

Horn Clause Techniques in Rehabilitation Clinic for Return to Work

Rawia Mohamed- Najeeb Abu Amr, Waidah Ismail, Lailatul Qadri Zakaria, Nurzi Juana Mohd Zaizi, Roesnita Ismail, Mahadi Bahari, Maryati Mohd. Yusof

Abstract: *Rehabilitation therapy aims to enable disabled patients to maintain optimal functioning upon achieving return-to-work (RTW) approval. The Berg Balance Scale (BBS) is a benchmark for activity accomplishment featured in the International Classification of Functioning, Disability and Health Framework (ICF). The ICF is used by physiotherapist (PT) and occupational therapist (OT) to determine the functional mobility of disabled patient. Conventionally, practitioners measure, record, and analyze assessment results manually which resulting in difficulty in predicting patient progression. The large data volume involved in the RTW process requires synthesize and reasoning for decision making purposes. Thus, there is a need to identify an efficient reasoning technique to facilitate the decision making process. This study highlights the use of Horn Clause in decision tree to assist medical doctor in assessing improvement of RTW approved patient based on the BBS assessment. The Horn Clause is one of the fundamental reasoning techniques applied in various domains including healthcare. The next phase of this study is to test the efficiency of the Horn Clause reasoning based on patient's stroke recovery and spinal cord injury.*

Index Terms: *Berg Balance Scale (BBS), Decision tree, Horns Clause, Rehabilitation therapy, Return-to-work (RTW).*

I. INTRODUCTION

Rehabilitation therapy aims to enable disabled patients to maintain optimal functioning upon achieving return-to-work (RTW) approval. During rehabilitation assessment, physiotherapists (PT) and occupational therapists (OT) normally employed the Berg Balance Scale (BBS) as a benchmark for activity accomplishment featured in International Classification of Functioning, Disability and Health Framework (ICF). PT and OT can determine the functional mobility of disabled patients easily based on ICF to help the disabled patient to achieve the goal for rehabilitation therapy.

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Rawia Mohamed- Najeeb Abu amr, Faculty of Science and Technology, Universiti Sains Islam Malaysia (USIM).

Waidah Ismail, Faculty of Science and Technology, Universiti Sains Islam Malaysia (USIM), Malaysia. Green Science and Technology Research Centre, Islamic Science Institute, Universiti Sains Islam Malaysia (USIM), Malaysia

Lailatul Qadri Zakaria, Faculty of Information Science & Technology, Universiti Kebangsaan Malaysia, Malaysia

Nurzi Juana Mohd Zaizi, Faculty of Science and Technology, Universiti Sains Islam Malaysia (USIM), Malaysia

Roesnita Ismail, Faculty of Science and Technology, Universiti Sains Islam Malaysia (USIM), Malaysia

Mahadi Bahari, Faculty of Computing, Universiti Kebangsaan Malaysia, Malaysia

Maryati Mohd. Yusof, Faculty of Information Science & Technology, Universiti Kebangsaan Malaysia, Malaysia

The main goal of rehabilitation process is to improve the physical and functional abilities of disabled patients. This is usually carried out through daily exercises performed regularly at certain time depending on the affected part of the body [1-2]. During early recovery, PT usually administers repetitive exercises that are essential in motion recovery process. The repetition exercises allow simultaneous improvement in the affected muscles and joints [3]. Each patient shows different ability of movement known as Range of Motion (ROM). According to Perkeso, [4] the success RTW program should give the RTW approval for the patient to return to same job same employer, similar job same employer, different job same employer, same job different employer, different job different employer or to do self-employed job[4].

RTW program involved numerous processes, specific features, and complicated relationships between them, which increases the complexity, creates high-dimensionality problems, and difficulty of making decision for the disabled patient. Ming et al. [5]

Large data volume involved in RTW process requires synthesize and reasoning. Thus, there is a need for a system that applies logical roles to this large data volume. These rules will be applied to deduce an assessment for the patient who suffers from disability to give consultation upon achieving return-to-work (RTW) approval. Therefore, there is a need to identify an efficient reasoning technique to facilitate the decision making process. In clinical decision support systems, there are many proposed techniques for decision making process. In addition, decision tree is a common technique used in data mining while Horn Clause is one of the fundamental reasoning techniques applied in various domains including healthcare. Applying Horn Clause in the decision tree could possibly assist practitioners to predict the progression of the disabled patients based on the BBS assessment. The Horn Clause will be developed based on experts in the Rehabilitation Center. The main objective of this paper is to propose a new reasoning technique that uses Horn Clause to support decision making in RTW assessment.

II. LITERATURE REVIEW

The development of decision hierarchies in engineering domain is based on drawing mechanism. This development proved that the hierarchies and data mining techniques are useful for classification of the features in complex relationships.



In the field of rehabilitation assessments, it often involved large and complex data and relationships. Ontology can be used to represent, transfer and reuse information and knowledge between users and software in different domains including rehabilitation in healthcare [6-7].

An ontological approach can consolidate knowledge from the existing literature, providing a solid knowledge for specific domain based for tool construction. Ontologies have emerged as an alternative to databases in applications that require a more 'enriched' meaning due to their capability to improve the performance of large data volume [8]. This is because the ontologies break a lot of unnecessary complexity that exist in the large traditional data base[9]. For example, Thuan et al. [10] proposed an ontology-based decision tool that supports business process. On the other hand, ontologies have been used in healthcare field to automatically share and reuse knowledge in CDSSs. This facilitates the use of knowledge to provide evidence-based and personalized therapies in addition of evaluating the effectiveness of a treatment. There are much standard ontology used for this purpose such as and not as a limitation ICF, ICD and SNOMED CT [11].

For rehabilitation purpose, ontologies have been used in many studies to represent person's medical information. For example, robles-bykbaev et al, [12] proposed an expert system able to automatically infer general intervention guidelines for children with disabilities and communication disorders. The system relies on ontologies and implements a semantic web environment to provide several services related with information querying, reports generation, inference of intervention strategies, etc. Moreover, Subirats and Ceccaroni, [13] proposed ontology based decision support system for rehabilitating people with functional diversity. One more example of ontology model which developed for an Upper Limb stroke rehabilitation known as 'ULSOnt' is illustrated in Figure 1. This Ontology enables Semantic knowledge representation of PIS [14]. The part of models includes diagnosis, score ranking and range of movement assessment are defined as following :

- a. Diagnosis: The patients will be diagnosis with their stroke subtype (i.e. intracerebral hemorrhage, or subarachnoid hemorrhage).
- b. Score ranking: The assessment includes Barthel Index, Lawton Scale, Hospital Anxiety Depress Scale (HADS), Functional Ambulation (FAC), Frenchay Athesia Test (FAsT), Mini-mental State Exam (MmSE), and Caregiver Strain Index (CSI) assessments.
- c. Range of movement assessment: The range of movement assessments includes Active Range of Movement (AROM), Passive Range of Movement (PROM), and Muscle Strength Grade at Active Range of Movement (MSG AROM).



Fig. 1 ULSOnt Ontology (adapted from Afandi et al. [14])

In Developing a CDSS, the main purpose is to find the most accurate and timely medical diagnoses or evaluation using the knowledge that was introduced to the system through ontology (knowledge base). This purpose is achieved in the reasoning part of the CDSS. There are many methodologies have been used for reasoning which applied in CDSS such as Fuzzy reasoning rule-based reasoning case-based reasoning [15]. For example Ping et al. [16] used multiple measurement case-based reasoning (MMC BR) in producing a model that can help in treating liver disease which achieved performance better than classical CBR. On the other hand, the CBR is integrated with a multi agent system to design a CDSS which explore gastric cancer [17]. Furthermore, Wang et al. [18] presented an adaptive neuro-fuzzy reasoning system (ANFIS) which achieves an accurate system for treating esophageal cancer patients. The reasoning methodologies are applied through different techniques such as and not limited forward chaining, backward chaining and rule elicitation. These techniques used to describe what the problem is, rather than a procedure or algorithm stating how to solve the problem [19-20]. For solving the problem described in reasoning techniques, declarative programming languages which based on mathematical functions and/or logic are clever enough to figure out how to solve the problem. Prolog is an example for declarative programming languages which based on the Horn Clause subset of first order logic. Prolog is perhaps the most prominent of these declarative languages [20].

Horn clauses are a restricted kind of formula in propositional or first-order logic which are computationally tractable, yet highly expressive. Thus, The Horn Clause is one of the fundamental reasoning declarative languages applied in various domains including healthcare [21]. Aliqbal, [21] used horn clause as a fundamental reasoning technique to proposed a web based CDSS that served the rural medical centers.

It is important to mention that horn clause has not been used in rehabilitation field before. Thus, this study explores the applicability of the Horn Clause in decision tree to assist practitioners in predicting the progression of the disabled patients based on the BBS assessment. The BBS has always been used to objectively assess whether a disabled patient with impairment can balance safely over a series of predetermined tasks. It is a valid instrument used for evaluating patients suffering from Spinal Cord Injury and Stoke Recovery.

III. METHODOLOGY

The main feature of BBS knowledge-based is the horn clause rules defined according to the ROM and implemented in a decision tree. This instrument could potentially aids physician to examine patients during RTW decision making and subsequent therapy arrangement. The integration of ontology-based knowledge with decision tree plays an important role in predicting patient progression. The sample of the ROM rules is illustrated in Table 1.

Table 1 . ROM for the shoulder

Joint	Range of motion	Rules
Shoulder	Abduction	$x < 45^\circ = 0$, $45^\circ < x < 90^\circ = 1$, $90^\circ < x < 150^\circ = 2$, $x > 150^\circ = 3$

Figure 2 illustrates how a specialist observed ROM to asses the motion ability of a patient’s upper limb. As shown in Table 1, the rules essentially guide specialist to observe the patient’s ROM.



Fig. 2 Assessment of shoulder ROM [11].

IV. THEORY

For instance, when passive shoulder abduction is limited to less than 45°, a score of 0 is given to a particular patient. Similarly, score 1 means that the joint can be abducted from 45° to 90°; score 2 indicates abduction from 90° to 150°; and score 3 indicates that abduction of the shoulder beyond 150° is possible [10]. Based on the scoring of BBS, the decision tree designed and categorized into three interpretations. These interpretations are high fall risk, medium fall risk and low fall risk. Figure 3 depicts a sample of a decision tree designed based on the BBS. Furthermore, figure3 show that the decision will be Redo Treatment (RT)

when the interpretation is high fall risk, while the BBS assessment recommended to be repeated when the interpretation is medium risk fall. On the other hand the patient achieved the RTW goal if his score indicates that he is under low fall risk interpretation. Table 2 depicts the instances that will be created and trained in the proposed decision tree.

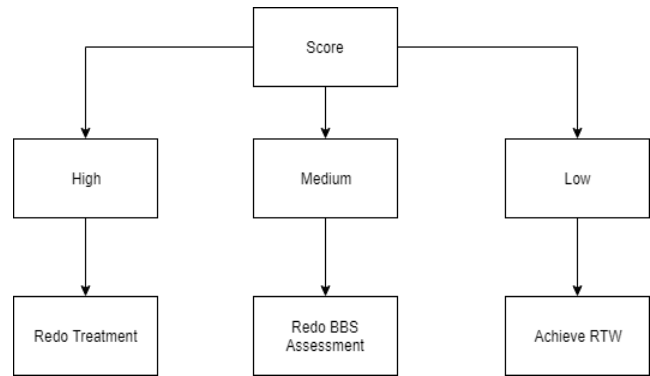


Fig. 3 Decision tree of Berg Balance Scale.

Table 2. List of instances for decision tree with the category.

Scoring	Interpretation	Decision
$0 < X \leq 20$	High fall risk	Redo the treatment
$21 < X \leq 40$	Medium fall risk	Redo the BBS assessment
$41 < X \leq 57$	Low fall risk	Achieve RTW

V. ANALYSIS

It is very important to enhance the decision based on the diagnosis. Thus, the decision is enhanced using horn clause for two types on diagnosis which are stroke Recovery (SR) and Spinal Cord Injury (SCI). For example, the score of the BBS between 0 and 20 means that the interpretation is high fall risk, but this risk may be caused by SR or SCI. Thus, the decision will be affected and related to the diagnosis. Where there are two probabilities of decisions for each diagnosis. As shown in table 3 for the patient scored from 0 to 20 and has been diagnosed as SR may be recommended to do NT or RT. On the other hand, the same two decisions can be recommended for the patients who have been diagnosed as SCI. In terms of achieve RTW decision, it can be recommended when the score of the BBS between 41 to 57 which indicates that the interpretation is low fall risk either for the SR or SCI diagnosis as shown in horn clause equation 9 and 12 and in Figure 4.



Table. 3 List of Enhancement Based on The Diagnosis

Scoring	Interpretation	Diagnosis	Decision
$0 < X \leq 20$	High fall risk	Stroke recovery	New treatment
$0 < X \leq 20$	High fall risk	Stroke recovery	Redo treatment
$0 < X \leq 20$	High fall risk	Spinal Cord Injury	New treatment
$0 < X \leq 20$	High fall risk	Spinal Cord Injury	Redo treatment
$21 < X \leq 40$	Medium fall risk	Stroke recovery	New treatment
$21 < X \leq 40$	Medium fall risk	Stroke recovery	Redo treatment
$21 < X \leq 40$	Medium fall risk	Spinal Cord Injury	New treatment
$21 < X \leq 40$	Medium fall risk	Spinal Cord Injury	Redo treatment
$41 < X \leq 57$	Low fall risk	Stroke recovery	Redo treatment
$41 < X \leq 57$	Low fall risk	Stroke recovery	Achieve RTW
$41 < X \leq 57$	Low fall risk	Spinal Cord Injury	Redo treatment
$41 < X \leq 57$	Low fall risk	Spinal Cord Injury	Achieve RTW

An example of Horn Clause rules that can be created based on the decision tree are as follows:

- $\neg H \cap \neg SR \cap NT$ (1)
- $\neg H \cap \neg SR \cap RT$ (2)
- $\neg H \cap \neg SCI \cap NT$ (3)
- $\neg H \cap \neg SCI \cap RT$ (4)
- $\neg M \cap \neg SR \cap NT$ (5)
- $\neg M \cap \neg SR \cap RT$ (6)
- $\neg M \cap \neg SCI \cap NT$ (7)
- $\neg M \cap \neg SCI \cap RT$ (8)
- $\neg L \cap \neg SR \cap RTW$ (9)
- $\neg L \cap \neg SR \cap RT$ (10)
- $\neg L \cap \neg SCI \cap RTW$ (11)
- $\neg L \cap \neg SCI \cap RT$ (12)

VI. RESULTS AND DISCUSSION

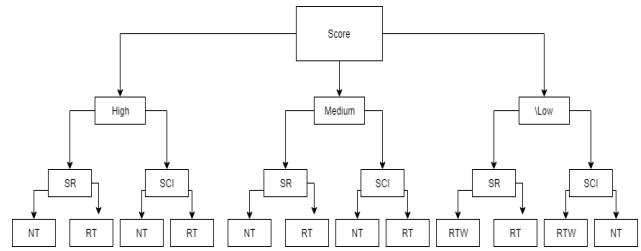


Fig. 4. Decision tree enhancement based on Table 3.

VII. CONCLUSION

The rehabilitation therapy needs computerized techniques which help PT and OT in assisting patient while conserving effort and time. This study explores the applicability of the Horn Clause technique in predicting the progression of disabled patients based on the BBS assessment. In the current practice, practitioners at rehabilitation clinic make decision manually to approve RTW patients. Since this process involved a large volume of data, particularly those of exercise assessments, it is time consuming and cumbersome. Therefore, there is a need to identify an efficient reasoning technique to facilitate this process. This study proposed the use of Horn Clause in assisting clinicians in assessing improvement and recommending therapy for RTW patients. In order to test its efficiency, the Horn Clause technique need to be validated by using patients' data. For example, stroke recovery and spinal cord injury.

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