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## Research and Education

### *New e-Health Tracks in Engineering Education of the Politecnico di Milano*

**Abstract:** In Italian universities, most curricula have recently been deeply innovated. Out of the historical and usual five-year-based degrees - to be taken after the five-year-based Secondary School/High School - the University system moved into a 3+2 year university framework. Engineering curricula were changed too. Such a wide reform forced the re-design of many courses, even entire course tracks. In some cases it also facilitated the re-design of Doctoral (Ph.D.) programs. The introduction of some one-year based and subject-focused programs, to be taken right after a specifically considered degree, was facilitated as well.

At the Engineering Faculties of the Politecnico di Milano, as far as it concerns Medical Informatics and Telemedicine, curricular courses and course tracks, as well as a couple of one-year subject-oriented programs have been widely re-organized. We describe the entire new educational offer.

The aim of the educational offer remains to enable students to acquire technical skills, and to use them for becoming Medical Information and Communication Technology experts. Often the student involvement in research is the practical pass for obtaining such result. In doing so students understand better what a positive technological return for the users is. Running research programs relate to the Visible Human Dataset and Digital Anatomy, to textual and image Data Integration, to Health Information System and e-Health, and to Bioinformatics. Some prototypes, developed at the Laboratory of Medical Informatics and Telemedicine, are briefly mentioned.

#### **1 The innovations of the Italian university system**

The need for the continuous revision of academic programs comes from the evolution of humanity and scientific knowledge, the progressive development of new technology, and the disciplinary fields involved in Human Knowledge. In the last year a substantial transformation of the Italian academic system has been started. The traditional five-year-based degree course, which for many years represented the only possible path for secondary school graduates who wanted a professional

education, has been renewed in terms of organization, subjects and purposes, to meet the new demands of a greatly changed society and technical-economic system.

The recent project to reform the Italian university system has introduced some significant innovations in the organization of academic study programs. The 3+2 (+3) year system has been introduced corresponding to three stages of career progression (Fig. 1, right side), which are the 3-year-based Bachelor Degree ("Laurea"), the 3+2-year-based Master Degree ("Laurea Specialistica") and the 3-

year-based Doctoral Degree, i.e. Ph.D. program, ("Dottorato di Ricerca"). Architecture, Industrial Design and Engineering, which are the kinds of faculty present at Politecnico di Milano, have been re-organized in that way [1]. The Biomedical Engineering programs, where the knowledge on Health and Medical Informatics and Telemedicine is delivered, are briefly described in following paragraphs. Then, we described the one-year-based course for a Health Informatics (Maintenance) Technician, which is devoted to Secondary School/High School

graduates, and the one-year-based Specialization Course on Telemedicine and Telehealth (Fig. 1, left side).

### 1.1 The ECTS Credit System

The European Credit Transfer System (ECTS) credits measure the student workload that is required to pass the examinations, and includes class attendance, class work, laboratory work and individual study [2]. Each course is assigned a number of credits, which the student obtains when he passes the final examination. However, the evaluation is based on a grade score of 30. One credit corresponds to a workload of about 25 hours and the yearly workload corresponds to about 60 credits. It will also be possible to obtain credits for activities other than training courses, such as theses, projects, apprenticeships, foreign languages, basic computing skills, training in communication and public relations, and group work. Ways of monitoring and evaluating such activities will be established.

### 1.2 The 3-year-based Bachelor Degree (“Laurea” Degree)

The Bachelor Degree is obtained after a 3-year course of study and aims to provide a solid foundation in the core scientific subjects as well as more specialized, professional training. During the third year, the student is expected to acquire work experience by participating in a company internship. The biomedical engineering graduate integrates an engineering preparation with a knowledge of medical and biological applications and can operate in the following fields: management of devices and systems in the hospital; development and production of medical devices and systems; technical and commercial assistance to biomedical products; and technical consulting in the biomedical field. After 2 years of common track, it is possible to follow an applied track or an introductory track to a Master Degree (Fig. 1) [3].

Once a student obtains the Bachelor Degree, he/she can either directly enter the job market or continue his/her studies and obtain the Master Degree.

### 1.3 The 3+2-year-based Master Degree (“Laurea Specialistica” Degree)

The Master Degree is awarded after two more years of study and aims to provide rigorous, advanced training in more highly specialized areas. The Master in biomedical engineering develops an advanced preparation by choosing a specific course track: Biochemistry and Biomaterials, Biofluidynamics and Artificial Organs, Medical Images, Biomechanical Design, Biomedical Signal and Data Processing, Health Care Management, Biomedical Informatics and Telemedicine, Neural Engineering, Tissue Engineering and Biotechnologies, Movement Engineering and Ergonomics, Biomedical Technologies and Biosensors. A biomedical engineer can operate in R&D and industrial design, technical and commercial support to biomedical products, clinical engineering and consulting [3]. Programs continue to be 5-year-based courses in order to comply with EU regulations and be officially recognized.

### 1.4 The 3-year-based Doctoral Degree – Ph.D. (“Dottorato di Ricerca” Degree)

The PhD is awarded after three additional years of study (180 ECTS credits) and aims to develop the professional competence to carry out high level research in manufacturing and service companies, public bodies and universities. Doctoral Program in Bioengineering prepares graduate students for high standard scientific and industrial research. This educational goal is achieved through three different areas: basic general preparation (introductory courses), basic research preparation (main courses), special purpose research preparation

(elective courses and training on specific themes) and a final dissertation on original themes of high standard in the international scientific framework. Stages in qualified research institutes in Italy and abroad are part of student preparation as well. The public presentation and discussion of the dissertation end the Program.

### 1.5 The One-year-based Course of Health Informatics (Maintenance) Technician

A post Secondary School / High School program to become a Health Informatics Maintenance Technician is offered with support of the Lombardia Region Council and founded by the European Union. Some Secondary Schools / High Schools, Universities, and Public Healthcare Providers are involved in this educational project. The course is one-year-based and takes 1,200 hours of didactic and practice activities. The objective is to prepare high level ICT Technicians devoted to the Health environment.

At the end of the course, acquired specific skills are: the ability to interact with users of Information and Communication Technology (ICT) instruments such as clinicians, nursing personnel and medical technicians; to support providers during installation of medical instrumentation; to help in designing and developing software programs to query and manage Hospital and Administrative Information Systems; to contribute in defining the workflow among hospital units; to manage maintenance of services and guarantee privacy and security of clinical and administrative data.

### 1.6 The program of Specialization Course on Telemedicine and Telehealth (One-year post “Laurea Specialistica” Degree)

The “Telemedicine and Telehealth Specialization Course” provides professionals highly demanded by the

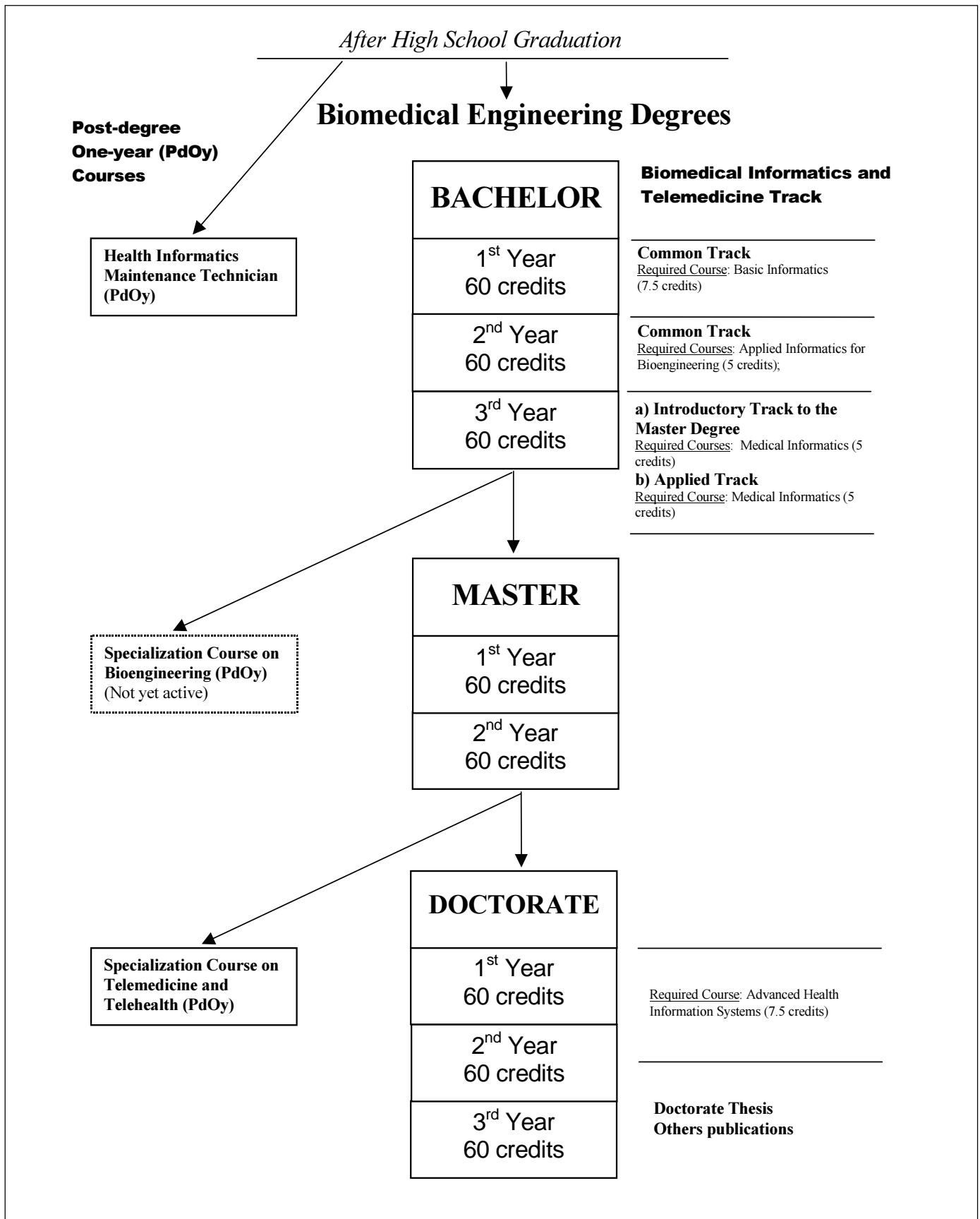


Fig. 1. The educational offer in Biomedical Informatics and Telemedicine at the Politecnico di Milano. (Credits are according to ECTS, the European Credit Transfer System).

market, and it is also addressed to people needing to redirect their profession. The aim is to train highly qualified people who will be fully acquainted with the latest technology and deeply aware of the needs of the sector.

The Course focuses on three fundamental aspects. The first is solid theoretical training in ICT and in the specific problems of its use in the Medical sector. The second aspect is the direct use of such technology as adopted by Treatment and In-patient Structures and by their supply Companies. High priority is given to participation in specific research and development projects. The third aspect is the ability to evaluate the economical impact of telemedicine projects.

The Course, which is full-time and takes 1,500 hours, has been designed jointly by the Politecnico di Milano Department of Bioengineering and the CEFRIEL Centre [4], which is the ICT Centre of excellence at Politecnico di Milano. Its main activities encompass research, innovation and education.

The Course includes lectures, analysis of Case Studies, laboratory practice, project development and prototype construction, assessment of the impact of use of technologies and evaluation of economical aspects of telemedicine projects. The training process involves 10 teaching units covering half of the total hours.

Laboratory activities and stages at specialized companies aimed at concrete Telemedicine applications cover the remaining half of the total hours.

## 2 The Medical Informatics and Telemedicine Track of the Engineering Curricula

So far we have briefly described the innovations of university reform in Italy and the programs in Biomedical Engineering. In this section we present the courses of the Medical Informatics

and Telemedicine track offered at Politecnico di Milano for each degree level.

The aim of each course is to enable students to acquire technical skills to become ICT experts for implementing the solutions for the problems present in Medicine and Health Care. In this environment we consider two interactive but separate roles: the Physician, who plays the customer role, asks for solutions and evaluates their implementation; the Medical Informatician, who plays the provider role, has to develop the solutions. Although the overall relation will probably lead to a permanent conflict and interactive negotiation between the two roles, they are aimed to develop solutions for the benefits of patients. To remain in good dialogue and collaboration with the Physician is necessary for the Medical Informatician, though it is a difficult task.

### 2.1 Courses for the 3-year-based "Laurea" program

#### 2.1.1 Basic Informatics (Code: 060016) – Credits: 7.5 ECTS

"Basic Informatics" is a required course delivered in the first year. The illustrated subjects are: the concept of algorithms, recursive algorithms, sort and search algorithms; and data structures such as arrays, lists, trees and graphs. The C and C++ programming languages, which are used to implement algorithms and data structures, are learned during Laboratory Sessions. An introduction to Internet, web browsers and the Hyper Text Markup Language (HTML) is also given.

#### 2.1.2 Applied Informatics (Code: 072415) – Credits: 5 ECTS

"Applied Informatics" is a required course delivered at second year. The illustrated subjects are: relational database theory, Unified Modeling Language (UML) and its extension to

design and development of relational data bases and Structured Query Language (SQL). A summary of types of networks and communication protocols is also given.

#### 2.1.3 Medical Informatics (Code: 060083) – Credits: 5 ECTS

The basic subjects - necessary for working with medical people - are described for both the clinical and the research settings. An ICT oriented taxonomy of health care and clinical information, data bases for Medicine and Healthcare, Health Information Systems, basics on security and privacy, major standards for Medical Informatics: all these subjects are illustrated and their concepts and effectiveness are described. A number of Medical Informatics subjects are approached through focused seminars, entirely and practically offered at an computerized room environment.

Electronic medical records, bio-signal and bio-image archives, health data security and privacy, digital libraries, medical terminology dictionaries, guidelines for medical practice, genomic databanks, telemedicine and telehealth and major applications of Internet for medicine and health care are the major examples of the presented topics.

#### Methods of Learning Verification:

- Attending the theoretical and practical lessons is heavy suggested.
- The overall score of examination is established considering the scores obtained in two written examination, each regarding a part of the program. If the score is greater than 18/30, then an overall score is proposed to the student.
- The ability to structure a description of arguments of the course using an appropriate terminological language and to single out the aspects useful for clinicians constitutes the fundamental criteria to assign a positive score.

## 2.2 Courses for the 2-year-based “Laurea Specialistica” Degree

### 2.2.1 Course on Health Information Systems (Code: 072533) – Credits: 5 ECTS

The course on Health Information Systems consists of five parts. The first part comprises user goals, architectures, legislation and normative on Health Information Systems. The second presents a Partonomy, which deals with Hardware, Network architecture, Software (Operating Systems and Object Oriented DBMS's, Picture Archiving and Communication Systems (PACS), Radiological Information Systems), Design methods, Data protection methods and instruments. The third part describes the Macro-functions present in a Health Information System: Workflow, Data acquisition, Queries, Archiving and Data protection. The fourth part deals with Management aspects: System monitoring, Human resources, Providers and Maintenance. The fifth part comprises Benchmarking issues: Technologic performance and User satisfaction. Most subjects are offered in a computerized room environment.

#### Methods of Learning Verification:

The exam is based on the two following parts: a) the arrangement of a scientific essay on an issue that will be agreed on with the teacher and chosen among the set of arguments the course has dealt to, b) an individual oral test devoted to the presentation of the scientific essay and oral discussion of other arguments of the course.

### 2.2.2 Laboratory Course on Medical Informatics and Distributed Systems (Code: 073589) – Credits: 5 ECTS

The course, held in the Informatics Room, is devoted to the experimental development of “Learning by Doing” Educational Projects of Medical

Informatics, Bioinformatics, Telemedicine, and Teleteaching. The educational purpose of the projects consists of allowing students to acquire satisfactory professional levels - intended as the set of knowledge, friendliness competence, and ability of critical analysis - about some specific web applications of distributed systems for Medicine and Biology. The operative purpose of the projects - in support of the educational aim and to practically demonstrate its results - focuses on the design and implementation of dynamic web sites, connected to a database, devoted to provide educational contents and to implement interactive services via intranet/Internet in Clinic, Healthcare, Bioinformatics, TeleMedicine, and Teleteaching fields, time by time oriented to researchers, doctors, patients and citizens. The aim is training students to be a human resource of immediate use. This makes it easier to find useful and appreciated job roles, either in business or in research. More information at: <http://www.medinfopoli.polimi.it/corsi/>

#### Methods of Learning Verification:

The exam is composed of the two following parts: a) implementation of a software project using web technologies and programming languages presented in the course, involving a considered application area, b) oral discussion on the project. If the obtained score in each part is greater than 18/30 then an overall score is proposed to the student.

### 2.2.3 Course of Biolanguages and Bioarchives (Code: 075236) – Credits: 5 ECTS

This course deals with issues related to bio-medical terminological knowledge representation, i.e. the way of representing terms and formal relationships among them. Principles of knowledge organization in the most popular classification systems (e.g. ICD-9-CM) and nomenclatures (e.g. SNOMED) are highlighted.

The features of some relevant on-line bio-medical data banks are presented (e.g. MedLine, LocusLink, OMIM). Issues related to ontologies and semantic web in bio-medicine are sketched out. Specific formalisms, languages and tools are outlined.

#### Methods of Learning Verification:

Compulsory attendance of 75% of the total amount of hours (the course is composed of 28 hours of theoretical lessons, and 42 hours of laboratory sessions). To pass a final written and oral examination is compulsory. Development of a project comprising course arguments is optional.

### 2.2.4 Elective Courses

To augment the skills of students, some elective courses such as Advanced Database, Information System, Soft Computing, and Knowledge Engineering are available. Each of them gives 5 ECTS credits.

## 2.3 Courses for the 3-year-based Doctoral Program

At the postgraduate level the authors have a newly defined track where the major component is a course on Advanced Health Information Management, from concepts to big systems.

### 2.3.1 Course of Advanced Health Information Systems – Credits: 7.5 ECTS

This course is going to be offered by the Politecnico di Milano within the refounded and now starting Ph.D. program in Biomedical Engineering. Dedicated to postgraduate students, the course aims at transferring solid knowledge on the relevant problems still to be solved, as well as on the ongoing update of some hospital information system building blocks.

Course contents are as it follows. Conceptual modeling for patients, general practitioners, hospitals, and healthcare administrators of information services.

Quantitative modeling: workflow methods for communication analysis between services and clinical departments.

Implementation tools: object-oriented languages in distributed and concurrent applications; temporal databases and management of multimedia clinical information; user views.

Large archives of bio-images: the Visible Human Dataset; the Unified Medical Language System for querying bio-images databases, the databases for the Human Genome Project, compression techniques for bio-images and bio-sequences, networking techniques, benchmarking of health information systems at department, hospital, and regional levels, fundamentals and techniques to manage clinical data privacy, elements of contracts and service providers' confirmation and management of innovation projects.

#### Exam Modality:

Development of a review paper to submit for publication and the corresponding oral presentation.

### 3 The Educational Research Scenario

The Medical Informatics and Telemedicine Laboratory promotes the application of advances in computer science, artificial intelligence, mathematics, and database theory to novel research approaches to Electronic Health Records, Patient Data Security, Genomic and Proteomic Data Analysis and Biomedical Ontologies. Research activity is concentrated in three lines of research: services based on a Visible Human Dataset, which is a long lasting theme, and Digital Anatomy; Health Information System and E-Health, another long lasting theme; and Bioinformatics, which is a recent theme.

The Visible Human Dataset - Milano Mirror Site<sup>®</sup>, which contains a copy of

the US National Library of Medicine Visible Human Dataset and offers the data to licensed users, opened its services on February 1997. From that moment Digital Anatomy became an effective research theme and remarkable results have been obtained, e.g. a novel approach to anatomy knowledge representation [5] and a Dynamic Histogram Viewer (DHV), which is an on-line virtual three-dimensional immersive environment to navigate through colorimetric characterization of the Visible Human Dataset (VHD) cryosectional cross-section color images [6], [7].

The Internet made it possible to access remote data via the Web. This had an impact on Electronic Health records: they could be made accessible everywhere where a PC is connected to the Internet, but data security and sharing became problems to solve. However, a web medical record for the patient at risk of emergency, in Italian, was developed by the MyAngelWeb<sup>®</sup> project [8]. The Speaker system, which experiments the use of a voice synthesizer in the MyAngelWeb<sup>®</sup> web medical record was implemented [9]. Only the textual subset of a patient medical record was considered and it was restructured according to the requirements imposed by vocal-only communication.

At the Medical Informatics and Telemedicine Laboratory the management and analysis of biological data using advanced computing techniques, and the analysis of genomic and proteomic research data for clinical application started five years ago. A number of software prototypes were developed: GAAS (Gene Array Analyzer Software) is an integrated software framework for efficient management, analysis and visualization of large amounts of gene expression data across replicated experiments [10]; Genome Function INtegrated Discoverer (GFINDER) is a web server able to automatically provide large-

scale lists of user-classified genes with functional profiles biologically characterizing the different gene classes in the list [11]; MyWEST is a software package for effectively mining biomolecular databanks on the web [12]. Further information is available online at <http://www.medinfopoli.polimi.it/> in the "Prototypes" section.

### 4 Concluding Remarks

We have described the educational offer and research activities in Medical Informatics and Telemedicine at the Faculty of Bioengineering at Politecnico di Milano. The educational offer is changed following the Italian university reform and research will feel the benefits soon.

In each course that is offered, technologies are presented for the improvement of the clinical environments. We do our best for implementing the claim "serving patients by serving doctors and institutions".

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