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Research Activities at the Research Centre for Science and Technology in Medicine

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Abstract
Research Center for Science and Technology in Medicine (RCSTIM), affiliated with Tehran University of Medical Science (TUMS), was established in Imam Khomeini Hospital, the largest hospital complex of this kind in Iran in 1994. A major strategy of RCSTIM has been providing a common research environment for close cooperation between specialists involved in science, medicine, engineering and industry. This collaboration in one hand highlights RCSTIM research policy direction and on the other hand assure high quality standards required for design and development of novel medical devices. Since 1998, in line with the Third Development Plan of I.R. of Iran, the work has been focused on applied research activities to promote technical knowledge of the medical device industry, advance the health technology and establish joint research programs between universities and industry. There are seven research groups within RCSTIM conducting advanced researches in their specialties. In these many advanced research have been performed leading to design of hi-tech devices and systems. Some of case reports of these technologies are being presented in this paper.

Keywords: *Medical instrument, Robotic surgery, Image-Guided Surgery, Iran*

Introduction
There are seven research groups within RCSTIM conducting advanced researches in their specialties; Biomedical Systems, Medical Informatics, Medical Imaging Systems, Functional Imaging, Robotic Surgery, Nano-Biomedicine and Dental Material.
The mission of Biomedical Systems group is to advance the art and science of extracting clinically significant information from physiologic signals. The objectives for this research program are to design of new medical devices considering new technologies, to develop new methods of signal processing that extract useful information from physiological signals, and to advance our knowledge of pathophysiology through the investigation of behavior manifest in physiological signals. The Medical Imaging group objectives are to develop image correction techniques, modeling/simulation tools and accurate quantitative analysis for Medical Imaging systems (Computed Tomography, Radiology, fluoroscopy, SPECT and PET), as well as the assessment of new possible designs and modification of system geometry, collimator and detection modules using experimental measurement and sophisticated Monte Carlo techniques. The goals of the surgical robotics group are to design and develop novel robotic instruments, methods and procedures with high efficiency and low cost, suitable for developing countries. The main fields of work in Nano-Biomedicine group are research on nanotechnology instruments, devices and materials and also works are

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being carried out on development of nanobiosesors.

Following extensive research works, many advanced biomedical systems have been developed. Here highlights of these systems are presented and their relationships with the emerging topics of biomedical engineering technologies are described. These R & D case reports in Research Center for Science and Technology in Medicine (RCSTIM) are presented as an example of design and construction of hi-tech systems in this research institute.

Design and Construction of Scanning Tunneling Microscope (STM)

Scanning Tunneling Microscopy (STM) uses a sharp conducting tip and applies a bias voltage between the tip and the sample. When the tip is brought close to the sample, electrons can "tunnel" through the narrow gap either from the sample to the tip or from the tip to the sample, depending on the sign to the bias voltage. This tunneling current changes with tip-to-sample distance, decaying exponentially as distance increases, thus affording remarkably thigh precision in positioning the tip (sub-angstrom vertically and atomic resolution laterally). For the electron tunneling to take place, both the sample and the tip must be conductive or semi conductive.

Design and construction of this high precision system which plays a major role in characterizing and surface imaging of nanostructures started in year 2004. The research and development of this high-tech system was supported by a research grant from Iran Nanotechnology Initiative Council (INIC) and 16 experts were involved in five specialized groups of electronics, mechanics, industrial design, computer hardware and software, and signal and image processing. This system is now produced and commercialized by Nanotechnology Systems Corporation (NATSYCO), a spin off company from RCSTIM. This system is now marketed under NAMA (Nano Magnifier) brand name.

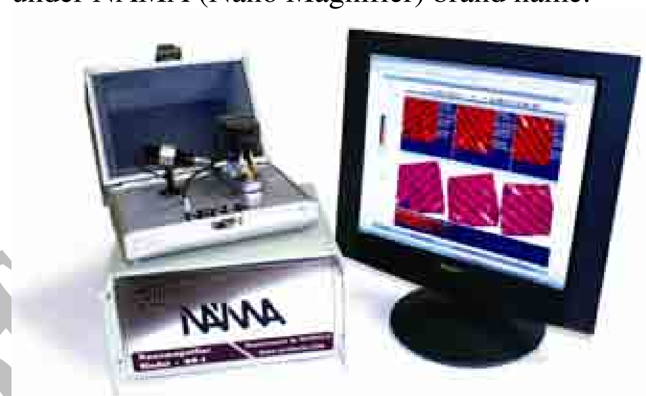
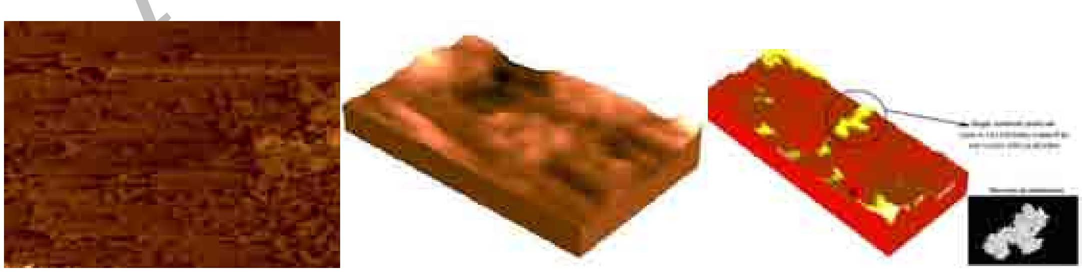


Fig.1: NAMA-STM System Design and Constructed In RCSTIM

Twenty of these systems are already sold 18 of which is installed and serving researchers in various universities and research institutes. Two of these systems are also exported and installed in Malaysia. The system and the images taken using this system are shown in figures 1 and 2 respectively. The state-of-the art image of figure 2-A, single IgG molecule, Fig. 2-B, single IgM molecule and Fig. 2-C. Nanosilver particles taken by NAMA STM clearly show the application of this system in Medicine.



(C) (B) A)

Fig. 2:A) single IgG molecule and its simulation on right, B) single IgM molecule, C) nanosilver particles

Computer Assisted and Robotic Surgery

Computer assisted and robotic surgery procedures have becoming common clinical practices in recent years as a result of rising trend towards more minimally invasive and geometrically precise surgeries. They are thought to provide better clinical results and lower the overall costs through shorter hospital stays, shorter recovery times, and reduced need for repeated surgery. The domain of applications has now been extended to the full spectrum of the medical treatment, from diagnosis to preoperative planning, surgery execution, and postoperative rehabilitation. As a result, the research and clinical activity is increasing sharply worldwide to develop new products and clinical applications for computer assisted and robotic surgery systems.

Following a detail study on the emerging medical technologies and realizing the significant and critical role of this discipline in future of the medicine, a research lab was established at the RCSTIM in 2003. This research lab, although relatively young, has managed to conduct valuable research activities in different fields of computer assisted and robotic surgery, through imposing an appropriate strategy. This includes developing a novel, general-purpose algorithm and technique for surface modeling based on the analogy between the B-Spline curve modeling and the force-deflection behavior of a beam subjected to lateral point loads. Also, considering the limitations of the presently available techniques for surface registration, we proposed a new technique based on the transformation relationships between the initial and transferred state of a mathematical function in space. This was then generalized for any points cloud using a mathematical representation for complicated freeform surfaces using the influence surface modeling approach and least squares method. In another field of computer assisted and robotic surgery research, our group has developed a model for more sophisticated and realistic simulation of the soft tissue deformation during laparoscopic surgery in real time. The mechanical realization of conventional Mass-Spring-Damper (MSD) models was improved through employment of nonlinear springs and dampers, while their high computational efficiency was maintained using an adapted implicit integration algorithm. Finally, at the core of the robotic surgery research, we have designed and developed a robotic cameraman for laparoscopic surgery, Robolens, which is dexterous, effective, simple to use, safe and low cost (Fig. 3). A key attribute of the Robolens system is its novel design with the minimum number of degrees of freedom, i.e., four, and actuators, i.e., three, to fulfill all surgeons' requirements; this is a major advantage over the previous designs considering the cost and maintenance issues of the system when using in clinical practice.

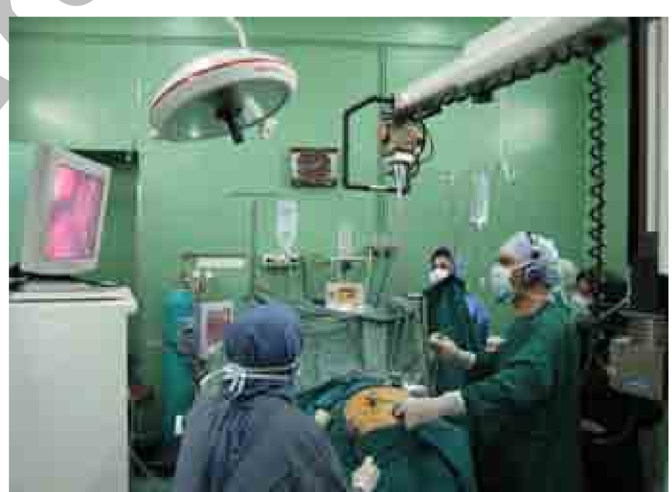


Fig. 3: Robolens during a laparoscopic surgery in Imam Khomeini Hospital

Clinical OAE System

OtoAcoustic Emission (OAE) is a surprising and exciting auditory phenomenon which allows us to explore peripheral hearing function in unprecedented depth and detail. OAEs have given us new insights into deafness and new possibilities for early intervention and treatment. People often ask what prompted the first OAE measurement. It was to explain a set of complex and little known psychoacoustic phenomena. Spontaneous subjective pure tones had been cited by Gold in 1948 as potential evidence for a cochlear amplifier. Today clinical OAE measurements are fast becoming a standard part of the audiometric test battery. OAEs have already had a major influence on newborn hearing screening programs across the world.

Since 1998, the bioelectric group of RCSTIM has been involved in design and commercialization of Transient evoked otoacoustic emissions (TEOAE). Prototypes devices were designed and tested. Due to very low amplitudes of the emissions to extract OAE from the background noise the traditional method is averaging at least 500 responses new algorithms for the denoising. In addition to the new hardware design, we proposed and implemented a novel algorithm using multi resolution decomposition to reduce the number of responses required for the averaging. Using this method reproducibility is increased and the test can be performed in a shorter time, enabling more efficient hearing screening process. Having tested the OAE instrument final version, the production has been designed and national and international marketing of the system have started.

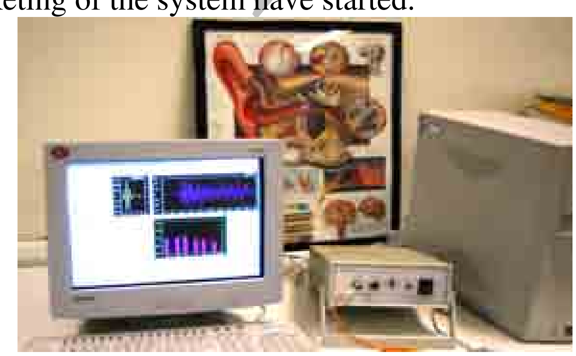


Fig. 4: Transient Evoked OAE Analyzer

Image-Guided Surgery System

Traditionally, surgeons have had to rely on two-dimensional X-rays coupled with their knowledge of human anatomy to prepare for surgical procedures. Once patients are opened up, surgeons relying on traditional methods are then only able to see the part of the anatomy that is exposed. This leaves patients with tumors deeply embedded in healthy tissue very vulnerable.

The state of the art image-guided surgical navigation allows surgeons to look inside of the body and see infected tissue inside of cavities, narrow passageways inside of arteries and awkwardly positioned tumors deep inside of the brain by sophisticated navigating through organs using three-dimensional (3D) images as their guide. Because the view is so precise and so controllable, a surgeon can actually see where healthy tissue ends and a brain tumor begins, or precisely where on the spine to place a pedicle screw to maximize patient mobility. This system enables surgeons to be able to create an exact, detailed plan for the surgery. The technology leads in shortening operating times, decreasing the size of the patient's incision, reducing the procedure's invasiveness, all of which can lead to better patient outcomes and faster recoveries.

The Image Guide Surgery group of RCSTIM has started working on design and implementation of a prototype system since 2007. This prototype not only provides the features of the current systems in the market but also aim to implement advanced features inside the system. This includes a fast and precise segmentation and registration of images from different modalities, and a user friendly visualization of images during surgery.

During surgery the instrument communicates with the computer and surgeon in real time basis. This means the surgeon can watch on a computer monitor as one precisely operates on the sensible organ. Looking at the computer monitor, the surgeon can see the position of the instrument as it relates to portions of the patient's anatomy that are beneath the surface of skin, hidden from the surgeon's direct view. Therefore, because of the provided virtual anatomy model of the patient, the surgeon does not need to make a large incision just to expose and see the anatomy underneath the skin.

We will release the first version of the system by the end of 2009 to be tested in the brain surgery room for performing an image guided tumor biopsy procedure. We will next modify the system for other applications such as orthopedic and ENT.

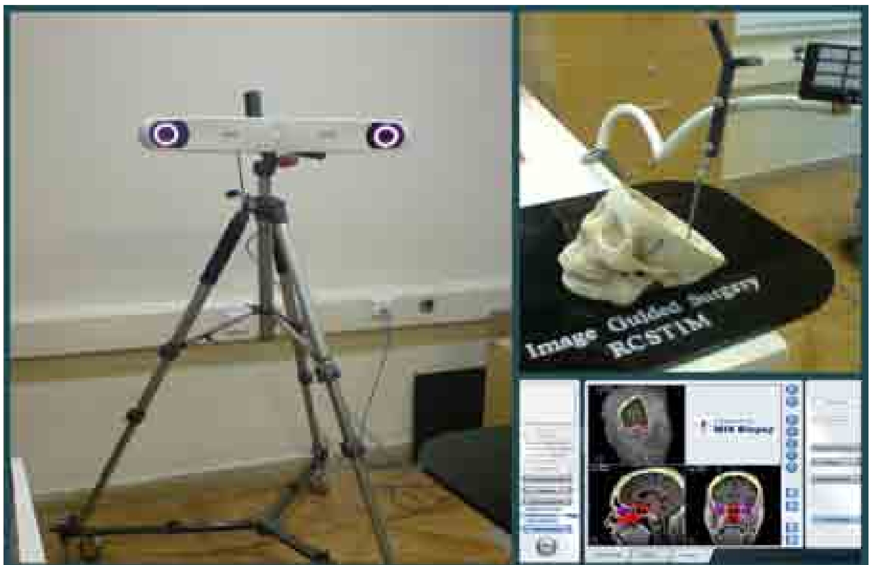


Fig. 5: Prototype System of Surgical Navigation under development in RCSTIM