The Contribution of IFToMM to Theoretical and Applied Robotics

Prof. dr inż. Adam Morecki
Past President of IFToMM and Member of IFR Executive Council
Warsaw University of Technology

WKŁAD IFToMM DO TEORII I PRAKTYKI ROBOTYKI

Międzynarodowa Federacja Teorii Mechanizmów i Maszyn (International Federation for the Theory of Machines and Mechanisms - IFToMM) powołana została w 1969 roku w Polsce i obecnie skupia 38 komitetów członkowskich z całego świata. W ramach IFToMM działają komitety techniczne, m.in. Robotów i Manipulatorów, Mikromechanizmów, Mechatroniki, Systemów Człowiek-Maszyna.

W artykule przedstawiono najważniejsze wyniki działalności IFToMM w zakresie teorii i praktyki robotyki.

Od 1973 roku IFToMM organizuje międzynarodowe sympozja Ro.Man.Sy (Robots and Manipulators Systems), których tematyka związana jest bezpośrednio z robotyką. W artykule omówiono trzy okresy tematyczne:

- 1973-1983, w którym głównymi tematami były: maszyny kroczące, biomechanika ruchu, sztuczna inteligencja, sterowanie ruchem i aplikacje,
- 1984-1993, w którym wiodącymi tematami były: teleoperatory i systemy zdalnego sterowania, planowanie trajektorii, manipulatory elastyczne, systemy sensoryczne robotów, nowe sterowniki robotów,
- 1994 do chwili obecnej, z następującymi tematami wiodącymi: mikroroboty, systemy mobilne, specjalne rozwiązania robotów, sieci neuronowe, sprzężenie siłowe i momentowe w sterowaniu robotami, specjalne algorytmy sterowania.

Na sympozjach Ro.Man.Sy prezentowano problemy: mechaniki, kinematyki i dynamiki manipulatorów, biomechaniki ruchu, maszyn mobilnych, mikrorobotów, sterowania ruchem, sztucznej inteligencji, systemów człowiek-maszyna, urządzeń sensorycznych, zastosowań robotów itp.

W artykule wymieniono najważniejsze przyszłościowe zagadnienia badawcze i aplikacyjne z zakresu robotyki:

- geometria i kinematyka, a w szczególności: niekonwencjonalne struktury kinematyczne, kalibracja i błędy kinematyki, przestrzenie robocze,
- dynamika, m. in: sprzężenie siłowe w sterowaniu robotami, manipulatory z izotropowymi właściwościami dynamicznymi,
- robotyka i mechatronika, m.in.: mechatronika systemów manipulacyjnych, robotyka i mechatronika w chirurgii,
- pomiary, sterowanie i eksperymenty - głównie: modelowanie otoczenia, systemy taktylne, nawigacja, przetwarzanie informacji, współpraca robotów,
- maszyny kroczące, m.in.: roboty dwunożne, roboty antropomorficzne, roboty z wieloma nogami, mieszane systemy lokomocji,
- manipulatory elastyczne, m.in.: manipulatory sprężyste i typu trąba słonia,
- mikroroboty i mikromechanizmy, o różnych sposobach lokomocji i wielorakich zastosowaniach (m.in.: endoskopia, inspekcja, mikromanipulacja).

W końcowej części artykułu przedstawiono wybrane problemy rozwoju technologii i możliwości przewidywania dalszego rozwoju w zakresie robotyki. Stosowane są różne techniki przewidywania przyszłości, oparte głównie na śledzeniu trendów rozwojowych wielu dziedzin. Zamieszczone rysunki ilustrują fakt coraz krótszego czasu upływającego od wynalazku do wdrożenia (rys. 1), szybki rozwój techniki komputerowej - dużych systemów komputerowych, ale szczególnie mikrokomputerów (rys. 2), wprowadzania nowych materiałów o coraz większej wytrzymałości, charakteryzujących się dużo wyższym współczynnikiem stosunku wytrzymałość/masa, niż stosowana dotychczas stal (rys. 3), podwajania się co roku liczby korzystających z sieci Internet (rys. 4). Rozwój techniki i technologii prowadzi do wzrostu produkcji i zastosowań robotów.

W podsumowaniu Autor stwierdził, że możliwe są zastosowania robotów w różnych obszarach działalności człowieka i robotyka rozwijać się będzie wspólnie z takimi dziedzinami jak: mechatronika, biologia i medycyna.*)

Ro.Man.Sy SYMPOSIA

We will concentrate on the activity of Technical Committee for Robots and Manipulators in the last 23 years and plans for the future [2].

Will describe also some connections with the activity in the areas of Micromechanisms and Mechatronics.

Robots and Manipulators Systems (Ro.Man.Sy) Symposia started in 1973 under sponsorship of two International Organizations CISM (Inter. Centre for Mechanical Sciences) and (IFToMM - Int. Federation for the Theory of Machines and Mechanisms). The main topics of this Symposia in the period 1973-1983 were: Walking Machines, Kinematics and Dynamics, Biomechanics of Motion, Man-Machine Systems, Artificial Intelligence, Control of Motion and Applications and Performance Evaluation. In the field of walking machines some important topics we-

*) *Referat prof. A. Moreckiego "The Contribution od IFToMM in the Next Decade to Theoretical and Applied Robotics" wygłoszony został na specjalnej sesji ROBOTYKA BLISKIEGO ROKU 2000, podczas 27 Międzynarodowego Sympozjum Robotów Przemysłowych (27th ISIR), które odbyło się w dniach 6-8 października 1996 roku w Mediolanie. Prezentowany artykuł jest skróconą wersją wygłoszonego referatu.*

re: the construction of the Biped Walking Machines developed by the group of Bio-Engineering of Waseda University (one of the first presentation), the construction of Quadruped by General Electric, Pony and the construction of six-legged vehicles by the group from the Ohio State University and the Institute for the Study of Machines in Moscow (analysis of the gait). The design of computer-controlled manipulators proposed at Stanford University, algorithms for solving dynamical problems in manipulators as well as algorithms for the kinematical investigation of manipulators were proposed. Interesting results obtained in the field of man-machine systems were: the design of master-slave manipulators, man-machine interaction in intelligent robotic systems and the application on sensory informations and multifunction learning.

Some topics were associated with space systems, such as remote control of manipulators in space, and remotely controlled systems for operation and exploration in space.

I like to underline also other impressive achievements dealt with remote surgery, remote mining, Hardy, Hardiman, rate control of the Rancho arm.

The second period of activity started in 1984-1993. New and important topics were: trajectory planning of redundant manipulators, computer-aided-generation of multibody system equations, robust control, actuator based on SMA communication in space teleoperation, sensory-based control for robots and teleoperators, tele-existence, elastic manipulators, a piano planning manipulator, parallel manipulators, sensor-gaided robot, control using fuzzy logic, new robot controllers, grippers, assembly with single and double arm robots.

The third period of activity started in 1994

I like to mention only a few selected topics presented in the period 1994-1996 dealt with: singularity analysis, anthropomorphic telemanipulation, force control in telerobotics, vibration control of flexible arms, design of underwater robots, design of microrobots, new parallel robots, robot systems for surgery, neural based sensing, dependent assembly planning, robust multiaxes controllers, mobile manipulator systems, based force/torque sensing, redundant SCARA robot, manipulators with kinematic and dynamical isotropic properties, Telbot-new telerobot system, biped robotics, contact tasks, back propagation algorithm for neural adaptive control, workspaces for parallel manipulators.

In the years 1973÷1996 mechanics, control of motion, synthesis and design, applications, mobile and walking machines, sensing and artificial intelligence were the main topics. We observe in the last years a growing interest in the new topics like microrobotics, mechatronics (neural control), computational kinematics, experimental robotics.

In the next item we will concentrate on some selected examples.

FUTURE RESEARCH AND APPLICATIONS

Geometry and kinematics

The topics mentioned below looks prospective for the future

- unconventional architecture (hybrid systems),
- continuation methods and elimination methods universally applicable to robot kinematics

Analitycal, graphical and numerical improvements of the these methods

Kinematics errors and calibration

Kinematics Algorithms

Singularities

Workspaces [3,4]

Dynamics

Will mention here a few selected topics

- high performance control using base force/torque sensing,
- manipulators with dynamic isotropic properties, fast manipulators with decoupling dynamic properties [2].

Robotics and mechatronics

The following topics looks important for the future mechatronics design

- mechatronics and system engineering
- mechatronics of manipulation systems
- intelligent actuation and sensing
- artificial intelligence and neural computing
- mechatronics in surgery
- robot-assisted invasive orthopaedic surgery mechatronic tool for drilling in the ostheosynthesis of long bones and ear surgery [5,6]

Experimental robotics, measurement and control

The main topics of interest for the present and for the future are

- world modelling,
- navigation,
- image processing
- intermittent tasks,
- cooperating robots,
- task guidance,
- tactile,
- kinematic calibration,

planning movement for two or three PUMA manipulators holding the same object [7,12].

Walking machines

Biped robots
I like to mention here a few examples only
- humanoid robots,
- anthropomorphic robots,
- robot-human collaboration,
- artificial emotion,
- social robots [8].

Four legged robots
- different kind of vehicles with four legs (for example for inspection in nuclear power plants)
- six legged robots (for exemple for vulcans exploation)
- climbing robots
- hybrid systems
- vehicles with two legs and two wheels
- snake locomotion for inspection, cleaning [9,13].

Elastic manipulators

- It seems to me that this class of manipulators will play an important role in the future. The main types will be so colled hyper-redundant manipulators
- snake type,
- trunk of elephant type,
- spine type [10,11].

Microrobotics

Micromechanisms with dimensions $10^{-3} \div 10^{-9}$ m will play an important role on the end of this century and in the next century [14].
The first and the second generations are now under investigations; the third generation just started from the artificial bactery. The further development will depens in high degree from the research of leaving organisms. It is expected that the production of micromechanisms in the future will based on moleculare technology. We like to underline here two areas namely microwalking and micromobile machines as well as micromedical robots.

Micromobile machines

Here belong
- walking machines,
- mobile machines,
- running machines,
- flying machines,
- swimming machines.

Among possible medical applications we like to mention
- endoscopy
- inspection
- micro tele-manipulation
- cell fussion

WHY FORECAST THE FUTURE

There are those who question the wisdom of forecasting the future because such forecasts tend to be so often wrong [15].
In spite of the risk associated with predicting what lies ahead, it seems clear that we must look toward the future.
An organization that concentrates on its past or, present will inevitably become a museum piece.
ISIR (ISR) needs to look to its future as the next decade unfolds.
Most experts agree that the basis for forecasting can be summarized through the use of several techniques (Mostino 1993).
Extrapolation-involes the use of patterns that have been found in the past to predict what the future will look like. For example the trends of our field are toward more robots being produced.
From this we might conclude that more robots will be produced in the future.
Leading Indicators - involes the use of some measurable parameter as a basis for predicting the advent of a new trend. A falling barometer often precedes rain, thus the barometric pressure becomes an indicator that allows prediction of weather.
Causal models - incorporate information about cause and effect. For example the advent of more powerful computational devices has led to an increase in the use of numerical methods as an approach to TMM and robotics problems.
Probabilistic methods - provides a prediction of the future based on probability distribution over a range of possible values. Weather forecasting has recently been done with this method.
It is important to keep in mind that technological forecasts are not prepared for their own sake but to assist an organization in making decision about its future actions. Of the four techniques, extrapolation and causal models seem to hold the most promise for use in predicting of the future of our field. There are further clues to predicting the future of our field that can be derived from consideration of the following guidelines:
1. Wach developments in related fields
2. Expect existing technologies to continue improving
3. Be were of trends based on single trend extrapolation
4. Give innovation just enough time to diffuse
5. Pay attention to the infrastructure on which a technology's succes depends.

The process of extrapolation and a consideration of causal models leads us very quickly to the selection of those supporting technologies that will most impact our field in the days ahead.
The next few Figures 1, 2, 3, 4 will illustrate some ideas concerning the Acceleration of Technolgy,

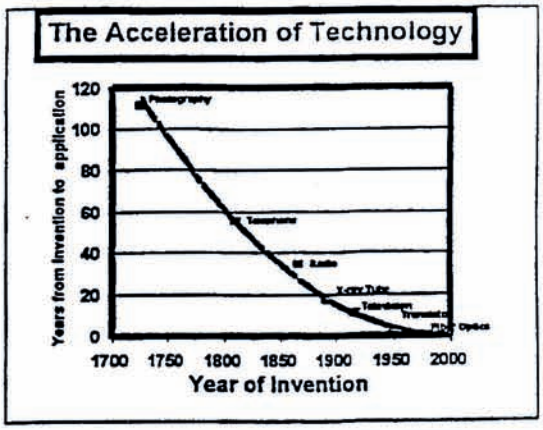

Fig. 1. The Acceleration of Technology

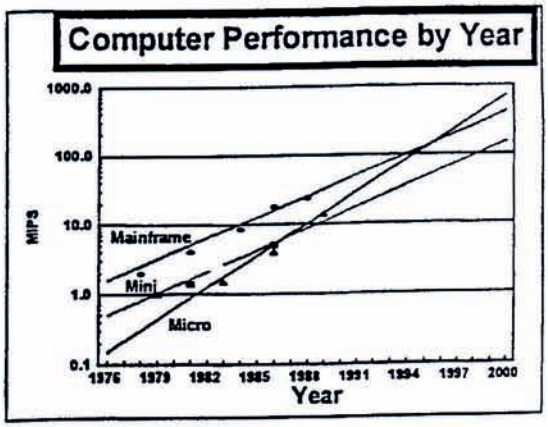

Fig. 2. The remarkable growth of computer performance

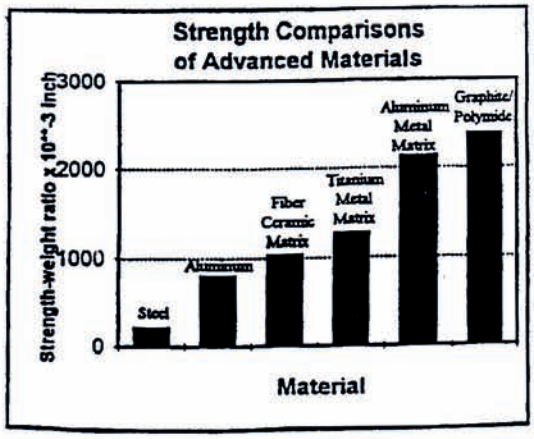

Fig. 3. Specific strengh of advanced materials

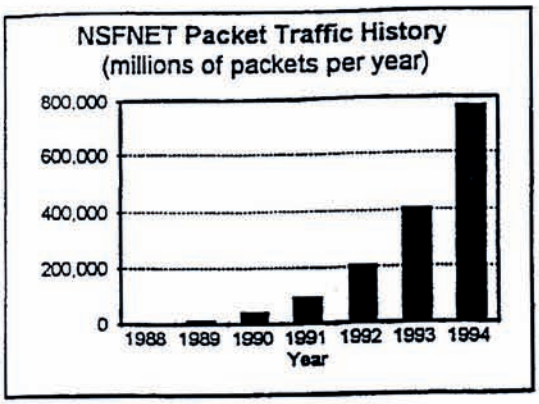

Fig. 4. Internet growth 1988-1994

growth of computer performance, strenght of advanced materials and internet growth in 1988-1994, they are the most important kinds of supporting technolog's.

Conclusion

This short survey shows the possible trends for the future in the field of robotics in collaboration with other areas like mechatronics, mobile vehicles, medicine and biology.

REFERENCES

[1] A. Morecki; Past, Present and Future of IFToMM, Mech. Mach. Theory, Vol.30, No.1, pp.1-9, 1995.
[2] A. Morecki; Past, Present and Future of Ro.Man.Sy Symposia. Where are we going? Proceed. of Ro.Man.Sy '10: The Tenth CISM-IFToMM Symp. Ed. by A. Morecki /G. Bianchi/, K. Jaworek, Springer-Verlag 1995.
[3] Advances in Robot Kinematic and Computational Geometry, Ed. by J. Lenarcic and B. Ravani; Kluwer Academic Publishers 1994.
[4] J.-P. Merlet and B. Ravani; (Eds.) Computational Kinematics '95, Kluwer Academic Publishers 1995.
[5] Mechatronics; Ed. by J. R. Hewit, CISM Courses and Lectures, No.338, Springer-Verlag 1993.
[6] Mechatronics, Vol.6, No.4, June 1986, An. Int. Journal Pergamon.
[7] V. Hayward, O. Khatib (Eds.), Experimental Robotics I, Lecture Notes in Control and Information Sciences, Springer-Verlag 1996
[8] Huro'96, First Inter. Symp. on Humanoid Robots, Tokyo, Japan.
[9] Machines that Walk: The Adaptive Suspension Vehicle, Shin-Min Song, K. J. Waldron, The MIT Press, Cambridge, Massachusetts 1989.
[10] G. S. Chirikjan, Hyper-redundant manipulator dynamics: a continuum approximation. Advanced Robotics, Vol.9, No.3 (1995).
[11] R. Cieślak and A. Morecki: Elephant Trunk Type Elastic Manipulator - a Tool for Bulk and Liquid Material Transportation; Proceed. of the 26th ISIR, Singapore, 4-6 Oct. 1995, SIAA, pp. 229-232.
[12] Measurement and Control in Robotics. Proceed T. C. on Robotics, TC-17, 6th Inter. Symposium, Brussels 9-11 May 1996.
[13] Nuclear Science and Technology TELEMAN, Published by the European Commission Brussel-Luxemburg, 1994.
[14] T. Hayashi, On Micromechanisms and Their Researches and Development. Proceed. of the Ninth CISM-IFToMM Symposium on Theory and Practice of Robots and Manipulators. Lecture Notes in Control and Information Sciences 187, Springer-Verlag, A. Morecki, G. Bianchi, K. Jaworek (Eds.), 1993, pp. 1-12.
[15] Terry E. Shoup, Future Trends in the Field of Mechanisms and Machines. Proceed. of the Ninth World Congress on the Theory of Machines and Mechanism, Milano (Italy), August 29/Sept. 2, 1995.

Abstracts

The Contribution of IFToMM to Theoretical Applied Robotics
Adam Morecki p. 9
The International Federation for the Theory of Machines and Mechanisms (TMM) was established in Sept. 27th 1969 at Zakopane, Poland. Brief description of history, activities and achievements of TMM in the field of theoretical and applied robotics are presented. Some important research problems and forecast for the future of robotics are recapitulated.