Towards the Identification of Intelligent Systems Currently in Routine Use in Medicine and Dentistry

Heidi King
Centre for Computational Intelligence
De Montfort University
Leicester, UK
heidi@dmu.ac.uk

Jon Garibaldi
Centre for Computational Intelligence
De Montfort University
Leicester, UK
jong@dmu.ac.uk

Simon Rogerson
Centre for Computing and Social Responsibility
De Montfort University
Leicester, UK
srog@dmu.ac.uk

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1 Introduction

Many medical applications are developed but few are actually utilised in accordance with established procedure in a medical or dental environment. [1] This paper details the methods being used to create a taxonomy of intelligent systems applications currently in use in medicine and dentistry in order to discover how many applications are actually used. It is intended ultimately to conduct research to discover clinicians' attitudes towards the use of intelligent systems in medicine, and the data found will be used as a foundation for further research into the acceptance of these applications.

2 Methodology

The search commenced by examining two different abstracts databases. The Web of Science (WoS) and MEDLINE were chosen as comprehensive registers giving a broad coverage of scientific papers: MEDLINE for medically-orientated papers and the WoS for more technical computing papers.

2.1 Web of Science

The intention was to identify medical applications from any branch of Artificial Intelligence and so the first search terms used in the WoS Science Citation Index Expanded database were application* AND medic* where an asterisk represents a wildcard in the search string, ANDed with:

- Fuzzy
- Genetic Algorithm
- Chaotic System
- Neural Network
- Bayesian
- Case Based Reasoning
- Evolutionary Computing
- Neuro-Fuzzy
- Rough Sets
- Vague Sets
- Artificial Life
- Machine Learning
- Rule Induction
- Soft Computing
- Computer Aided Diagnosis
- Expert System
- Knowledge Based System
- Artificial Intelligence

The first fifteen search terms were selected by the Computational Intelligence group during an informal discussion of what constitutes the specialist areas in Artificial Intelligence (AI) research, with the last three added as a catch-all for applications papers in the relevant area where keywords did not include the more technical terms. The search terms were compared against the paper's title, abstract and keywords. Early on it became apparent that the scope of the task had potential to become very big. For example, "application* AND medic* AND fuzzy" generated 106 matches in the WoS; projecting this figure forwards to estimate the

number of papers that could be expected to be found over all categories was in the order of 2000 articles and it was clear that further restricting parameters were needed, without compromising the rigorousness of the search. Since the ultimate aim of the research is to produce a taxonomy of applications that are actually in use at the moment, older, obsolete applications could be filtered out at an early stage. It was assumed that any application that had reached maturity and was still in use today would have a minimum of two papers written about it since 1995. For this reason the above search was restricted to papers published between 1995 and 2001. The identification of multiple papers written about a single application will take place at a later stage.

Each paper's abstract generated by these criteria was then examined to identify whether it was likely to be a paper detailing an application currently in use. Abstracts that only made reference to, for example, algorithms were filtered out: evidence of the further development of an application was required.

Some papers featured in more than one category, for example Kentala et al (2001) [2] was detected in the searches for fuzzy, genetic algorithm, expert system and artificial intelligence. In these instances where a paper could fit in more than one area, care was taken to ensure that duplications were not counted and that the paper was allocated to the most specific and appropriate group.

2.2 MEDLINE

Initially the same criteria were used on the MEDLINE database, with the addition of "Human" as a search constraint, however the first search for "application* AND medic* AND fuzzy" generated significantly fewer 'hits' than was expected. It was decided that whereas the WoS would have many papers detailing the whole scope of AI, not just applications, this would be different with MEDLINE. Since MEDLINE is primarily a medical database, any reference to the search terms representing the different fields in AI would almost certainly be discussing a medical application. Furthermore, it seemed that the papers referenced in MEDLINE did not make use of this more technical term and hence the expression application* was deemed not necessary. Aditionally, the search term medic* was dropped on the basis that it was likely that any paper referenced by MEDLINE would be concerned with that field anyway.

The same technical terms were used as in the WoS but when searching for "Neural Network", MEDLINE turned up far more unconnected papers. Since this is also a medical term and so common in a medical database, this search term was refined to "Artificial Neural Network" The process of checking the papers' relevancy was repeated. Again, if any paper was found in searches from more than one category, duplicates were removed and the paper was counted in the most appropriate section. Additionally, if a paper had already been found in the WoS search, it was not included in the MEDLINE papers, ensuring that the results from each database search were not duplicating each other.

2.3 Further Searching

The two searches detailed above also generated some papers of a different nature. 24 papers on the WoS and 11 papers on MEDLINE had overviews of certain types of intelligent systems applications used in specific fields, e.g. neural network applications in physical medicine and rehabilitation [3]. Each of these papers was examined for references to further applications. The first author of each reference was then used as a search string in both the WoS and MEDLINE, and every paper produced by that author post 1995 was examined. It was felt that having already produced one relevant application in the past and demonstrated that they had been productive in a relevant area, it was worth looking for any papers produced by these authors after 1995 indicating either that an older application was still in use (usually the application referred to in the overview papers), or that they had produced a newer one since then.

3 Results

3.1 WoS

The search for application* AND medic* AND each of the categories on the WoS highlighted some 637 papers across the 18 different categories. Some overlap of different categories was found to occur and 38 duplicate papers were detected and eliminated. The examination of the abstracts to identify relevant papers detailing applications

reduced this number to 142; six of the terms used as search strings did not generate any 'hits' at all. These were: Chaotic System; Evolutionary Computing; Vague Sets; Artificial Life; Rule Induction and Soft Computing. A full breakdown of the distribution of applications in the different fields found on the WoS from this search can be seen in table 1.

Search term	No. papers found	AND application* AND medic*	No. relevant papers found
Fuzzy	16504	86	29
Genetic Algorithm	3971	18	4
Chaotic System	378	0	0
Neural Network	13629	96	14
Bayesian	6267	16	4
Case Based Reasoning	589	14	10
Expert System	2661	53	16
Knowledge Based System	617	15	2
Artificial Intelligence	2564	42	10
TOTAL	47180	340	89

Table 1: Distribution of different types of applications in the WoS, 1995-2001

3.2 MEDLINE

Using only the fifteen specialist subject terms and the three more generic terms as detailed above, some 1741 papers were identified in the MEDLINE database. Of these some 127 papers were duplicates and these were also eliminated from the list, leaving 1614 distinct papers. The abstracts were examined in a similiar way as previously described in the WoS section and the number of papers that appeared to be relevant totalled 540. Eight technical terms did not generate any relevant findings: Chaotic System; Evolutionary Computing; Neuro-Fuzzy; Rough Sets; Vague Sets; Artificial Life; Rule Induction and Soft Computing. Table 2 shows the distribution of applications across the different fields.

Search term	No. papers found	No. relevant papers found
Fuzzy	134	56
Genetic Algorithm	117	42
Chaotic System	86	0
Artificial Neural Network	456	202
Bayesian	60	28
Case Based Reasoning	114	29
Expert System	308	115
Knowledge Based System	58	22
Artificial Intelligence	198	41

Table 2: Distribution of different types of applications in MEDLINE, 1995-2001

3.3 Other Results

The use of first author names from application overview papers as a search term found 138 relevant papers in the WoS and 219 papers in MEDLINE. The distribution of different types of applications found in these papers can be seen in table 3.

Search term	No. relevant papers found - WoS	No. relevant papers found - MEDLINE
Fuzzy	19	41
Genetic Algorithm	0	1
Chaotic System	0	0
Neural Network	88	107
Bayesian	6	12
Case Based Reasoning	7	5
Expert System	4	15
Knowledge Based System	0	6
Artificial Intelligence	14	32
TOTAL	138	219

Table 3: Distribution of different types of applications found by author keyword search in WoS and MEDLINE, 1995-2001

4 Discussion

If a paper turned up in more than one category, it was listed under the most relevant category it had been found under. Many papers had AI as a keyword but they were listed under the specialist fields if at all possible. If a paper was found on both WoS and MEDLINE, it was only counted in the WoS figures.

Approximately 2% of the papers shown in the citation databases that met the criteria did not have abstracts. Since it is recognised academic practice for a paper's title to reflect what is contained within the paper, in these cases the relevance of that paper was assessed merely by analysing the title. It is recognised that some papers may have titles that do not lead one to think that they are relevant to the search and so these will have been left out of the list.

The titles and abstracts were used to decide which category that paper should be placed under. In the case of the papers found through searching for author names, a significant proportion of the abstracts did not contain any of the specialist terms used to categorise them, as opposed to the papers where those keywords had been used as search terms. In these instances the papers were placed in the AI category.

The specialist keyword searches on the WoS and MEDLINE found a far greater percentage of papers with technical terms as opposed to the more generic terms such as AI, than the author name search.

5 Conclusions and work in progress

The papers will be examined to ascertain which abstracts refer to the same applications. This will not be a trivial task as researchers come and go from projects, first authors change and applications named in one paper may only be referred to as for example an expert system in another. It is anticipated that the most rigorous but simple method of doing this is by cross-checking every author cited on each paper in the specialist fields with every other author cited on any paper in that field or in the catch-all categories of expert systems, knowledge-based systems and AI. The remaining papers will be cross-referenced with each other to see if they refer to common applications. When this has been achieved, applications that have only one abstract about them will be eliminated from the list. It is anticipated that any application currently in use would have had two or more papers published since 1995 and these papers will form the basis of the survey. It is expected that these results will be presented at the conference.

It is then intended to contact the first authors of papers meeting the criteria of multiple papers post 1995 about the same application. The authors will be asked if, to the best of their knowledge, the application is still in use in a medical environment. The authors will also be asked if they perceive their applications to have been a success, both technically and comercially. These answers will be used as the basis of a study of the success rate of AI applications within medicine.

References

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