A. Geissbuhler, C. Lovis, J. P. Vallée, S. Spahni, R. Baud

Division of Medical Informatics
Geneva University Hospitals
Geneva, Switzerland

Research and Education

A 2'200-bed laboratory: research and education in medical informatics at Geneva University Hospitals

Introduction

For more than three decades, the focus of medical informatics at Geneva University Hospitals has been the development of innovative, patient-centered computer-based tools to improve the quality and efficiency of healthcare delivery. Created under the visionary leadership of Professor Jean-Raoul Scherrer [1], the Division of Medical Informatics (Division d'Informatique Médicale, DIM) has always combined its service and research missions, leading to the development of influential real-world systems, such as the DIOGENE hospital information system [2,3], pioneering medical image management tools [4,5], and bioinformatics resources [6], as well as significant contributions to the fields of medical knowledge representation and natural language processing [7], image processing, federated health care records architectures, and e-health.

This paper presents the philosophy and scope of the research and education efforts of the Division of Medical Informatics at Geneva University Hospitals and School of Medicine.

Geneva University Hospitals, a 2'200-bed laboratory

With the development of the DIOGENE hospital information system in the 70's, informatics made its way into the daily life of the collaborators of Geneva University Hospitals. Computing resources being limited, the idea at the time was to give priority to the applications for care-providers. Without terminals and 15 years before the advent of personal computers, the challenge was to create a convivial man-machine interface: a pool of phone operators who mediated the interactions between professionals and the mainframe computer, sending direct visual feedback through video cables, was an exemplary solution, the so-called "Geneva solution" [8], to an ergonomic, organizational and technical problem that can still be found in today's systems.

This example illustrates the key philosophy that has guided not only the service mission of the DIM, but also most of its research activity: innovative solutions for patient-centered, real-world problems. The emulation between these two missions, the proximity of researchers, informaticians and clinicians, and the cultural acceptance of innovative computer-based tools within the real-world care processes have enabled new synergies, development strategies, and production systems.

The importance of communication, collaboration and knowledge management within the hospital is now better understood, but the actual role of information and communication technologies in such complex organizations and processes need to be further studied. Ethnographic techniques, coupled with the analysis of usage logs and outcome measures, can be applied to this "laboratory" environment where actors can be finely observed, and, when necessary, randomized in prospective studies.

Today, Geneva University Hospitals (HUG) comprise a group of primary, secondary, and tertiary care facilities, employing 8'000 collaborators (including 1'300 physicians and 3'000 nurses), totaling 2'200 beds, 50'000 admissions, 70'000 emergency room visits, and 732'000 outpatient visits each year. Numbers reflect its level of computerization: there are 4'600 PCs, 500 physicians are equipped with institutionally-

managed PDAs loaded with clinical information resources and dozens of wheel-mounted computers are used to provide point-of-care information through a wireless communication network. Digital information has been accumulated for decades, in the form of text, images, and encoded data. It is now available online within the computerized patient record and a clinical datawarehouse. The Picture Archiving and Communication System (PACS) handles 85 percent of all radiology images, which are available on all clinical workstations within the computerized patient record.

Based on a distributed component architecture [9], using HTTP/XML and DICOM as standards for interoperability and a strong terminology management, the clinical information system can easily be extended to provide specific views or new business logic, while maintaining a globally coherent system. As interoperable components or applications can be shared over the internet, these extensions can be functional as well as geographical, leading to various telemedicine applications, ranging from sharing of knowledge components, to teleradiology and teleconsultations.

The Division of Medical Informatics (DIM)

The DIM [10] is based in the Geneva University Hospital as a clinical service, and in the Geneva University School of Medicine as an academic division. This dual attachment facilitates the links between fundamental and applied research, and the transition between pre-graduate education and post-graduate or professional training.

The DIM consists of more than 50 collaborators who work in one or more of the four operational groups:

- the integrated patient record group: in charge of the design, development and deployment of the institution's clinical computer-based tools, including the computerized patient record, clinical data capture tools, and clinical decision support tools. Areas of research include: innovative human-machine interfaces, role-based information integration and presentation, and knowledge-coupling in clinical workflow,
- the digital imaging unit: in charge of the institution's image management system (PACS) and the support of clinicians for image analysis. Areas of research include the development of specific algorithms and tools for image analysis (segmentation, 3-D reconstruction, augmented reality), and, in connection with the radiology services, the development of new image acquisition techniques, in particular in the field of functional magnetic resonance imaging,
- the middleware group: in charge of the clinical information system's foundation components. Areas of research include open, component-based architectures, federated health-record systems, telemedicine infrastructures, and security in distributed systems,
- the natural language group: in charge of terminology management and the integration of operational natural language processing (NLP) tools in the clinical information system. Areas of research include innovative NLP techniques, clinical knowledge representation and engineering [11,12].

The DIM has established numerous academic collaborations that extend its research and education potential. These include:

- within Geneva University, the Faculty of Sciences and the Faculty of Literature, for the co-direction of doctoral students (computer science, physics, mathematics, linguistics),
- other universities, and in particular the Swiss Polytechnical Schools in Lausanne (EPFL) and Zürich (ETHZ), with projects dealing with advanced image analysis and operational research for resource usage optimization,
- the Swiss Institute for Bioinformatics, whose director is also a member of the DIM,
- the European Nuclear Research Center (CERN), based in Geneva, with projects on medical imaging instrumentation, and others on grid- and super-computing.

Current research activity

Current research activity at the DIM can be grouped in four mains areas:

- **techniques and tools for enabling the learning healthcare institution**: healthcare being fundamentally a knowledge business, there is a need for improving the ability of healthcare institutions to capture, manage, activate, and discover knowledge within the immense amount of information that is being produced by the care processes and by biomedical research. Tacit knowledge capture can be enhanced by various tools [13,14]. Knowledge representation techniques can improve the quality and reusability of knowledge bases. The combination of data mining with NLP techniques and image features extraction could lead to innovative "multidimensional" knowledge discovery applications. Links with bioinformatics open perspectives both for the integration of genomics and proteomics information in the clinical processes, and bioinformatics research can be helped by medical informatics tools such as ontology management tools and NLP techniques,

- **clinical information systems that make a difference**: with numerous different types of stakeholders involved in the process of care production, in a complex environment characterized by discontinuities and nomadism, the clinical information system must be able to adapt its human-machine interfaces to bring the appropriate information at the point of decision, in a form factor adapted to the needs of the user. Research topics include clinical decision-support systems, component- and agent-based open architectures, intelligent notification systems, workflow and resource usage optimization, and the evaluation of the cognitive and communication impact of information technology in clinical environments [15],
- **from medical image acquisition to augmented reality for clinicians**: the complete medical image production chain is a subject of research activities at the DIM. It starts with the optimization of medical image acquisition techniques [16], the storage, communication and integration of images in various clinical applications, automated feature extraction for diagnostic assistance, to the post-processing of images, automated segmentation [17], multi-modality co-registration, tridimensional reconstruction and use in augmented-reality tools for surgery,
- **medical information technologies as enablers for developing countries**: the potential of information and communication technologies to improve the health system of developing countries is real. Infrastructures that can survive rough environments must be designed, telemedicine applications that help distributing expertise, and medical contents that is adapted to the resources and culture of the country are current topics of research, through collaborations with several Western Africa countries [18] and the deployment of a multilateral, south-south, network of tele-expertise and tele-teaching [19].

Education

The DIM is involved in various educational activities. Medical students follow courses on medical information retrieval and critical appraisal of web-based information. In parallel, a web-based medical informatics course for medical students is being developed as part of the Swiss Virtual Campus [20]. This course will be used by all five Swiss medical schools starting in 2003.

At the post-graduate level, the DIM provides a biostatistics course for physicians, a medical imaging course for radiologists, and a short-course in medical informatics open to healthcare and informatics professionals [21]. Several doctoral students in computer science, physics or linguistics are hosted at the DIM and are co-directed with the Geneva University Faculty of Sciences of the Faculty of Literature.

Medical residents and post-graduate students interested in the field of medical informatics can spend a one- or two-year fellowship at the DIM. Physicians are usually encouraged to spend at least two years of clinical practice before joining the DIM, in order to develop clinical skills and a good understanding of the care production processes.

Medical informatics training is still in its infancy in Switzerland, but the need for trained professionals is pressing for the development of structured curricula. A master-level degree is being set up in collaboration with the DIM and the Geneva University Computer Science Department. It should be available in 2004 and followed by a PhD-level degree in 2005. It is also likely that the Federation of Swiss Physicians (FMH) will recognize medical informatics as a specialty within a few years.

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Address of the first author:
Prof. Antoine Geissbuhler, MD
Division of Medical Informatics
Hôpital Cantonal
24 rue Micheli-du-Crest
CH-1211 Genève 14
E-mail : antoine.geissbuhler@hcuge.ch