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FACULTY OF COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME I

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

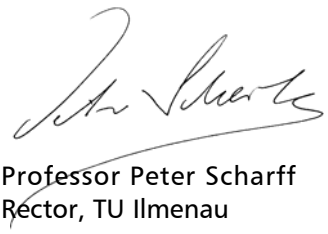
- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.



Professor Peter Scharff
Rector, TU Ilmenau

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Head of Organisation

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V. Lysenko/ W. Minchenya/ K. Zimmermann

Minimization of the number of actuators in legged robots using biological objects

Bionically Inspired Robotics Biomechanics

Abstract

A new approach of special problem-solving methods at the initial design stages is presented. The methods are based on the analysis and the combination of technical or biological objects and a legged robot. Described techniques allow us to create several new legged robots. A new class of micro robots and a new class of legged mechanisms is chosen to present the possibilities of the method. Merging the kinematics of a salamander with the kinematics of an octoped allows us to develop a new eight legged robot with only three actuators. Combining a flying insect and a piezotransducer with extremities supplies a new object - the piezomicrorobot. For movement of multi-legged robot through a pipe we use the travelling wave of the Holothouria.

Introduction

Biological objects as prototypes are used preferably due to the fact that during millions of years of evolution their principles of motion have been developed contemplating minimal energy wasting. [1]

The essential design stage, which is discovering ideas for new functional principles of technical systems, is almost entirely based on the know-how of the engineer [2, 3].

The subject of our work is the development of new functional principles of legged robots.

By using the working principle and the kinematics of biological prototypes it is possible to develop new ideas for mobile robots. Some biological objects use unusual ways of moving of the extremities to obtain the necessary trajectory. They change form and sizes of the body to create the necessary movement of legs.

By applying the introduced method new robots can be created. It is based on the

combination of biological and technical objects. The developed method is based on the well-known principle known as the combination of alternative systems. It enables the transfer of characteristics and structure from one object (i.e. its kinematics) to another object leading to new desirable characteristics or to the optimization of existing technical objects[4].

Biologically inspired robots

A multi-legged mobile systems classification is represented (Fig.1.). In our opinion, there exist only 4 - 5 main principles of functioning of biological objects for providing the necessary trajectory of the legs movement. The suggested classification and the analysis of biological prototypes have allowed us to create some new mobile robots. In known walking machines the several actuators for moving each leg are used. Our design principles allow us to use each actuator for moving several legs. Thus, we managed to minimize number of actuators at the robot. It opens new possibilities of the considerable miniaturization of mobile robots in future.

Thus, the ability to develop new functional principles of legged robots (i.e. new motion principles, new kinematics etc.) is provided. The analysis is used to realize the transition from known (in biological objects) to new (for legged robots) forms of motion.

Minimization of number of actuators multi-legged robots can be reached through:

use of periodical changing the shape of the body of the robot in horizontal dimension (salamander, lizard)

use of periodical changing the size of the body of the robot in vertical dimension (flying insects)

use of anisotropy of friction (snake)

use of periodical character or feature of trawling wave (holothouria)

use of multidimensional resonance swinging of elastic extremities (mosquito)

reducing of number of bearing legs (kangaroo, basilisk, birds).

For micro robots it is possible to use a principle of movement as at Polichetae (Fig.2). In this biologic object the legs have no actuators and no degrees of freedom relative to a body. They are rigidly attached perpendicularly to a surface of a body, so they move and incline together with deformation of this surface. To create necessary trajectory of a distal end of a leg, Polichetae and Holothouria uses deformation of the case as trawling wave.

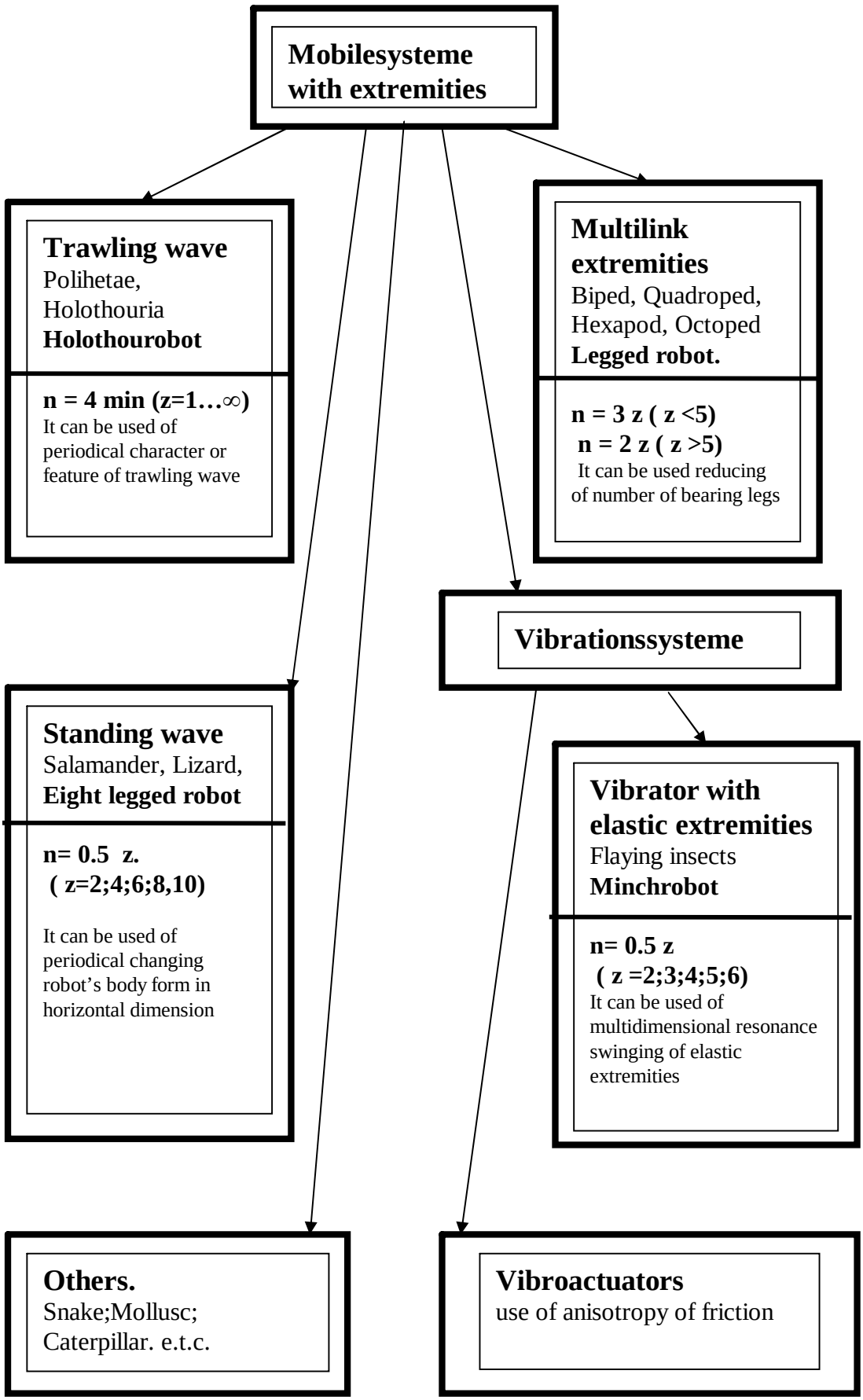

Fig.1 Multy-legged mobile systems classification

(n- number of actuators, z- number of legs.)

The number of legs-needles is not limited, but number of the actuators enabling deformation of the case, is minimal. It is possible to create tiny robot with a plenty of legs and with low number of small-sized actuators.

We have developed the moving robot-probe with 100 legs and with only four actuators - "Holothourobot" (Fig.2). It can be used in medicine for minimally invasive surgery.

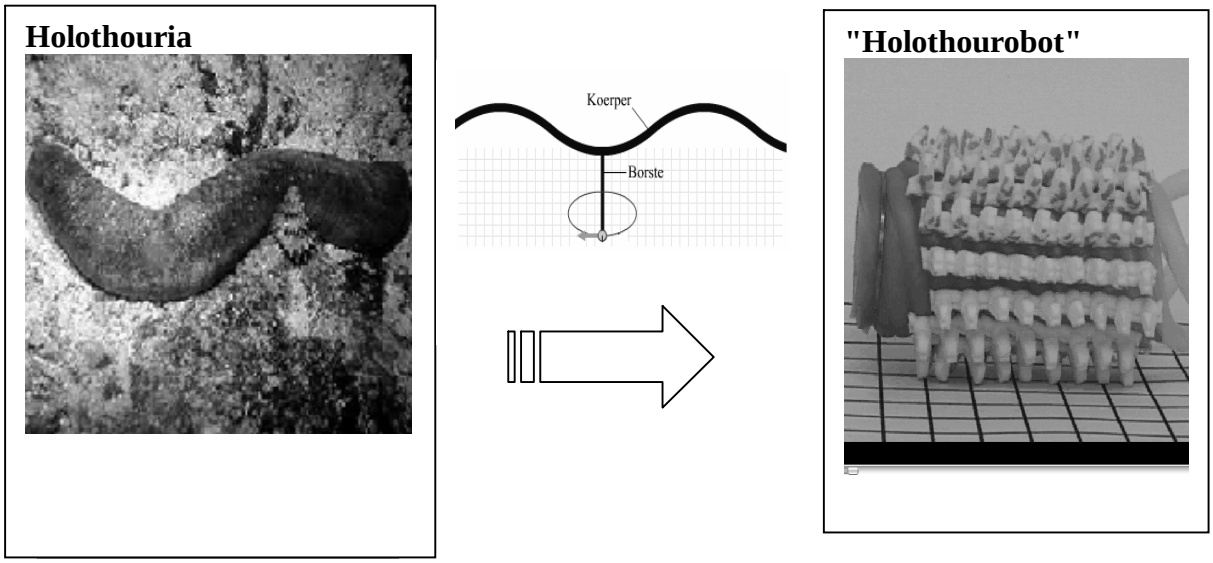

Fig.2. Using of periodical character or feature of trawling wave

The salamander bends its body in a horizontal plane and due to this, the body moves relative to the points of support (Fig.3). By using the deformation of a robot body in a horizontal plane it is possible to provide it's motion due to a minimum number of actuators. The actuators are not connected to legs and they are necessary only for the deformation of the robot body. Having as few as three actuators it is possible to realize the motion of the robot with eight legs "Eightleggedrobot" (Fig.3).

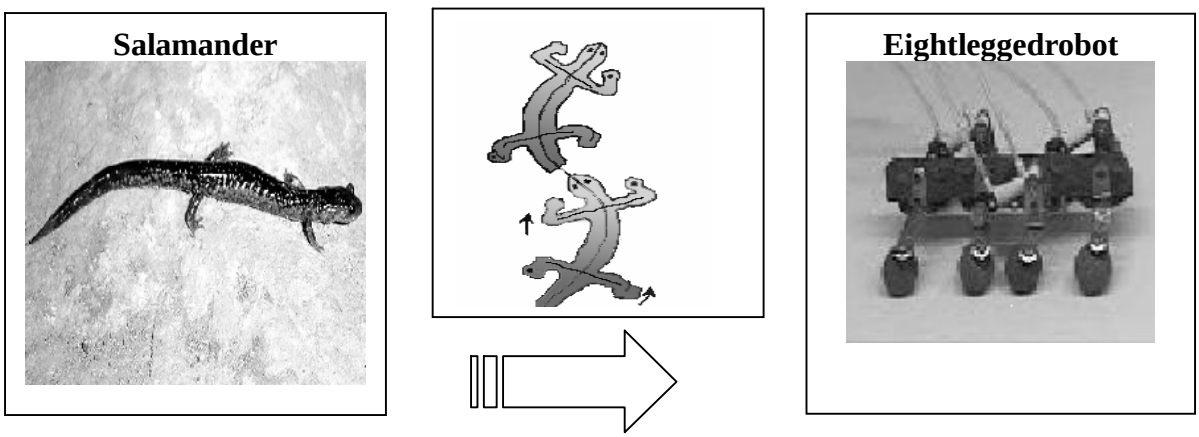

Fig.3. Motion due to periodical changing of the shape of the body in the horizontal plane

Some flying insects create resonant oscillations of the wings due to periodic change of the form and the sizes of the rigid body (Fig.4). The insects' muscles are connected not to the wings, but to the walls of a rigid body and deform it. The deformation of the body turns into swinging of wings.

It is possible to create the mobile robot at which the body vibrates, and legs have no actuators. The necessary trajectory of the distal part of a leg is formed due to excitation of the high-frequency swinging in proximal part of an elastic curvilinear leg and due to mechanical transformation of these swinging in low-frequency.

We developed an essentially new type of a moving system "Minchrobot" (Fig.4). As the body and as the actuator a piezo-bimorph-plate is used. It can cover 1 meter per 1 second.

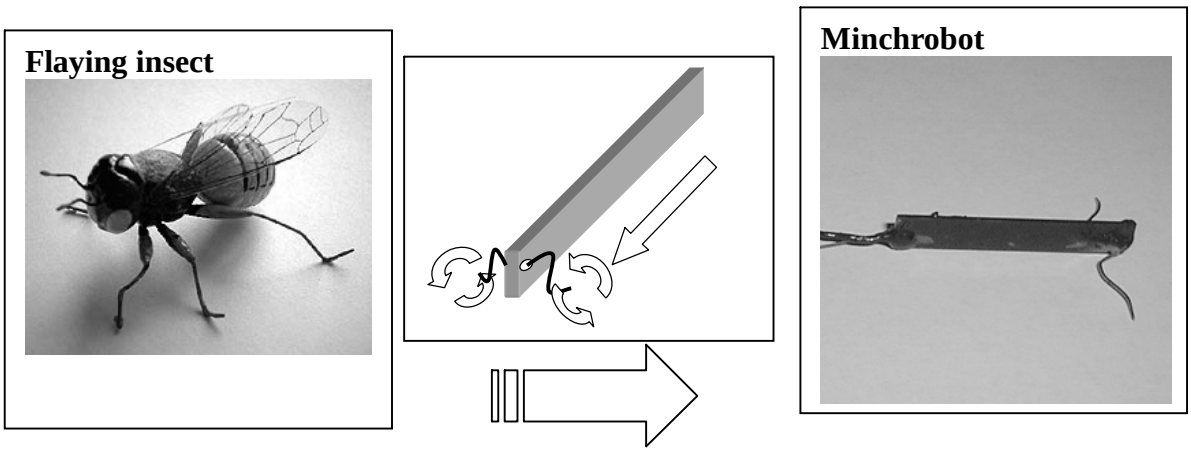

Fig.4. Motion by multidimensional resonance swinging of elastic extremities

Summary

The analyses of biological objects and alternative technical systems offer new opportunities for the engineers. That analysis is an indistinct provisional approach of solving a technical problem. In further stages of the design process the engineer formulates precisely this solution and verifies it by means of mathematical modeling and calculation.

The described technique does not supply convertible constructive drawings

immediately. However, it provides new solutions with new ideas. Furthermore, it is possible to develop essential new legged robots with minimal number of actuators.

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