Teaching Soft Computing in Medicine: an Interdisciplinary Experiment

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Abstract
The objective of this study was to test the feasibility of teaching some of the many engineering applications within medicine to medical students together with engineering students. A summer school was created in a block-course design that lasted one week. Different teaching modules were divided into lecture and exercise sessions. Several engineering topics combined with medical examples were presented. Half of the students were engineering or computer science students and the other half medical students. The staff of lecturers was also mixed. At the end of the course the students had to pass a web-based examination and fill out an online evaluation-sheet. Most of the students regarded the cooperation between physicians and engineers as very important. The major challenge of the course was the interdisciplinary aspect of teaching: medical students had to learn about methods of information technology and engineering students were exposed to medical information analysis. Teaching both groups of students together resulted in a close collaboration between both groups. The paper highlights some pitfalls and gives recommendations for a similar type of course. In particular, the main recommendation for the future, given the technological advances in medicine, is a closer cooperation with disciplines such as information technology.

1. Introduction
The computer era poses a challenge for many healthcare professionals [1, 2] and information technology (IT) has broad impact to medicine [3]. In the past few years much interest focused on the discovery of information hidden in large collections of medical data. Data mining is the extraction of regularities hidden in the data as well as the search for relationships and global patterns. It combines statistics, visualization, machine learning and other intelligent techniques in order to analyze large medical databases [4]. Moreover, most of the medical data is incomplete and imprecise. This is described by the term ‘soft’, which describes the medical data as being ‘soft’ in contrast to crisp data commonly used in many technical fields. Soft computing lacks a unifying theory, but groups of methods within soft computing do build on a common theoretical basis. The biomedical professionals have to deal with computer engineering methods, but the engineers on the other hand have to be aware of the ‘soft’ characteristics of medical data. The healthcare professionals must be able to deal with computer applications. Moreover, engineers and physicians have to learn to communicate with each other. The idea of this study was to deliver an interdisciplinary course focusing on soft computing methods in medicine. Here medical students should learn together with engineering students about medical applications of artificial intelligence.
2. Methods

2.1 Educational Goals
Medicine as well as engineering requires the ability to delimit, structure and solve complex problems under practical constraints. This can be reflected in the goal for a course, for instance:

(1) ability to identify central concepts;
(2) ability to recall the central concepts;
(3) ability to solve typical problems;
(4) ability to assess whether theory and methods apply to a given problem.

The goal levels are organized such that, starting from the top, each level requires an increasing amount of understanding on behalf of the student. While it is preferable to be on level 4 for an engineer facing a technical problem, level 2 can be sufficient for a medical doctor facing a technical problem - and vice versa. Considering an average course duration of five days, it seems feasible to achieve just levels 1 and 2, and disregard the higher ones. A way to achieve level 1 could be to lecture in the traditional manner, and level 2 could be achieved through exercises.

To support the building up towards the two levels, it is advisable to let the course consist of three distinct components: textbook material, lectures, and exercises. For convenience, the textbook material should be electronic, downloadable, and available any time. An exercise demonstrating central topics was to back each lecture. Thus the smallest course-block consists of a lecture with an exercise. Exercises should be performed on personal computers using software which is either available on the Internet for free or readily available and established in the field. Software can be regarded as a computational laboratory for experiments performed under guidance by tutors. A web site is preferable to organize the electronic material as well as the exercises. Usually, goals are broken down into a number of skills, that students should acquire. For example,

(1) to be able to recall factual knowledge;
(2) to be able to perform standard calculations.

Students usually find these algorithmic skills easy to acquire. From a teacher's point of view, skill 1 could be trained using the exercises mentioned above. Skill 2 could be trained using assignments with closed design problems, having unique solutions. The level of difficulty could be increased gradually, and eventually one could introduce open design problems with many solutions, some possibly unknown even to the teachers. On the other hand, students usually find it difficult to acquire skills that require an understanding of the subject. For example,

(3) ability to delimit and define concepts and models;
(4) ability to intuitively understand theoretical items;
(5) ability to physically or spatially visualize a theory;
(6) ability to recognize a principle in different representations;
(7) ability to recognize a principle in different degrees of idealization or generalization;
(8) ability to set up and analyze scenarios;
(9) ability to assess a model’s assumptions;
(10)ability to assess the consequences of modelling;
(11)to be able to delimit, structure, and model a problem;
(12)to be creative, in design problems for instance.

Skills 3 to 12 could be trained using didactic utilities, such as slide presentations, simulations, and project reports. To make it easier for the student to digest the material, the material should have a clear structure, the terminology should be fixed, and illustrations from real world projects should support the theoretical presentations. Our ideal course organization would then consist of modules containing one lecture and one computer exercise, a web organizer and assignments and reports to test and establish the learning.

This is the plan we set out to follow. Due to practical constraints, the final course of action deviated somewhat from the ideal plan.

2.2 The Aachen Summer School
The Aachen Summer School took place at the Institute of Anatomy at the RWTH Aachen (18th to 22nd September 2000). The location was chosen since it features medical and technical faculties that are directly neighbored, so that it seemed best suited to find medical and engineering students for the course. It was organized in a blockcourse-design and lasted one week. The time schedule is shown in table 1. Different teaching modules were developed. The modules were divided into lecture and exercise sessions. In the lectures insights on theoretical aspects of IT and some concrete medical problems were given. The exercise sessions took place in a computer room with one PC for each student: here students solved some medical problems using computer science methods.

Several engineering topics were presented to the students, such as data analysis, feature selection, fuzzy
<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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</thead>
<tbody>
<tr>
<td>Welcome</td>
<td>Lecture (45 min): Data analysis</td>
<td>Lecture (45 min): Medical imaging, Fuzzy Imaging</td>
<td>Lecture (1.5 hours): Decision trees</td>
<td>Lecture (1.5 hours): Classification using Neural Networks</td>
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<tr>
<td>Medical Data</td>
<td>Exercise (45 min): Data analysis</td>
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<td>Exercise (45 min): Queries to data bases</td>
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<tr>
<td>Lecture (45 min): Types of Data</td>
<td>Lecture (45 min): Analysis of Polarized Light Images Using Fuzzy Inference</td>
<td>Lecture (1.5 hours): Medical Example (application + results from decision trees)</td>
<td>Exercise (1.5 hours): Classification of PAP smear images</td>
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<tr>
<td>Exercise (45 min): Variables from data sets</td>
<td>Factor analysis</td>
<td>Excursion</td>
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<tr>
<td>Lunch</td>
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<td>Lunch</td>
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<tr>
<td>Lecture (45 min): Variable relations</td>
<td>Lecture (45 min): Feature selection</td>
<td></td>
<td>Examination and evaluation</td>
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<tr>
<td>Exercise (45 min): Calculation</td>
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<td>Coffee break</td>
<td>Coffee break</td>
<td>Coffee break</td>
<td>Coffee break</td>
</tr>
<tr>
<td>Lecture (45 min): Matrices</td>
<td>Lecture (30 min): Clustering II</td>
<td>Final Discussion</td>
<td>Exercise (1.5 hours): Feature selection</td>
<td>Graduation party</td>
</tr>
<tr>
<td>Exercise (45 min): Create matrix operations</td>
<td>Lecture (30 min): Clustering II</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>Exercise (30 min): Fuzzy techniques</td>
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</tbody>
</table>

Table 1: Schedule of the course.

logic, artificial neural networks, digital image processing, decision making, and classification methods. The medical applications presented were diagnosis of aphasia, classification of cytological images (cervical PAP smears), neuroanatomical threedimensional computerized atlases, magnetic resonance imaging and decision trees in medical diagnosis. In the middle of the course an excursion was organized with three possible destinations for the students: a group visited the Department of Radiology, where magnetic resonance imaging was explained and demonstrated; a second group visited the psychiatric clinic in order to learn about methods of neurophysiology and psychological tests; a third group stayed at the Institute of Anatomy, where some imaging routines used in neuroanatomical research were demonstrated such as confocal laser scanning microscopy and computerized threedimensional brain atlases. The course was organized in a modular manner, so that the different modules could be developed independently as lecturers came from different European countries. All teaching material was organized on the internet and available at the TEDServer [5], the official ERUDIT website for training and education in fuzzy technologies (see section 5).

2.3 Examination and Evaluation
At the end of the course the students had to pass an examination. They had to solve online a multiple-choice test. The computer selected the questions randomly from a database. Afterwards they were asked to fill out an online evaluation. The evaluation consisted of three sheets. The first was created by ourselves, and the questions focused on the interdisciplinary aspect of the course. The two next sheets were the official course evaluation sheets used in all courses of the Technical University of Denmark. These focus on course quality and lecturers and allow comments in a free text format.

3. Results

3.1 The Aachen Summer School
Of the 22 students completing the summer school, 9 were female and 13 male, 14 coming from Germany and 8 from other countries. Further information about the participants is shown in table 2. Half of the participants were engineering or computer science students, the other half were medical students. The staff of lecturers was also mixed (4 engineering and 3 medical, table 3). The course was held in English.
### Table 2: Participants

<table>
<thead>
<tr>
<th>Students</th>
<th>No.</th>
<th>Universities</th>
<th>No. Nationalities</th>
<th>No.</th>
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<tr>
<td>Total number</td>
<td>22</td>
<td>RWTH Aachen, Germany</td>
<td>14 German</td>
<td>14</td>
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<tr>
<td>Male</td>
<td>13</td>
<td>Albert-Ludwigs-Universität Freiburg, Germany</td>
<td>2 Kenyan</td>
<td>2</td>
</tr>
<tr>
<td>Female</td>
<td>9</td>
<td>Cambridge, UK</td>
<td>1 Danish</td>
<td>1</td>
</tr>
<tr>
<td>Medical</td>
<td>11</td>
<td>Technical University of Denmark</td>
<td>1 Greek/British</td>
<td>1</td>
</tr>
<tr>
<td>Engineering</td>
<td>11</td>
<td>Markere University Kampala, Kenya</td>
<td>1 Indian</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thomas Jefferson University, USA</td>
<td>1 Italian</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Università degli studi di Bari, Italy</td>
<td>1 Portuguese</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>University of Beograd, Yugoslavia</td>
<td>1 SRJ - Yugoslavian</td>
<td>1</td>
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### Table 3: Lecturers

<table>
<thead>
<tr>
<th>Lecturers</th>
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<th>No. Nationalities</th>
<th>No.</th>
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</thead>
<tbody>
<tr>
<td>Total number</td>
<td>7</td>
<td>RWTH Aachen, Germany</td>
<td>2 German</td>
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</tr>
<tr>
<td>Male</td>
<td>5</td>
<td>Technical University of Denmark</td>
<td>1 Danish</td>
<td>1</td>
</tr>
<tr>
<td>Female</td>
<td>2</td>
<td>Politecnico di Bari, Italy</td>
<td>1 Greek</td>
<td>3</td>
</tr>
<tr>
<td>Medical</td>
<td>3</td>
<td>University of the Aegean, Greece</td>
<td>1 Italian</td>
<td>1</td>
</tr>
<tr>
<td>Engineering</td>
<td>4</td>
<td>Skilitsion General Hospital, Greece</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MIT GmbH, Aachen, Germany</td>
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</table>

In addition, some web-based teaching material was developed, such as texts, slides, demos and online applications [6, 7]. Even though the summer school is over, this collection of documents and demonstrators remains available the internet and can be used for future teaching to engineering and medical students.

#### 3.2 Examination and Evaluation

In the final examination 19 of the students received more than 70% of the maximal receivable points and 5 students more than 90%.

21 students filled out the evaluation sheets. 19 of them would recommend the course to other students, and the quality of the course was evaluated as being good by 12 students and very good by 4. Generally, most of the students regarded the co-operation between physicians and engineers as to be very important. On the positive side is the fact that the students judged to have an opportunity to get exposed to the theory, methods, and applications of the cross-disciplinary area. The social aspects scored high, too. Altogether, this suggests that it is a good idea to bring together the two types of students, and there will likely be enough interested participants in the future to make such a course worthwhile. On the negative side, it is clear that the course suffered from some standard shortcomings, namely: too high density, unclear relevance of basic theory, incoherent structure, poor expectation management. This was most likely due to a shortage of preparation time and experience on behalf of the teachers. In summary, it does seem like a successful event, but more work is needed to streamline such a course in the future.

Two student comments deserve special attention. The first concerns the difference in medical and engineering views of the world: “I don't think that explaining clustering methods is useful for a medical student; on the other hand, a technical student needs to understand when a clustering technique can be applied, its points of strength and weakness, etc.”. To interpret: medical students wish to see how clustering can be applied, while engineering students wish to see how it is done. If this statement is taken literally, it implies that a cross-disciplinary course is impossible, because there is a gap between the two groups of students; the two viewpoints are mutually exclusive, a dichotomy. The problem will have to be addressed in a future course. Another comment is related, but concerns the learning process: “I think a more practical approach would be more capturing for the students. For example, feature selection and clustering methods can easily be studied in a computer room, discussing a particular problem from the beginning to the end.”. To interpret: it is easier to understand theory if one sees the application first. This viewpoint is central to the so-called inductive method of teaching. It is clearly preferable to present the material
that way, rather than first having to build an arsenal of axioms and theories, before embarking on the applications. It would be preferable to use the inductive method in such a course, since theory is closely tied to applications, but it is difficult to do so for a teacher. With the current setup, however, a teacher could try and switch the two halves of a module, presenting the exercise before the lecture (table 4).

4. Discussion
There is a broad impact of IT in medicine [1], which is leading to changing the role of the physician in the 21st century in a new healthcare environment [8]. Tomorrow’s physicians have to cope with information management demands which are largely increased due to the immense technical advance. Thus, there is need for more academicians with a thorough understanding of information technology [9]. IT provides key methods of thinking and problem solving which fundamentally affect all of healthcare. However, medical informatics is a broad interdisciplinary field, and there is a need to promote the kind of multidisciplinary thinking required in this field [10].

The major challenge of the Aachen Summer School was the interdisciplinary aspect of teaching. On one hand, medical and engineering students learned together about soft computing methods in medicine, on the other hand, the group of lecturers was interdisciplinary.

The demand increases for medical students who will work with IT tools in the future to learn about the background of these methods as well as for engineering students to be exposed to medical information analysis. Teaching both groups together in a course will result in an attitude for a closer collaboration between both groups.

There are some risks on doing this: one is the use of different terminologies in engineering and in the medical field, e.g. engineers speak about classification while physicians prefer the term diagnosis. Engineers find the medical terminology difficult, and they have to be exposed to the way of thinking in medicine. On the other hand, medical students find excessive use of numbers and mathematical symbols difficult, although they have basic courses of biostatistics and medical informatics in their curriculum. From a teacher’s point of view, this limits the possible pedagogical achievements. The knowledge of medical students of artificial intelligence is rather low and a lot of engineering basic knowledge has to be explained to them, which is familiar and rather low-level for the engineering students. Vice versa, the medical themes may be very interesting for engineering students, while the medical students know them already. Thus making such a course interesting for the two groups is a challenge for the teacher. On the other hand, the combination of theoretical background with concrete medical problems and applications increases the interest of both groups. In each session there should be new information combined with known information for each student. Moreover, the different backgrounds of students facilitate learning from each other. This can be done particularly in the exercises, because here students have to solve problems in collaboration.

As seen in the evaluation of the course, the attitude towards interdisciplinary collaboration is very positive. Nevertheless, the students considered to have learned more about artificial intelligence than about medicine. Thus in a future course the medical part should be enlarged. Moreover, it became clear that the students preferred the modules about artificial intelligence rather than the modules about statistical exploration of medical data.

In summary, the outcome of the first Aachen Summer School encourages us to repeat this course in the future, but more work is needed to streamline it. We will reduce the statistical part of the course in order to enlarge the parts about different fields of artificial intelligence. In addition, the medical themes of the course should be enlarged. Good experiences were made with the practical sessions, i.e. exercises and the excursion.

As mentioned above, it is easier to understand the theory if one sees the application first. It would be preferable to use the inductive method in this course, since the theory is closely tied to the applications. With the current course design the teacher could switch the two halves of a module, presenting the exercise before the lecture. Table 4 shows a template for a schedule of the next summer school, which pays attention to the comments and suggestions of the students, trying to preserve those topics regarded as useful. In the following we summarize of the recommended course components:

(a) use a web site to organize the material;
(b) provide downloadable textbook material;
(c) use e-mail assignments and web based quizzes;
(d) use (commercial) software simulators;
(e) set a web-based exam, grade it quickly or even automatically;
(f) devise block lectures and exercises in pairs;
(g) form mixed teams of engineering and medical students;
(h) organize excursions and social events.
The international composition of the students was a further advantage because it increased the interest of the students to speak with each other and created a frank atmosphere. Such interdisciplinary courses can be important for the students in achieving an attitude towards multidisciplinary collaboration, which will be necessary in the future. The technological advance in medicine will require a closer co-operation with disciplines such as informatics but also with areas such as biochemistry and physics.

5. Acknowledgements
The Aachen Summer School was a project of the ‘ERUDIT medical task force’, which was founded to advance the collaboration in the field of soft computing in medicine. The project was supported by ERUDIT [11], a European Network for Fuzzy Logic and Uncertainty Modeling in Information Technology supported by the European Commission DG III Industry-Esprit Programme as a Network of Excellence.

6. References

<table>
<thead>
<tr>
<th>Day 1</th>
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<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
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</thead>
<tbody>
<tr>
<td>Lecture: Introduction and overview</td>
<td>Lecture: Data acquisition – Aphasia – ‘Soft’ data</td>
<td>Lecture: The visual system + digital image processing</td>
<td>Exercise: Classification of PAPSmear images</td>
<td>Exercise: Medical Example</td>
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<td>Coffee break</td>
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<tr>
<td>Exercise: Introduction to lab room and software</td>
<td>Exercise: Exploring the aphasia database</td>
<td>Exercise: Fuzzy inference analysis polarized light images</td>
<td>Lecture: Classification using Neural Networks</td>
<td>Lecture: Decision trees</td>
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<tr>
<td>Lunch</td>
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<td>Lecture: Introduce a case</td>
<td>Lecture: Feature Selection</td>
<td>Lecture: Fuzzy Image Processing</td>
<td>Exercise: Diagnosis of aphasia</td>
<td>Examination and evaluation</td>
</tr>
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<td>Exercise: computer solution</td>
<td>Exercise: Medical Imaging</td>
<td>Lecture: Fuzzy Clustering</td>
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Table 4: Template for a schedule