Fifth National Scientific and Applied Science Conference ET'96, Sozopol, Bulgaria.

MICROSYSTEMS IN MEDICINE

Work at Delft University of Technology and Prospects

Rogier P. van Wijk van Brievingh, Ph.D, Ms.E.E,
Associate Professor of BioMedical Engineering,
Department of Electrical Engineering,
Delft University of Technology,
Delft, The Netherlands

Introduction

BioMedical Engineering (BME) comprises the application of engineering methods, devices and materials in medical science and health-care. It is essentially multi-disciplinary at both ends: engineering as well as medicine have many sub-specialties. In educating engineering students, teaching of (functional) anatomy and physiology is done in close relationship with technical methods and equipment. In research, intensive collaboration of engineering groups with academic clinicians is required to avoid 'brilliant solutions to non-problems'. Therefore, three part-time professorships at the Delft University of Technology (DUT) are fulfilled by full-time professors at Faculties of Medicine.

Three **main trends in BME** have been identified by a national panel of experts:

-*Early-warning diagnosis* with specific *non-invasive* procedures by identification of parameters at cell-cluster level;

-*Therapeutic procedures* which become more *specific* in the space and the time domain, e.g. precise delivery of very specific drugs in small volumes;

-*Improvement of the 'Quality of Life'* in rehabilitation by sophisticated devices, which offer relief and regain of independence to the patient.

At the Delft University of Technology, several faculties are engaged in the following thematic BME **projects**:

-*Image processing and computation*
-*Development of measurement techniques and equipment*
-*Modelling of physiological systems*
-*Tools for the disabled*

Method

The Royal Dutch Institute of Engineers (KIVI) has founded in 1968 the Netherlands Study Centre for Technology Trends (STT) with the aims:

-to evaluate technological trends from the viewpoint of the engineering sciences and to explore their interaction with other developments in society as a whole;

-to give publicity to its findings as a contribution to a more integrated picture of the future of society in the Netherlands and elsewhere.

-The STT adresses itself to industry, government, science and the interested layman.

Its method is:

-identify experts on the subject at hand and invite them to participate in a task force;

-have them present their views among the panel members;

-in a second round, give the participants the opportunity to adjust and/or expand their statements based on the total image emerging (the so-called "Delphi Method");

-integrate the results and have an editor prepare a booklet on the subject;

-desseminate the results among the interested parties.

In 1994, a team of experts has been selected in the field of Microsystems (MST), among which a group on "Microsystems and Medical Technology" (Ref 1).

Highlights of the results will be communicated in this paper.

Trends in BME

It has become apparent that the traumatic side-effects of current medical procedures have often created similar risks to the patient as the primary cause or affliction, impairing the quality of life after treatment.

Consequently, three main trends in the support that BME can offer have emerged:

-Early-warning diagnosis

With specific *non-invasive* procedures such as NMR and ultrasound, it becomes possible to identify parameters at cell-cluster level.

-Therapeutic procedures

The need for treatment without trauma to surrounding healthy tissue has increased.

This has led to procedures which become more *specific* in the space and the time domain. Especially, the precise delivery of very specific drugs in small volumes would fulfill this requirement.

-Improvement of the 'Quality of Life'.

From such simple devices as hearing aids to sophisticated pacemakers and insulin pumps, from artificial limbs to portable oxygenation and ventilation systems, patients experience tremendous relief and regain independence.

Advantages of MST

The trends mentioned above have directed the development of medical need for engineering solutions. In view of this, MST has a number of advantages to offer:

-In-situ operation

Minimal invasive surgery (microcameras and robotic steering devices) and highly specific drug administration (mechatronic pumps) allow more specific treatment.

-Function integration

Combination of sensors, processors and actuators in a very small volume again yields specificity. Integration with a transponder reduces cabling and powering requirements. Improved reliability and EMC also call for integration.

-Reduction of costs

Cost-effective production of MST-devices will reduce costs, especially when high volumes are generated by using subsystems or modules in different applications.

-Reduction of size and power consumption

This will relieve the patient of the constraints of present technology and improve the dwelling time within the body or reduce traumas in use.

Classification

To catalogue the areas where the application of MST will have the most impact, these have been classified in a matrix, listing medical disciplines versus system integration.

The headings on the systems-integration axis are classified in order of increasing complexity and nearness to the patient. (Table 1).

Table 1 Classification of Microsystems (from Ref 1)

systems integration / *disciplines*	basic technologies						diagnostic instruments		therapeutic instruments				
	signal processing	sensor technology	remote sensing	micromanipulation	ultrasound	portable instruments	stereotaxy	endoscopy	invasive instruments	medicine administration	epidural stimulation	peripheral nerve stimulation	thermal stimulation
general surgery		◑	○	●	○			○					
urology		○	◑		○	○							○
neurosurgery	○	●	◑	○			○		○				
anaesthesiology	○	●								○			○
pain treatment						○				○	○	◑	
ear nose throat	○	○		○					○		○		
ophthalmology		○	○	◑					○				
cardiology	○	●	○	◑	○			○	○	○			○
rehabilitation	○	○				○			○			○	
drug treatment	○	○		○		○			◑				
internal medicine		◑								○			◑
ambulatory care	○	◑				○				○			

● strong growth area

◑ medium growth area

○ growth area

Growth areas for MST in BME

The following medical fields have been identified, in which MST will have a growing impact:

-*General surgery* (sensor technology for intensive care and minimal invasive surgery);
-*Urology* (dataloggers combined with urethra sensors);
-*Pain treatment* (implantable drug delivery and peripheral nerve stimulation);
-*Ear, nose and throat* (programmable hearing aids and cochlear implants);
-*Opthalmology* (implantable eye pressure systems and micromanipulation for operations);
-*Cardiology* (remote sensing);
-*Rehabilitation* (movement control, nerve-driven prostheses);
-*Internal medicine* (drug treatment by micropumps, thermal stimulators);
-*Ambulatory care* (patient monitoring, expert systems for home-use).

BME-themes at DUT

Research in the BME-field at DUT takes place traditionally in many groups, devoting part of their capacity to challenges from academic hospitals or industry. Inter-faculty collaboration is made visible by defining the following **thematic** fields, comprising about 10% of DUT research capacity:

-*Image processing and computation*
  .Medical image analysis and interpretation
  .Ultrasonic cervical cancer scanner
  .3D medical visualization
  .Computation of the field and temperature distribution in irradiated biological tissue
-*Development of measurement techniques and equipment*
  .Mobile optical telemetry and control
  .Ultra-low power electronics for medical applications, hearing aids
  .Optimal measurement of bioelectric events
  .Design of integrated thermal flow sensors using thermal sigma-delta modulation
  .Intelligent anesthestia monitor
  .Radiotracers: development of techniques for research and diagnosis

.Minimally invasive surgery

-*Modelling of physiological systems*

.Modelling of pilot-aircraft interaction

.Ventilation modelling of the human lung

.Kinematic and dynamic analysis of the shoulder mechanism

.Identification of the coronary circulation

-*Tools for the disabled*

.Enhancement of speech intelligibility with a microphone array: 'hearing spectacles'

.Design and development of aids for the severely physically handicapped

Conclusions

-Identification of trends by expert opinion supports the decision process in BME-research;

-BME is an essentially multi-disciplinary field: relevant developments require networks;

-BME research projects will only be successful in close collaboration with a highly-qualified medical group;

-Patients will benefit from MST through growing specificity of diagnostic and therapeutic procedures.

References

G. Klein Lebbink (Ed.), Microsystem technology, exploring opportunities. Report STT56, Samsom, Alphen aan de Rijn, 1994, ISBN 90 14 05088 7