida, and T. Doi, "A small humanoid robot sdr-4x for entertainment applications," in IEEE/ASME Intl Conference on Advenced Intelligent Mechatronics, 2003.

[5] http://paro.jp/english/index.html

[6] http://www.hasbro.com/furby

[7] http://segatoys.co.jp/nearme

[8] J. Yamaguchi, E. Soga, S. Inoue, and A. Takanishi, "Development of a bipedal humanoid robot - control method of whole body cooperative dynamic biped walking," in IEEE International Conference on Robotics & Automation, 1999.

[9] I. Mizuuchi, M. Inaba, and H. Inoue, "A flexible spine human-form robot - development and control of the posture of the spine," in IEEE/RSJ Intl. Conference on Intelligent Robots and Systems, 2001.

[10] I. Mizuuchi, R. Tajima, T. Yoshikai, D. Sato, K. Nagashima, M. Inaba, Y. Kuniyoshi, and H. Inoue, "The design and control of the flexible spine of a fully tendon-driven humanoid kenta," in IEEE/RSJ Intl. Conference on Intelligent Robots and Systems, 2002.

[11] R. Brooks, C. Breazeal, M. Marjanovic, and M. Scassellati, B. Williamson, "The cog project: Building a humanoid robot," Computation for Metaphors, Analogy, and Agents, LNCS 1562, pp. 52-87, 1999.

[12] Y. Bar-Cohen and C. Breazeal , "Biologically-Inspired Intelligent Robots," SPIE Press, Vol. PM122, ISBN 0-8194-4872-9.

[13] C. Breazeal, "Designing Sociable Robots," MIT Press, ISBN 0-2620-2510-8, 2002.

[14] Aude Billard, "Robota: Clever toy and educational tool," in Robotics and Autonomous Systems 42, pp 259-269, 2003

[15] T. Asfour, K. Berns, and R. Dillman, "The humanoid robot armar: Design and control," in IEEE/APS Intl Conference on Humanoid Robots, 2000.

[16] J. Saldien, K. Goris, D. Lefeber, "ANTY: the Development of an Intelligent Huggable Robot for Hospitalized Children," CLAWAR, 2006.

[17] T. Shibata, "Mental Commit Robot for Healing Human Mind", Journal of the Robotics Society of Japan, Vol.17, No.7, pp.943-946, 1999. (in Japanese)

[18] M. Fujita, "Emotional Expressions of a Pet-type Robot", Journal of the Robotics Society of Japan, Vol.17, No.7, pp.947-951, 1999. (in Japanese)

[19] C. Breazeal, "*Toward sociable robots*," Robotics and Autonomous Systems 42, pp.167-175, 2003.

[20] J. cole, "About Face," MIT Press, 1998.

[21] Mehrabian, "Communication without Words," Psychology Today, Vol.2, No. 4, 1068, 1967.

[22] C. Breazeal, "Regulation and Entrainment for Human-Robot Interaction", D. Rus and S. Singh (Eds.), in: Int. Journal of Experimental Robotics, 21(10-11), pp. 883-902, 2002.

[23] D. Miyauchi, A. Sakurai, A. Nakamura, and Y. Kuno, "Human-Robot Eye Contact through Observations and Actions," IEEE, Int. Conference on Pattern Recognition, 2004.

[24] R. H.S. Carpenter, "Movements of the Eyes (2nd ed.)," Pion Ltd, London. ISBN 0850861098, 1988.

[25] G. Westheimer, S. P. McKee, "Visual acuity in the presence of retinal-image motion". Journal of the Optical Society of America 65(7), 847-50, 1975.

[26] Gray's Anatomy, "Muscles of the eye-based on image 889 from online edition of Gray's Anatomy," online edition of the 20th U.S. edition of Gray's Anatomy of the Human Body, originally published in 1918.

[27] R. J. K. Jacob, "Eye tracking in advanced interface design," *in* W. Barfield & T. Furness, eds, `Advanced Interface Design and Virtual Environments', Oxford University Press, Oxford, pp. 258-288, 1995.

[28] V. Bruce, P. R.Green, "Visual Perception: physiology, psychology and ecology*,"* 2nd edn, Lawrence Erlbaum Associates Ltd., Hove, UK. 1990.