

HYBRID INTELLIGENT SUITE FOR DECISION SUPPORT IN SUGARCANE HARVEST

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ABSTRACT: This paper presents a hybrid approach to Artificial Intelligence in Decision Support Systems. The focal point was the use of Fuzzy Logic and Artificial Neural Networks for the generation of predictive decision scenarios with flexible parameter boundaries. This approach was tested via a case study concerning harvest selection of plots cultivated with sugarcane. The results have shown that the combination of the two AI techniques allowed a better tackling of complex decision problems. In the case studied, it was possible to adjust the decision problem boundaries dynamically in order to optimize the harvest logistics.

KEY-WORDS: Artificial Intelligence, Hybrid Systems, Decision Support Systems, Fuzzy Systems, Artificial Neural Networks, sugarcane harvest.

UMA SUÍTE INTELIGENTE HÍBRIDA PARA SUPORTE À DECISÃO NA COLHEITA DA CANA-DE-AÇÚCAR

RESUMO: O presente trabalho introduz uma abordagem híbrida para utilizar Inteligência Artificial em Sistemas de Apoio à Decisão. O enfoque central foi utilizar Lógica *Fuzzy* e Redes Neurais Artificiais na geração inteligente de cenários preditivos com limites de parâmetros de decisão flexíveis. Essa abordagem foi testada através de um estudo de caso aplicando seus princípios à seleção de lotes para colheita da cana-de-açúcar. Os resultados mostraram que a combinação das potencialidades das técnicas de IA utilizadas, permite tratar de forma mais eficaz problemas de decisão complexos. No caso estudado, foi possível flexibilizar os limites de decisão dinamicamente para otimizar a logística da colheita.

PALAVRAS-CHAVES: Inteligência Artificial, Sistemas Híbridos, Sistemas de Apoio à Decisão, Sistemas Fuzzy, Redes Neurais Artificiais, colheita da cana-de-açúcar.

1. INTRODUCTION

The decision making process in semi-structured environments is a difficult task because the conditions that lead to an optimal decision change over time. Additionally, the decision maker must deal with conflicting objectives, there is a large number of options to be analyzed and there are relevant financial implications concerning every selected option.

Previous studies have shown the possibility of using Artificial Intelligence (AI) techniques to forecast productivity factors on sugarcane decision problems (Trigo et al., 2005) and to build Decision Support Systems (DSS) which support decisions in sugarcane harvesting (Lima Neto,1998)(Pacheco, 2006). These studies used Artificial Neural Networks

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(ANN) to perform the forecasting, following which linear programming heuristics were used help selections of the best plots for harvesting.

This paper presents a different combination of AI techniques to support the sugar cane harvesting decision. A new DSS was implemented, employing ANN and Fuzzy Logic (FL). Here, the ANN is responsible for forecasting attributes of all considered productivity factors for each plot. Following this phase, a Fuzzy Logic module was used to provide flexible decision (parameter) boundaries to the decision maker

Results have shown that this approach allowed the user to handle complex problems better than when using a single technique. Furthermore, the new system made possible optimizations onto the harvest logistic because of its ability of dynamically adapting to the problem characteristics.

2. BACKGROUND

2.1. DECISION SUPPORT SYSTEMS

A Decision Support System (DSS) can be described as a special software tool, which combines computational capabilities with intellectual assets of Decision Makers. Its main objective is to improve the quality of decisions in semi-structured problems (Turban, 1995).

Due to its peculiar characteristics, a DSS is focused on mid to high managerial personnel. This kind of system must focus on flexibility, adaptability, and a fast response to user inputs. The Decision Maker is a central part of this system initiating and controlling its execution (Sprague, 1991). In most cases a DSS aids in generating decision scenarios, which are possible lines of action to solve a problem.

2.2. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks are a brain-inspired AI technique that is capable of learning through example and of generalizing this acquired knowledge, giving good responses when confronted with unseen situations (Haykin, 1994). ANNs have been used for numerous purposes such as regression and classification problems. In a previous work (Buarque,1998), ANN has been proposed to help on decision systems. In that study the n-DSS (*i.e.* Neural Decision Systems) was introduced, which is a novel kind of system that uses at its core an ANN for modeling various real world phenomena.

2.3. FUZZY LOGIC

Fuzzy Logic, as proposed by Lofti Zadeh of the University of California at Berkeley in the early 1960, is an extension of Aristotelian Logic; it is characterized by dealing more effectively with ranges of values whose limits are not well known. In addition, it is also capable of dealing with linguistic values, which are inherently imprecise. For example, the statement: 'this is a good decision' is rather imprecise; notice that the boundaries of a 'good' or 'bad' decision probably overlaps.

A Fuzzy Logic Controller (FLC) is a device (hardware or software) responsible for giving dynamic responses when a user or a system is trying to attain a desired objective or to control another entity. A FLC uses a desired value and a feedback signal from the other entity to perform its task (Kasabov, 1996).

3. HYBRID INTELLIGENT APPROACH TO DECISION SUPPORT

The approach presented in this paper proposes the creation of a DSS using two combined IA techniques. Our hypothesis is that combining individual potentialities of each technique allows for tackling complex problems more effectively than when using just a single technique. The predictive module is used to compose future decision scenarios. Then, the Search Module could create alternative lines of action, based on input received from the Predictive Module and from the decision maker.

Figure 1 shows a schematic view of a Hybrid Suite for Decision Support (HIDS). The decision-making process using this approach follows:

- The decision maker must inform decision objectives and boundaries. Examples of boundaries and objectives are minimum PCC and minimum sugarcane tonnage.
- The Predictive Module forecasts attributes for a decision, which are combined with decision objectives and initial boundaries in the Decision Model. This model depends on the specific problem and results in at least one decision scenario. The scenario generated and boundaries informed by the decision maker will form the basis for the following iterations.
- Using the produced decision scenario, the FLC can perform its calculations striving to attain new boundaries to optimize the solution (*i.e.* create better decision scenarios). This adjust shall increase or decrease the value for each boundary.
- The new calculated boundaries will be fed into the decision model and this cycle (decision model – FLC – decision model) will be repeated until a sufficient number of alternative decision scenarios is created.
- The decision maker must analyze and select the best decision scenario, considering the initial boundaries and objectives.

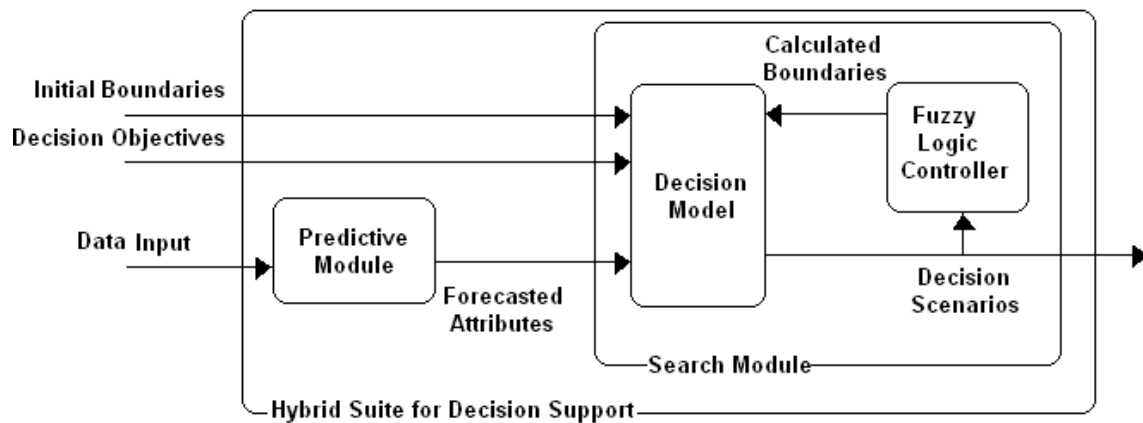


Figure 1: Schematic view of a Hybrid Suite for Decision Support

It is worth mentioning that the FLC computation is also particular to each problem, because its membership functions must be based on how changes in boundaries relate to decision outcomes.

Each boundary must be evaluated individually and after enough samples are collected, they can be optionally combined, trying to find even better solutions. This heuristic explores the decision space dynamically, evaluating the impact of adjusting one boundary at a time. This allows for avoiding the Inverse Problem (Tarantola, 2005).

4. A CASE STUDY – SUGARCANE HARVEST

In this case study, five experiments were conducted. All of them aimed at simulating the managerial decision support in a sugarcane mill. The Decision Model was built using the abstract model contained in (Oliveira et al., 2006). The decision maker has to inform the desired number of tons of sugarcane to harvest, the minimum values for PCC and Fiber, and their weights in the weighted average computed by a productivity indicator (*i.e.* their relevance towards the final decision).

The ANN considered for the problem was trained according the work of (Pacheco, 2006) and was used to forecast PCC, TCH and Fiber values for all 418 available plots.

In the Decision Model, each plot is ranked according to its relevance, a sum of PCC weight * PCC * TCH and Fiber weight * Fiber * TCH. This sum indicates to what extend each plot is in accordance with the decision maker's criteria. After the plots had been ranked, those under the minimum values for PCC and Fiber were removed. Then, they were stacked up until the desired tonnage of sugarcane was reached.

After some early studies, we found that reducing the values for minimum PCC and Fiber, allowed the Decision Model to select amongst a bigger variety of plots. This way, it was possible to reach the desired tonnage using fewer plots. After this point, the matter was to discover the best adjust in the initial boundaries. The FLC was modeled using this information, to provide the dynamic adjustment in boundaries, according to the number of plots presented after each cycle. Table 1 shows the values used for each experiment.

Table 1: Values used for experiments performed in sugarcane harvest case study.

| Experiment | PCC Weight | Fiber Weight | Min PCC | Min Fiber | Desired ton. |
|------------|------------|--------------|---------|-----------|--------------|
| 1 | 10 | 5 | 16 | 15 | 650 |
| 2 | 5 | 10 | 15 | 15 | 500 |
| 3 | 5 | 7 | 15 | 14 | 500 |
| 4 | 10 | 4 | 15.5 | 14.5 | 600 |
| 5 | 7 | 5 | 14 | 13 | 450 |

5. RESULTS AND DISCUSSION

In the five simulations carried out according to Table 1, it can be seen that to use flexible limits was a reasonable strategy to reduce the number of plots for harvesting. Table 2 shows the best results for each experiment, using Fixed and Flexible limits.

Table 2: Comparative values for each experiment, using Fixed and Flexible limits.

| Experiment | Min. PCC | Min. Fiber | Avg. PCC | Avg. Fiber | Ton. Cut | Plots |
|---------------------|-------------|-------------|--------------|--------------|---------------|----------|
| 1 – Fixed | 16 | 15 | 16.26 | 16.07 | 715.88 | 8 |
| 1 – Flexible | 15.6 | 15 | 15.87 | 15.74 | 651.93 | 6 |
| 2 – Fixed | 15 | 15 | 15.57 | 16.32 | 559.29 | 6 |
| 2 – Flexible | 14.3 | 15 | 14.50 | 15.11 | 527.81 | 4 |
| 3 – Fixed | 15 | 14 | 15.12 | 14.58 | 539.11 | 5 |
| 3 – Flexible | 15 | 13.9 | 15.44 | 13.99 | 533.34 | 4 |
| 4 – Fixed | 15.5 | 14.5 | 15.9 | 17.2 | 482.25 | 6 |
| 4 – Flexible | 15.1 | 14.5 | 15.16 | 14.76 | 692.35 | 5 |
| 5 – Fixed | 14 | 13 | 14.55 | 15.12 | 526.93 | 6 |
| 5 – Flexible | 13.5 | 13 | 13.58 | 13.68 | 461.38 | 3 |

In most cases, the average values for PCC and Fiber using flexible boundaries were lower than when using fixed ones. However, a consistent reduction in the number of plots and a better adjustment to desired tonnage of sugarcane for harvesting were observed. The experiment confirmed the hypothesis that a second IA technique would be useful to provide alternative options to the decision maker, improving the harvest logistics (*i.e.* using fewer plots).

6. CONCLUSION

This paper has presented a hybrid suite for decision support and applied it to a sugarcane harvest case study. In the decision suite presented, two IA techniques (ANN and FLC) were utilized for forecasting productivity indicators of sugarcane plots and to provide flexibility to the limits informed by the decision maker. The aim was to make the decision limits more flexible, in an attempt to reduce the number of plots and, consequently, improve the harvest logistic. The results obtained have shown that the approach presented is consistent and it is useful for generating decision scenarios with flexible boundaries.

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