Intelligent Reasoning Systems for Decision Support in Farming Mechanization Management

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論文要旨

1. Introduction

Study has been shown that farm mechanization accounts for the drudgery of farming works aside from increasing the farm efficiency and productivity in some countries. However, socio-culture and behavior and farming management systems are barriers in increasing the adoption level of farm mechanization systems in some South East Asia countries. In Indonesia, these barriers are nature since to increasing the recent subsistence agricultural system to the commercial agriculture would transform the recent socio-culture and behavior of the local people about adoption the relatively new system such as farm machinery. Therefore, it needs reformulation of the farming management system to consider the socio-culture and behavior to avoid inappropriate machinery management offered in a given region. The problem arises in acquiring the data observed and analyzing the socio-culture and behavior variables to the decision making process. It is because socio-culture and behavior problem in planning decisions is a complex and fuzzy problem without a cut and dried solution, while such kind of various criteria and alternatives of different decision makers must be considered for optimal decision making. The difference in these approaches is usually related to particular problem aspects such as the number involved in decision making and the degree of vagueness (fuzziness) of human judgment. To coping this problem decision support system software is developed to acquire the socio-culture and behavior of the local people's conditions and analysis such kind of data. It is designed to assist the decision maker to identify the important socio-culture and behavior criteria that underlie farmers to make a decision, and to give advice on the appropriate farm machineries in a given region. It is hoped to supporting a farm mechanization plan before it is applied to farmers, to avoid fault of work, and wasting subsidy if it failed after its application in mechanization project.

2. Decision Support System in Farming Mechanization Management

The developed Decision Support System (DSS) is a computer based system for aiding decision makers who deal with farm mechanization planning such as local government and manufacturers of farm machineries. The DSS used matlab and C++ for program based and comma separated variables for tabular data. The intelligent system is developed to cope with the problem of quickly perceiving and computing the complex data since the problem is a complex and fuzzy problem without a cut and dried solution. The inputs are socio-culture and behavior data observed from a given region. The outputs are presenting the set of alternatives with explanations to support the decision maker in making decisions.

3. Intelligent Reasoning Systems for Decision Support System

In order to enhance the analyzing process acquiring the human reasoning, the DSS uses inference method that can reason more efficiently about occurring kinds of data such as what underlies the farmer making a selection of farm machineries that the decision maker can analyze for better understanding and better decision for a given region problem. Such systems are utilizing to the ANFIS system (Adaptive Neuro-fuzzy Inference System), and referring the FAHP (Fuzzy Analytic Hierarchy Process), and the ACO-F (Ant Colony Optimization with Fuzzy restricted goals).

The ANFIS model is utilized to select the important perceptional and behavioral variables or criteria and determine the farmer's interest in farm equipment. From some variables from the questionnaire, the output is fed to the FAHP model for assessing farmer's perceptions and calculating their perceived important criteria to propose the best appropriate selection. The triangular fuzzy member is utilized for the fuzzification of the crisp Pair-wise Comparison Matrix (PCM). The Given crisp PCM, having the values ranging from 1/7 to 7, are fuzzified using the triangular fuzzy number $f=(l,m,u)$. The alpha cut analysis is applied to transform the total weighted performance matrices into interval performance matrices to account for the uncertainty in the fuzzy range chosen. The confidence value ranges from 0 to 1, from the least confident to the most confident. The alpha cut analysis is used to transform the fuzzy performance matrix representing the overall performance of alternatives with respect to each criterion into an interval performance matrix to rank the level of importance of each criterion of behavioral judgments for each criterion from fuzzy environments. In the other side, the ACO is developed as a learning system tool using a biologically-inspired agent that is set up to emulate decision-making behaviors by demonstrating the implications of various decision model types, with various ant internal behaviors toward the targets. In ACO model, the finite state automata engine is designed to simulate the agents' searching for foods in specified boundaries, demonstrates the agents' behavior in finding the foods, and calculates the successful number of agents finding the foods, to compare the implications of each ant behavior. Then the ACO is set to gather the information about the variables based on the objective function stated using our developed heuristic algorithm. The objective function is stated based on three most important variables: cost, preference and profit expectation. The level of important (high, moderate and low) of the attributes combination is set as subjective weight using eight defined objective fuzzy rules to satisfy the constraints for the goals (the profit expectation should be higher than goal profit expectation ($f_{PE} \geq G_{PE}$), the cost should be less than goal cost ($f_C \leq G_C$), and the preference level should be higher than goal preference level ($f_P \geq G_P$)). The preferable mix combination selections are determined by specified fuzzy subjective classification of the decision maker using fuzzy logic reasoning subsystem.

4. Validation of the Proposed Decision Support System

Each method is tested and evaluated using real data from North Sulawesi Province, Indonesia. The data used were 51 farmers observed and 74 students (representing young people) observed from three upper secondary schools in North Sulawesi Province Indonesia using questionnaires. Three kinds of interest perception to the hand tractors, small tractors and cow and plow are the alternatives of selection in this attempt as they are the most known farm machineries in the observed area to evaluate the system. The farmers' opinion was also assessed to obtain their subjective opinion without direction with questionnaire for making comparison the negative and positive perception impact to the farm machineries selection model.

The proposed DSS has been testified with resulting satisfactory solution as the set up rules and the objective function fed in the models with the data gathered. The ANFIS model gives satisfaction to identifying the important variables of the interest in farming jobs of the young people, and the important variables to the prediction of farmers' interest in farm machinery as set up using some rules and ANFIS parameters. The FAHP model is also tested with satisfactory to acquire the objective function in the algorithm with subjective perception of farm machinery interest to the farmers to explain the criteria contribution to the ranking of selection. The ACO-F is satisfactorily simulating the virtual ants as stated in our optimal heuristic algorithm to finding optimal restricted mix attributes of machineries' criteria as stated in the optimization function with fuzzy goals we developed.

5. Results and Discussions

The results show that the proposed intelligent DSS are sophisticated for socio-culture and behavioral complex problem solution. The ANFIS approach produces reliable results in selecting the important variables of human perception and behavior which are complex and non linear. The FAHP numerical examples with data observed are demonstrated and the results of the hierarchical assessment approach are subsequently proposed. The problem in determining appropriate farm machinery in relation to the dynamics of farmer preferences is addressed with showing the optimistic, pessimistic, and moderate (kansei words) of decision makers' attitude behavior to the alternatives. The results of ACO-F show that the efficacy of biologically-inspired agents as a learning simulator demonstrates the implications of the behavioral decisions meta-heuristically to find the optimal mix combination as specified in fuzzy restricted functions. The implementation of the ACO-F is useful for determining appropriate farm machinery and guiding the planning and evaluation of such kind of farm machinery being offering in selected regions according to the local preferences and decision maker limitations.

6. Conclusions and Future Works

More informative decisions for several models are recognized and the more appropriately accurate selected farm machine can be modeled using this DSS by acquiring the socio-culture and behavior of the local people condition and giving advice for appropriate machinery. The advantage of this system is in intelligent analysis of the complex data for identification, prediction, determination, and classification with excelling in reasoning out such complex problems to the optimal decision support. It would aid problematic imprecise judgment of decision makers to incorporating some parties' perception, some criteria with some alternatives for determining appropriate relatively new systems offered in a given region.

Future work would be in developing a bio-economic model to incorporating this system to give more information to the impact of socio-culture & behavior change to the economic outcome in an integrated planning system of specific farming crops in a given region.

審査結果の要旨

東南アジア諸国ではインドネシアをはじめ多くの国々がそれぞれの実情に合わせて農業の機械化を進めている．大型の国家予算を必要とする機械化による農業振興の大きな課題の一つが適切な農業機械の導入である．農業機械への過剰投資が発生しないように機械の組織的利用をはじめとして，一定の地域的広がりの中での機械の能力に対応した作業面積が確保されることなどが基本的に求められる．適正な機械を導入するためには，地形や気象条件，圃場の区画，土地条件，作業条件に応じた作業能率，実作業率，対象作物，地域における農業労賃，利用規模，機械利用経費などの多くの条件を考慮しなければならない．以上のような諸条件を考慮して地域の農業構造等の実情に即した農業機械を導入することで地域の農業生産力の増進と農業経営の改善が期待できる．このような複雑な条件を満たす最適な農業機械を選択することは容易ではなく意思決定支援システムといったソフトウェアが利用されるケースもある．また，更にこれらの条件に加え，インドネシアなどでは地域ごとの民族や文化の差異，あるいは教育水準の違い等のヒューマンファクターを考慮しなければならないという課題がある．そこで本研究は，農作業の機械化管理を対象課題として感性工学の手法を導入した意思決定支援のための知的推論システムの構築を目的としている．

第 1 章では，機械導入による農業振興を図る際の適正農業機械の選択を例に，地域の社会構造や文化あるいは地域の農業従事者の価値観の差異などが適正農業機械を選択する上でいかに重要であるかについて言及し，その課題解決のために目的とする意思決定支援のための知的推論システムの構築を行う手順を示した．

第 2 章では，農作業の機械化管理における意思決定支援について概観し，ソフトウェアの開発環境と知的推論を実現するためのシステム構築に取り入れる各種アルゴリズムを明らかにした．

第3章では，ヒューマンファクターを扱う推論システムについて詳述し，新規開発アルゴリズムの特徴，適用手順および数学的誘導について明らかにした．適応型ニューロ・ファジー推論(ANFIS)，ファジー階層分析法(FAHP)およびファジー目標型蟻コロニー最適化法(ACO-F)を主要アルゴリズムとして開発した．ANFISは，農業機械導入に関して考慮すべき諸条件の中で，人の思考パターン，嗜好あるいは感受性などに影響される条件選択に適用するアルゴリズムとして開発した．アンケート調査などにおける質問項目の重要度を自動的に分析し，次段でファジー階層分析法を適用して目的とする適正農業機械を推定可能なソフトウェアとした．本研究では階層分析法の総合評価値の加重和の計算を，ファジィ積分に置き換え，評価項目間の相互作用を加えた総合評価を行えるファジー階層分析法に改良した．評価項目間の一対比較をし，各評価項目の重要度を求め，各評価項目について代替案間の一対比較を行い，各評価項目についての各代替案の個別評価値を求める手法を開発した． 用いたファジーメンバーシップ関数は，いずれも三角形型とした．ファジー目標型蟻コロニー最適化法の探査プロセスでは有限オートマトンを用いた．

第 4 章では，開発したアルゴリズムの動作確認を行った．実際にインドネシアで 125 人を対象にアンケート調査を実施し，小型乗用トラクター，耕運機および家畜を選定対象として開発ソフトウェアのテストを行ったところアンケート調査を実施した地域の実情からその結果が妥当であると判断できた．

第 5 章では，開発したアルゴリズムのそれぞれ ANFIS，FAHP および ACO-F に入手した調査データを与え，結果を求めた．ANFIS は重要変数の自動選択を担うプロセスであるが，農

業機械を導入しようとする作業者が必要と感ずる変数として耕運の必要度，作業の熟練度および機械導入に関してのリスクの 3 変数が選択された．変数間に非線形性の強い関連が存在する感性由来の多変数からこれらの 3 変数を正しく導くことができた．ステップサイズ関数を適応的に 1.0～0.5 に変化させることで出力誤差が 14.4 から 3.8 に収束し良好な結果が得られた．FAHP モデルにより得られた結果では最も導入すべき農業機械として耕運機(ランク 0.777)つづいて小型乗用トラクタ(ランク 0.720)最後に家畜による鋤(ランク 0.27)という順序が示され開発した FAHP 意思決定支援システムが正しく回答していることが確認できた.ACO-F についてはα=0.6 β=0.4 において第 8 番トラクタ(管理費 US$50，利益約 US$60000，満足度 7）が推薦され，導入条件である管理費 US$1000 以下，利益約 US$2000 以上，満足度 4 以上を満足しており，良好な結果となった.

以上のように，インドネシアにおける適正農業機械導入に関わる問題を例として，地域の多様な文化や価値観などの特殊な条件を考慮した意思決定支援のための知的推論システムの構築を試み目的の成果を得た．これらは情報工学や感性工学などの基礎分野ばかりでなく，最適化手法や意思決定支援システムに関わる応用分野にも寄与するところが大きい.よって最終試験の結果とあわせて，博士（学術）の学位を授与することを適当と認める.