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Non-Invasive Approach towards Remote Control of Insects in the Implementation of Bio-Robotic Mobile Platforms

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Abstract: *The nature, objectives and tasks set in front of bio-robotics have been discussed. The contemporary achievements and the opportunities for targeted control by animals through invasive manipulation of bio-potentials are presented. A non-invasive approach for remote control by insects in the realization (implementation) of bio-robotized systems is demonstrated. A mobile platform, set in motion by a live cockroach has been implemented.*

Keywords: *Biorobotics, cyborg, insects, mobile robots, remote control.*

Introduction

The flight of human imagination and desire for knowledge has always been ahead of the real possibilities of current science. Literature, movies, television and media generally demonstrated us a fantastic view of robotics, which unfortunately does not always represent objectively the contemporary achievements in this challenging field. However, impressive are the characters of the Terminator, Robocop, Universal Soldier and others, but they rather show a hypothetical look forward in indeterminate future.

If we go back to reality, flipping the pages of millennial history, we will find a countless number of evidence of the innate human urge to know, copy and rediscover the wonders of nature. Certainly this was not accidental. The biological world has gone a long evolutionary path before acquiring its present appearance, since each species is perfectly adapted to its surrounding and dynamically changing environment. Quite understandable is the drive this perfection to be copied and recreated by the curious human nature. This trend is still preserved today as the time changes only the means and the technology.

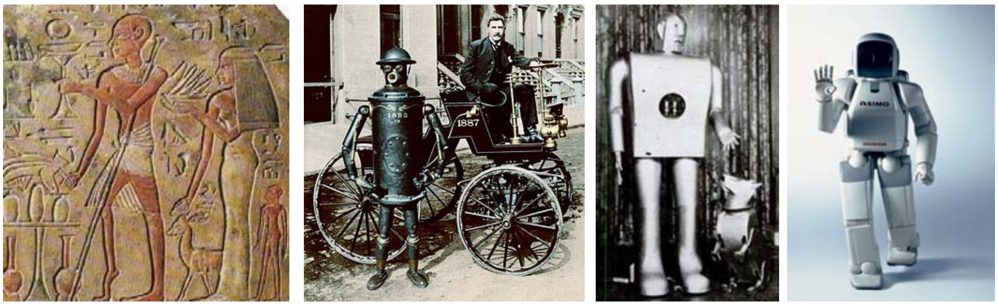

Fig. 1. Time changes technology, but not the reasons

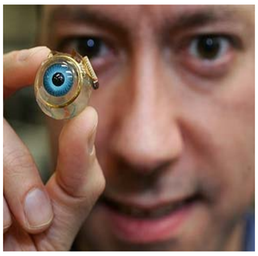

Fig. 2. A synthetic eye

The technological boom of the last half century has provided us with the tools, knowledge and confidence which allow us to focus on the area, long time considered as taboo. Consciously or not the idea of interference in the human body in order to “improve” or “correct” certain functions, has recently been rejected by some religious, moral or medical prejudices. If we take a look from a completely different angle, creating cyborgs (CybOrg – Cybernetic Organism) [1], could significantly facilitate and improve the quality of life of many people. Artificial joints, prostheses, intelligent implants, exoskeletons, devices for improving visibility in adverse conditions, for improving hearing and sense of touch – these are all real life examples that most of us accept as normal and necessary.

During the last couple of years an increasing interest towards the opportunities of implementing specific electromechanical devices in representatives of the animal fauna has been observed, the purpose of which is to extract specific information or direct impact on the movement. The utility of this kind of experiments could be easily proven in real life. For example, during rescue operations, where in most cases the access is limited or not possible, instead of using humans or dogs, small mam-mals or insects could successfully be used.

The difficulties here are how to control animals that defy training. Results of successful experiments with rats, beetles, butterflies and others have already been published, where the bodies of animals were implanted with electrodes. The electrodes are localized either directly into specific brain areas (in mam-mals) or nerve clusters (ganglia) – in invertebrates [2–8].

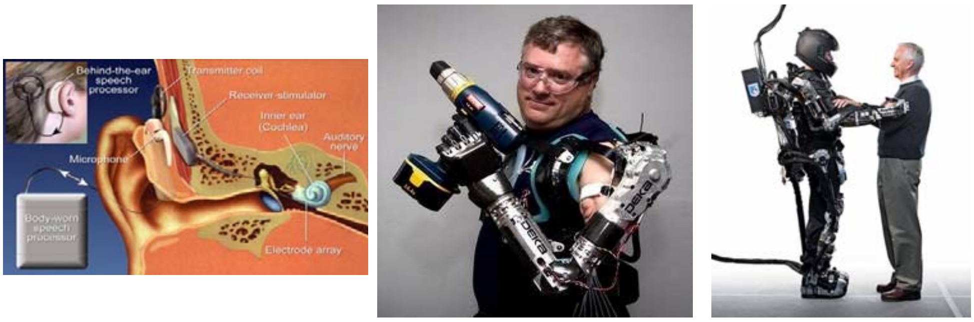

Fig. 3. A cochlear implant (left), synthetic prosthetic arm (middle) and exoskeleton (right)

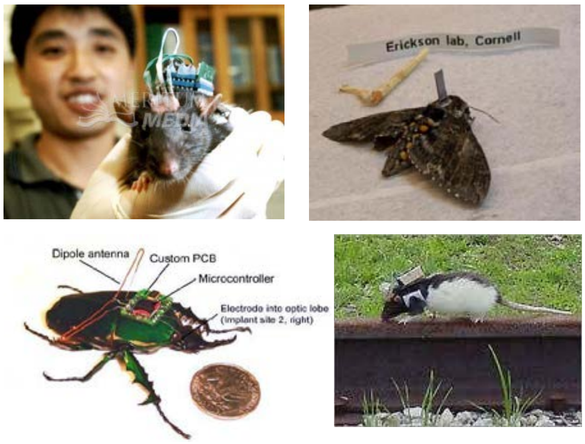

Fig. 4. Animal behavior control by invasive implantation of electrodes

Noninvasive approach for control of insects

The methods above described are surgical and suggest a teamwork of specialists – biologists, medics and engineers who are also provided with solid technology and financial support. In 2004 in public space an interesting prototype of a mobile robot has been presented, controlled by a live cockroach [9]. The “back” of the cockroach is fixed to a stationary base and its “feet” are touching a ping-pong ball, which rotates in a certain direction, depending on the movements of the insect. The rotation of the ball was intercepted by optical encoders (the principle of action is similar to the work of the old computer mouse with a ball).

The system is also providing a feedback that allows the insect to move the platform by avoiding the obstacles in the surrounding area. There is a pair of InfRared (IR) obstacle detection sensors and Light Emitting Diodes (LED). The sensors measure the distance up to the objects which appear in front of the robot and activate the corresponding LED if the distance is critically small and there is a danger of collision. Many insects, including cockroaches have developed an interesting evolutionary mechanism as a self-defense instinct, which protects them from the dangers of going out in open spaces. Deprived of the shelter of darkness, the insects easily fall to predators. Therefore a well-known aptitude of cockroaches is to avoid lighted areas as well as strive towards their desire to quickly direct to darker areas. As a result when the LED is activated, the insect, striving to avoid the light, turns away the entire mobile platform (through the ball). By using this instinct, the whole structure/construction/ avoids successfully the obstacles in the area.

Fig. 5. Mobile robot driven by live cockroach [9]

On a similar basis in 2008 a mobile robot using a moth as an "engine unit" [10] was designed. Ryohei Kanzaki, Professor of Tokyo University's Research Centre for Advanced Science and Technology and his team used the sensitive olfactory system of the male moths, which allows them to follow the pheromone trail left by the females, for miles. Similarly, the insect here is placed on a lightweighted ball.The experiments demonstrate the ability of the mobile robot, directed by the moth, to be driven in a certain direction by following the pheromone trail.

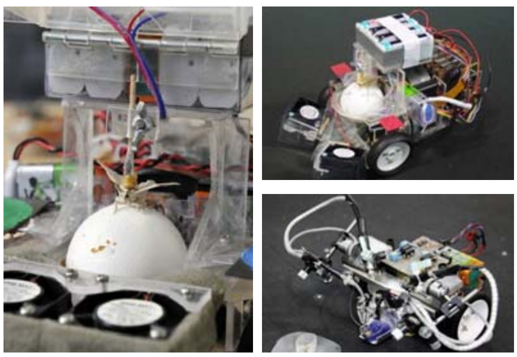

Fig. 6. Mobile robot driven by a moth

Implementation of the mobile platform "Cyroach"

The results of the prototypes described inspired the realization of the current mobile platform. The project was called "CyRoach" (Cyborg cockRoach, Fig. 7). The project was launched at the end of 2010.

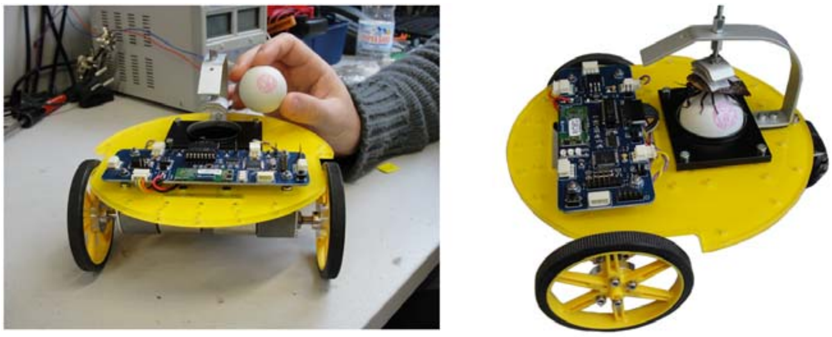

Fig. 7. Mobile platform "CyRoach", driven by a cockroach

What are the essential parts of the platform? A key element here is the device which helps tracking the movements of the cockroach. For this purpose an old industrial trackball (Fig. 8) was used. The trackball has two optical encoders which record the movements of the ball on the two rectangular axes. Since the original ball is too heavy and its surface is too smooth to be powered by an insect, the hole surface has been expanded. This enabled the installation of a standard ping-pong ball with 38-40 mm in diameter. In order to increase the adhesion, the surface has been scratched with coarse sandpaper. At the bottom of the trackball a processor board was installed in order to process the pulses from the encoders and form a 4-bits logical combination which appoints the direction and speed of the ball rotation. For the robot foundation a plexiglassic sheet is used, which is cut in the suitable shape. The drive of the entire construction is classical. It is made of two PWM controlled DC motors and one swivel castor wheel. The information processed from the trackball and the control of the motors is done in an electronic module which is located on the platform surface. The board is equipped with a second processor – PIC18F452. This board is equipped with wireless communication via a Bluetooth module.

Fig. 8. An industrial trackball

The Cockroach’s thorax is attached to a bended metal plate through a sticky tape (Fig. 9). Thus when necessary, the insect can be painlessly removed from the platform. The sticky tape attached ***to the cockroach’s back does not cause discomfort to the animal and does not interfere with its normal life***. All larger and more active species of cockroaches are suitable for the experiments. In this case *Gromphadorhina portentosa* [11] and *Blaberus craniifer* [12] types were used.

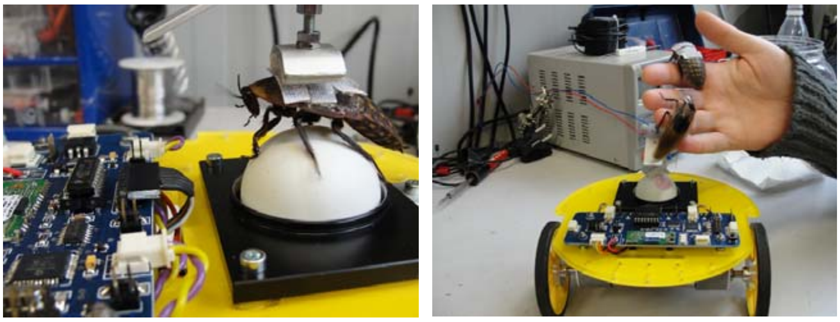

Fig. 9. Fixing the cockroach over the platform

When the cockroach is fixed onto the ball, every movement can be caught so that the entire platform changes its position in the direction corresponding to the movement direction of the insect. It was clarified that cockroaches prefer the dark and moist habitat. In the particular project this fact could be successfully used for directing both the cockroach and the entire platform in the desired direction. The influence of the sudden changes in the airflow on the cockroaches’ behavior (and other insects), have been documented and studied a long time ago. The experiments made confirmed the better sensitivity of the cockroaches to the airflow compared to direct and intense light, used in the US prototype described above. Therefore it was preferable to use three fans which are situated in front and on both sides of the animal (Fig. 10). When a particular fan starts working, the cockroach deviates the platform opposite to the fan direction in its attempt to avoid it. The fans are activated by three infrared obstacle detection sensors (SHARP GP2D120) which are installed in front of the robot. The sensors’ range is 30 cm. When a sensor detects an obstacle, the corresponding fan is activated. Thus without a supervisor a fully autonomous control is performed and the “platform-cockroach” avoids the obstacles in the surrounding area.

Fig. 10. The robot in action. In the picture the mounted fans can be seen

Specialized software for a PC was designed and a mobile phone which enables the remote activation of the fans, adjusting the maximum speed (PWM duty) of the platform and collecting information from the sensors and many others.

Video materials and additional information about the project are presented in **[13-17].**

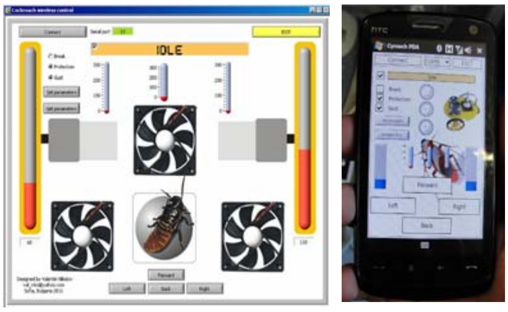

Fig. 11. The designed software (for a PC – left and for a mobile phone – right) for platform remote control

Future work

After successfully completion of this stage the idea is the project to be further developed by invasive placement of electrodes through which the bio-potentials of the animal (as a feedback) could be monitored and directly affect certain groups of nerves with weak electrical signals. Furthermore, a software module for a PC intended for processing of the statistical information from the sensors, as well as the relevant cockroach's reactions is to be designed. Thus algorithms could be generated for autonomous mobile robots control based on real behavioral models, inspired by biological species.

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Неинвазивный подход для дистанционного управления насекомыми при реализации биороботизированных мобильных платформ

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(Р е з ю м е)

В работе исследуются природа, цели и задачи биороботики. Представлены современные достижения в разработках целенасоченного управления насекомыми при помощи инвазивной манипуляции био-потенциалов. Демонстрирован неинвазивный подход дистанционного управления насекомыми при реализации био роботизированных систем. Создана мобильная платформа, которая приводится в движение при помощи живого таракана.