Connecting Medical Informatics and Bio-Informatics
R. Engelbrecht et al. (Eds.)
ENMI, 2005

Knowledge Discovery on Functional Disabilities: Clustering Based on Rules versus other Approaches

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Abstract

In Europe senior citizens are a fast growing part of population, increasing proportion of disabled persons and that of persons with reduced quality of life. The concept of disability itself is not always precise and quantifiable. To improve agreement on it, the World Health Organization (WHO) developed the clinical test WHO Disability Assessment Schedule, (WHO-DASII) that includes physical, mental, and social well-being, as a generic measure of functioning. From the medical point of view, the purpose of this work is to extract knowledge about performance of the WHO-DASII using a sample of patients from an italian hospital.
This Knowledge Discovery problem has been faced by using clustering based on rules*, an hybrid AI and Statistics technique introduced by Gibert (1994), which combines some Inductive Learning (from AI) with clustering (from Statistics) to extract knowledge from certain complex domains in form of tipical profiles. In this paper, the results of applying this technique to the WHO-DASII results is presented together with a comparison of other more classical analysis approaches.*

Keywords:
Disability; Scale (clinical test); Assessment, Neurological Disease; Knowledge Discovery; Clustering based on Rules; Knowledge-based Applications in Medicine.

1. Introduction

The senior citizens represent a fast growing proportion of the population in Europe and other developed areas. Today [18], 629 million of persons aged 60 years or older is estimated to be around the world; it is expected to grow about 2 billion by 2050, when the population of older persons will be larger than that of children (0-14 years) for the first time in human history. The largest proportion (54%) of this people lives in Asia; Europe is the second (24%). This ageing population increases the proportion of individuals with physical and/or mental impairment that need any help for the daily tasks. According to Laselett [11], "*the human life span is now divided into four ages: the first is an age of dependency, childhood and education, the second is an age of indepen-dence, maturity, and responsibility, and although the third age is considered a period of fulfillment for physically and mentally fit people in retirement, the fourth age is associated with chronic diseases, disability and dependence''.* A direct consequence is the increasing number of people affected by chronic diseases, such as heart disease, cancer and mental disorders, which are fast becoming the world's leading causes of death and disability. In fact, according to the *World Health Report 2001* [20], 59% of whole-world deaths relate to non-communicable diseases. In both developed and developing countries, chronic diseases are

significant and costly causes of disability and reduced quality of life. Size and pattern of the fourth age is critical for the quality of life of elderly people but also for the use of health and social services [2]. Functional ability (FA), highly correlated with physical and mental health, is an important determinant of quality of life [17], and to measure it is increasingly important. Activities of Daily Living (*ADL*) rating scales are widely used for that [10]. However, disability scales typically including bathing, toileting, eating, dressing, and transferring from bed to a chair, like ADL, have been criticized. There is lack of consensus about measurement of FA [12]. The WHO, proposed a new reference classification (*ICF*) and an assessment instrument (*WHO-DASII*) [13] to complement the process (see bellow).

In this work, the functional disability degree of a neurological patients set is evaluated using *WHO-DASII*. First, extracting knowledge contained in the database to see how *WHO-DASII* provides information for identifying typical profiles of disabled patients. Afterwards relationships between *WHO-DASII* and other scales, like *SF36*, will be analyzed as well. Typical answers to *WHO-DASII* need first to be identified, together with the characteristics of the groups of patients providing each *type* of answers. This raises a clustering problem, but classical clustering cannot well recognize certain domain structures [7], producing some non-sense classes that cannot be interpreted by the experts. In fact, this happens with *ill-structured domains (ISD)* [4] [5], where numerical and qualitative information coexists, and there is relevant semantic additional (but partial) knowledge to be regarded.

Clustering based on rules (ClBR) [4] is especially introduced by Gibert to improve clustering results on *ISD*. It guarantees the semantic meaning of the resulting classes. Since an *ISD* is faced here, this work will show the advantages of *ClBR* vs other approaches.

Contents of the paper is: Introduction to the *WHO-DASII* scale, description of the target sample and the characteristics of the study, description of the analysis methodology, details on *ClBR*, results of applying *CLBR* to the sample and comparison with other approaches.

2. Methods

Scales and ontologies

The International Classification of Functioning

Regarding the controversy about disability, the *WHO* provided a common framework and language for the description of health and health-related domains. ICF (*International Classification of Functioning, Disability and Health)* defines components of functioning and disability, activities and participation [20]. It is a review of ICIDH-2 [19], moving from a classification of *consequences of disease* (1980 version) to a *components of health*; is the newest version of disability classification, systematically grouping different domains for persons in a given health condition (what a person with a disease or disorder can do or does). As f*unctioning* encompasses all body functions, participation and activities, *disability* encompasses impairments, activity limitations or participation restrictions. *ICF* lists environmental factors interacting with these constructs, allowing records of useful profiles of individuals' functioning, disability and health in various domains.

WHO-DAS II scale

WHO-DASII (*World Health Organization Disablement Assessment Schedule*) is a scale especially designed and proposed by the *WHO* [13], for assessing disability levels according to *ICIDH-2* (and with *ICF*). It includes mental health factors related to disability together with physical ones in the same set of instruments. It is a fully-structured interview measuring self-reported difficulty of functioning in six major domains considered important in most cultures: *Understanding & Communicating* (6 it), *Getting Around* (5 it), *Self Care* (4 it), *Getting Along with People* (5 it), *Life Activities* (8 it) and *Participation in Society* (8 it).

The *WHO-DASII* employs a 5 point rating scale for all items (1 is used for no difficulty and 5 for extreme difficulty or inability to perform the activity). Six *WHO-DASII* domain scores may be obtained by summing the answers in each domain, normalizing them on a 0 to 100 scale (expressing percentages) in such a way that higher values represent greater disability. Information related to the extent of disruption in life caused by these difficulties, extends of difficulties experienced in life and extends of dependence of assistive devices or other persons is considered as well. Items usually enquire about the last 30 days. Validation of *WHO-DASII* is in progress in international field trials (16 centers of 14 countries). Sample (1564) was drawn from population with physical, mental, drug, alcohol problems and general.

Experimental procedure

The target sample includes 96 neurological patients between 17 and 80 years, who were recovering at the *IRCCS Fondazione Santa Lucia di Roma* between October 1999 and February 2000. A control group of 20 healthy people, have also been enrolled.

Functional status and health-related quality of life of all patients was measured with *WHO-DASII* at admission. Patients were evaluated upon two other standardized clinical scales: Functional status was quantified using the *Functional Independence Measure (FIM)*. The *FIM* is a well-established measure for which reliability and validity have been proved. Patients' Quality of Life *(QOL)* was quantified using the *Short Form (SF-36)*, see [16].

Data analysis methodology

Here, a brief description of the whole proposed analysis methodology is presented: First, d*escriptive statistics of every variable* was done. Very simple statistical techniques [15] were used to describe data and to get preliminary information: histograms or bar charts to display variability, plots and multiple box-plots to observe the relationship between some pairs of variables, etc; classical summary statistics were also calculated. Next, *data cleaning*, including missing data treatment or outlier detection was performed. It is a very important phase, since the quality of final results directly depends on it. Decisions are taken on the basis of descriptive statistics and background knowledge of the experts.

Data was analyzed using three methods**: *i)*** Following the classical approach, the behavior of g*lobal WHO-DASII score* regarding the patient's pathology was studied. Since the global score is not normal, Kruskall-Wallis test was used to assess significant differences between groups. In case of rejecting null hypothesis, graphical representation is used for interpretation of differences. ***ii)*** Going into the multivariate approach, first a selection of *WHO-DASII* items was done, avoiding redundancies or inconsistencies. A hierarchical clustering was performed, using chained reciprocal neighbors method, with Ward criterion and the Gibert's *mixed metrics* [3], since both numerical and categorical variables were considered. ***iii)*** Finally, *clustering based on rules (ClBR)*, described bellow, was used on the same items selection. This paper does not go into mathematical details, just gives an intuitive idea of the method [5]. It was originally presented in [4]. It is a hybrid AI and Statistics technique combining inductive learning (AI) and clustering (Statistics) for KD in *ISD*. A *KB* is considered to properly bias clustering of the database. It is implemented in the software KLASS and it has been successfully used in several real applications. Our experience from previous applications [7] [8] [1] [14] is that using ClBR use to be better than using any statistical clustering method by itself, since an important property of the method is that semantic constraints implied by the *KB* are hold in final clusters; this guarantees interpretability of results, *meaningful* resulting classes. Also, it uses to be better than pure inductive learning methods, reducing the effects of missing some implicit knowledge in the *KB*. The general idea of *ClBR* is:

1. build a *Knowledge Base (KB*) with additional prior knowledge provided by the expert, which can even be a *partial* description of the domain
2. evaluate the *KB* on data for *inductive learning* of an initial partition on part of the data; put the data not included in this partition into the *residual class (RC).*
3. perform one independent hierarchical clustering for every *rules-induced class (RIC).*
4. generate prototypes of each *rules-induced class*.
5. build the *extended residual class* as the union of *RC* with the set of prototypes of *RIC*, conveniently weighted by the number of objects they represent.
6. use a hierarchical clustering for weighted clustering of the *extended residual class*.
7. in the resulting dendrogram, substitute every rules-induced prototype by its hierarchical structure, obtained in 3. This integrated all the objects in a single hierarchy.

For methods *ii)* and *iii),* clustering process can be graphically represented in a *dendrogram*. Final number of classes was determined on its best horizontal cut (where the largest gap exists). This identifies a partition of the data in a set of classes. *Interpretation of the classes* was based on conditional distributions of *WHO-DASII* items through the classes, displayed through multiple boxplots, and the corresponding significance tests to assess relevance of differences between classes (ANOVA, Kruskall-Wallis or χ^2 independence test, depending on the item). The aim is to extract qualitative information from the classes, to obtain a meaningful description for the user which indicates particularities of every class.

3. Results

In the sample, 58 patients were males (60.4%) and 38 females (39.6%). Average age was 56 years. Twenty patients had spinal cord injury (age 47.20, s= 17.6), 20 Parkinson (69.25, 6.53), 20 stroke (63.40,15.96), 16 depression (46.56,11.15) and 20 control (55.05,s=15.57)

i) Upon the classical approach, Kruskall-Wallis of *WHO-DASII* global score (GS) *versus* pathology showed signifficant difference ($p<0.05$). Fig. 1 displays multiple boxplot of GS *vs* pathology: GS only allows distinction between non-disable and disable patients.
ii) With classical hierarchical clustering, 4 classes emerged. However, their interpretation was confusing and physicians could neither identify their *meaning* nor explain *why* depressed patients scattered along classes with other diseases fig.2.
iii) Using *ClBR*, 4 classes (and three outliers) of functional disabilities were found. Look-ing at different variables, a clearer conceptual interpretation of the classes is possible [9]:

Low (Cr93): no problems self-sufficient subjects, neither physical nor mental problems (includes all control patients and a few patients without apparent functional disability).

Intermediate-I (Cd52): moderate mental and/or cognitive disability and physical disability with a low to moderate degree of disability, physical and emotional, with perception of high disability but really showing lower level (e.g. on daily work or standing up to 30 minutes).

Intermediate-II (Cr89): moderate/severe disabilities with exclusive moderate physical disability related to autonomy (difficulties on toileting and dressing), non emotive problems.

High (Cd53): higher disability degree, physical and mental.

Relationship between discovered classes and global *WHO-DASII* score was studied and significant differences were found ($p<0.05$). Fig. 3 shows increasing scores from group **Low** to **High**, according to the increasing degree of disability represented by the classes.

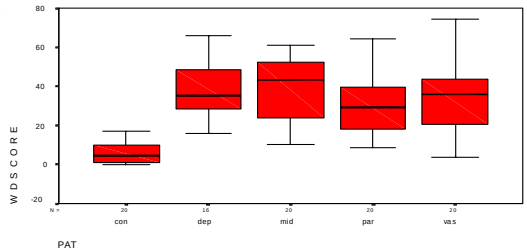

Figure 1 – Multiple boxplot of WHO-DASII Score vs pathology (i).

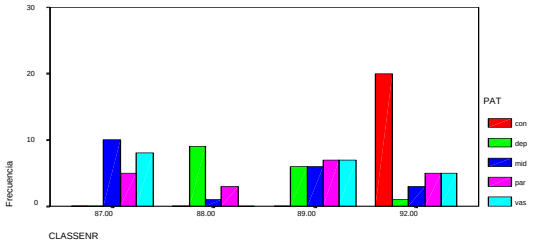

Figure 2 – Pathology versus classes with classical clustering (ii).

4. Discussion, Conclusions and Future Work

As said before, the study is mainly focused on identifying different kinds of responses to the *WHO-DASII* as well as to characterize the groups of respondents of any kind.

The (*i*) analysis only allows a trivial distinction between able and disable, missing the whole potential of *WHO-DASII*, which provides lot of information that, can sensibly enrich analysis. Facing a complex phenomenon as disability, concerned with a lack of consensus, requires a *multivariate approach* considering all the items of the test. Clustering techniques are suitable for detecting groups upon *WHO-DASII* responses. First, an standard clustering *(ii)* was used with Gibert's *mixed metrics*; results had confusing interpretation and the underlying clustering criteria was no clear. Although theoretical properties of solution could be clearly established, non-sense classes are useless in real applications. Patients with disabilities can be considered an *ISD*, as stated in [5] and clustering use to be unable to capture their complex structure by itself. *ClBR* is a more suitable approach *(iii)*. Additional knowledge supplied by the experts for *ClBR* regards to emotional problems, since results of method (*ii)* show especially high confusion on this topic. Expressed by means of logical rules, it use to be a *partial* description of the domain (as usual for *ISD*, it is very difficult to make explicit a complete domain-*KB*, what is a great handicap for pure AI methods). Rules used for *ClBR* concern items of *WHO-DASII* regarding *emotive behavior*:

B4: *Rate your mental or emotional health in past 30 days?*
B9: *Worry or distress about your health in the past 30 days?*
S5: *Emotionally affected by your health condition?*
R2: *Have difficulties been caused by mental health or emotional problems?*

People providing values 4 or 5 to that questions should have any kind of emotive problem. So, the proposed *KB* for biasing cluster in method *iii)* is: ***KB=****{r1:If B4 is in [4,5] then emotive-problems (EP), r2: If B9 is in [4,5] then EP, r3: If S5 is in [4,5] then EP, r4: If R2 is in [4, 5] then EP}*

ClBR was used with *KB* on the target sample. Rules divided the sample and clustering was done in the single *rules-induced part* (56 patients) as well as on the *extended residual class*, building a global hierarchy. None of the classical statistical methods support expert knowledge influencing the analysis. *ClBR* is a hybrid technique which sensibly improved results, regarding method *ii)* [9], by integrating clinical knowledge inside the analysis.

Finally, a set of 7 classes was recommended by the system. Three of them contain isolated patients that have outlier behavior; they were studied individually. Several tools were used to assist the interpretation of final classes. In case *(iii)*, although rules proposed by experts represent partial knowledge on *FD*, the *KB* captured all the depressed patients (which are supposed to have emotive problems), but the clustering divided them into two main subgroups (Fig.3). This still follows understandable criteria: Cd53 has greater physical and mental problems (learning new computes, participating in community, concentrating, working) compared with Cd52; also Cd53 feel that difficulties (including toileting and dressing) affect much more to their life; on the contrary, Cd52 cannot stand up, while Cd53 can do; Cd52 can interact with other people and perform daily activities, while Cd53 cannot. Even with this subdivision, final classes fit on the semantic constraints expressed in *KB* (not to scatter patients

with emotive problems along all the classes without criteria). *ClBR* identifies four disability profiles, representing a new taxonomy that contributes to improve the knowledge about Disability. Main group characteristics elicit that, from the medical point of view, groups indeed well correspond to 4 *different profiles* of *FD*, associated with increasing *WHO-DASII* global score; in consequence, they can be ordered according to increasing disability gravity, making even possible distinction between intermediate degrees, which are qualitatively different. The proposed profiles really face disabilities *from a functional point of view*. Furthermore, they are not directly associated with underlying pathology (fig.4), according to the geriatric approach, which regards functional improvement rather than medical aspect. There is no a group with high cognitive and no physical disability, probably owing to apraxia (impossibility of performing coordinate and finalized tasks) strongly related to severe degrees of cognitive impairment. Correlation between the gravity of the disability and the depression is being studied at present. Relationship with *FIM* and *SF-36* is also in progress.

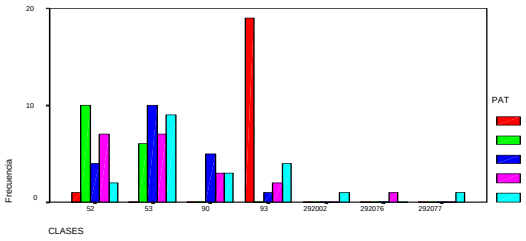

Figure 3 – Pathology vs classes with ClBR.

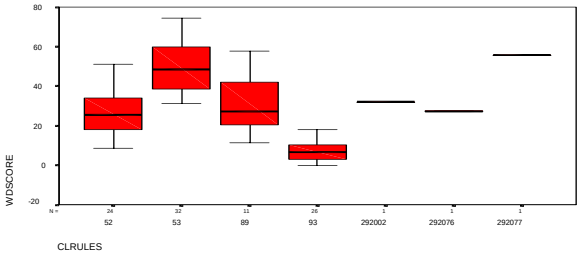

Figure 4 – Multiple boxplot of GS vs classes of ClBR

An appropriate analysis of assessment scales is critical to get good results; interpreted under a multivariate approach (considering the individual items of the scale) they are a rich source of information and produce a much more rich results than using the single global score. In this application *ClBR* produces meaningful classes and sensibly improves, from a semantics point of view, the results of classical clustering, according to our opinion that *hybrid* AI and Statistics techniques are more powerful for *KD* than pure ones, even in Disability.

5. Acknowledgements

To the EURO-MDSBL and WHO Assessment Classification and Epidemiology Group (WHO-DAS II designers).

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