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A Knowledge-based System for Selection of Trees for Urban Environments

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ABSTRACT

Urban forestry is key in mitigating the environmental effects of urbanization however urban environments presents arboricultural challenges such as limited root and canopy space, poor soil quality, deficiency among others. This study presents findings of investigation into challenges caused by planting of inappropriate tree species and proposes a knowledge-based model. The model is validated through experiments based on a prototype that assists in the selection of the appropriate tree species for the diverse urban environments. Through the research it was evident that a better understanding of how urban ecosystems functions, how to take care of trees, where to strategically plant them and how to maintain them is the only way to maximize potential benefits of urban trees. The prototype was evaluated through selected test cases and the results were fairly accurate and promising when compared with the results of domain experts. Such a system would assist Governments, city-planners and conservationists to plan in advance for urbanization's threats to nature and thus shape the growth of cities through incorporation of successful urban forests initiatives.

Key words: Knowledge-based system, urban forestry, Jess

INTRODUCTION

Urbanization is the driving force for economic growth however it has adverse effects, principally on human health, livelihoods and the environment (Rees and Wackernagel, 1994). Urban forests are pivotal in mitigating the environmental effects of urbanization. This they achieve through reduction of urban surface temperatures (Souch and Souch, 1993), cleaning the air by filtering out particulate matter (Nowak, 1994) Noise reduction (Coder, 1996; Dwyer *et al*., 1992) reduce energy costs for heating and cooling thus, lowering emissions (Heisler, 1986, 1990). Other benefits of urban trees include reduction of surface run off that causes erosion and also for wind control (Coder, 1996).

Despite the many benefits that are attributed to urban forests if improperly done they can lead to huge costs that include financial loss due to high mortality rates of trees, structural damage Limiting access to solar energy, threats to humanity, encouraging unorganized waste disposal (Carter, 1995). Thus the success of urban forest initiatives is only possible thought appropriate selection of tree for planting given that urban environments presents arboricultural challenges of limited root and canopy space, poor soil quality, deficiency or excess of water and light, heat, pollution, mechanical and chemical damage to trees (NKUCFC, 2008).

Knowledge-based systems: Knowledge-based systems, a branch of Artificial Intelligence has been defined as computer-based models that simulate human expertise in a specific domain while making use of extensive knowledge bases and reasoning mechanisms (Shortliffe *et al*., 1973).

This study proposes a methodology for overcoming urban-trees selection problem using automated intelligent methods. This is presented as framework in later sections of this study. It proposes a methodology that allows the storage of large repositories of expertise knowledge and rule-based inference mechanisms.

Knowledge-based systems in Forestry: Considering the many challenges faced in urban tree planting initiatives, there is need of integrating information from many different perspectives for planning and managing the trees. Incorporation of Knowledge-based system in the area of urban forestry through maintaining tree and planting site inventories could play critical role in ensuring that we maximize the benefits of trees and minimize costs of maintaining these forests. The study presents the design and development of a knowledge-based system (expert system) that can be utilized in the provision of advice on selection of appropriate tree species for urban environments.

Different researches have attempted to address the need for provision technical advice in the area of urban forestry. Many of these attempts have involved the incorporation of knowledge-based systems in this area. Kaloudis *et al*. (2005) have developed an insect identification expert system for forest protection which identify forest insects and propose relevant treatment. A web-based system also been developed to advise on the relative efficacy of different herbicides for mixes of weed and crop species at different times of the year in a forestry or farm forestry setting (Thomson and Willoughby, 2004).

Schmoldt and Martin (1986) developed an expert system named PREDICT, which could help foresters diagnose pest problems in red pine (Pinus resinosa) stands, based on symptoms easily observed in the field. A Fuzzy expert system for laying out forest roads based on the risk assessment has also been developed (Yoshimura and Kanzaki, 1998). The system utilized in the mountains of Japan where it was very difficult to construct forest roads because the topography is very steep and slope failures often occur when constructing them.

A number of knowledge-based systems have been also been developed to assist in the selection of tree for planting within urban environments. SelecTree is a web based database system designed to match specific tree species to particular sites based on compatible characteristics. http://selectree.calpoly.edu/). Beck *et al*. (1994) have developed TREES-Tree REcommendation Expert System, a program using CD-ROM Technology system that recommends species and cultivars of trees to plant at a particular site in an urban environment in the southeast United States. The system also was based on a database and allowed users to query the database and locate trees satisfying particular characteristics.

The system presented in this study is purely based on the knowledge-based system principles and doesn't incorporate the conventional database technologies. It provides an interactive user interface and given the nature of expert system shell used it would requires very limited computing resources to execute.

MATERIALS AND METHODS

The Study was conducted in four phases:

- Survey-involved collection of data from different stakeholders on issues regarding tree selection for urban environments

- Data Analysis-collating the data to as determine the requirements for the knowledge-based system to be developed
- Design-Formulation of a solution to the problem of providing expert advice in urban forestry
- Implementation and evaluation of the solution

In evaluating the existing models and provision of advice in the area of urban forestry data was collected from Tree nursery owners, an officer of the Environment section of the Urban Centre, an Engineer with the Kenya Power-a power distributing company and a Domain Expert with the Kenya Forestry Service. The following data collection methods used during the study included Interviews, direct observation, and document reviews which involved getting information from journals, textbooks, internet and electronic libraries on the area of urban forestry.

Tree nursery owners provided insights on the techniques they utilize in providing advice on selection of tree species for urban environments. Information on required planting set back requirements for urban tree in regard to power lines and challenges on power transmission posed by urban tree were obtained from the Power distributing company. The study also established the formalized approach to urban site assessment adopted by the domain experts in identifying the appropriate tree species for planting in urban areas. The approach focused on the following aspects Soil characteristics (Texture, Drainage, Compaction Levels and pH levels), climate (Hardiness zone, Sun light exposure), Topography of the area, Potential planting conflicts (Space Limitation), Levels of human traffic among others.

Observation was used to evaluate the effects of inappropriately planted trees on different urban environments. It was evident that inappropriate selection of trees had adverse effects on Street lights (Fig. 1), signs (Fig. 2), overhead power lines (Fig. 3) and buildings (Fig. 4).

Prototype design: During conversations, human beings do not necessarily have to repeat the subject of conversation. Pronouns such as he, she, they, it possessive determiners his, hers, their and noun phrases such as the cat, this land etc are used to denote entities implicitly so long as they are mentioned in the discourse. Occasionally speakers may want to emphasis on an issue and a phrase may be repeated without the subject reference. This phenomenon is referred to as anaphora and systems build on NLQ models have to deal with more than anaphora. They have to deal with remarks that carry meaning from the discourse and without the rest of the input they would be meaningless even to human respondents. Such would be the interleaving remarks in a dialogue within an NLQ interfacing system. This is the essence of this study.

Consider the following conversation:

- Human: Do you have penicillin for chickenpox?
- Computer: No, Sir.
- Human: Any other?

In this case 'Any other?' would require deeper processing of discourse for a correct answer to be given. Another example is as illustrated here below.

- "Where is Janet? Jane?"

Such are the kind of problems the proposed model described hereafter intends to handle. It is not easy for systems to overcome both anaphoric and elliptical problems. The approach given in this

Fig. 1: A Street light covered by tree branches

Fig. 2: A sign whose view has been blocked by an urban tree

Fig. 3: High and Low voltage power lines interfered by an inappropriately planted urban tree

Fig. 4: A tree planted very close to a building and thus hindering access to natural light

paper uses context free grammar rules based on past cases to intelligently guess the entries in the transfer tables. These transfer tables are described later in this study.

The spiral model of Expert System Development Methodology (ESDM) similar to Boehm's spiral model for software development was adopted in the design and development of the model. The model presents a life cycle in which a prototype evolves through five stages of development. Feasibility Demonstration Prototype-determine if at least one key cognitive function of the expert can be modeled, Research Prototype-determines whether additional functions can be modeled, Field Prototype-ascertains the combination of conventional and expert system techniques needed to model all necessary cognitive functions, Production Prototype-asks whether the manual system can be modeled in a way that is robust and efficient and Operational Prototype-being able to emulate the human expert.

The Java Expert System Shell (JESS), a rule engine for the Java platform was selected as the development environment for the prototype given the immense advantages that it provides. Some of these would include its ability to integrate with other systems. To use it, a user is required to specify logic in the form of rules using one of two formats: the Jess rule language (preferred) or Extensible Markup Language (XML). Figure 5 illustrates the basic architecture of the system in which order to re-constitute a question where missing information is intelligently determined and included in query, we need to understand the general framework that the NLQ model would operate. A simple transfer model suitable for Swahili language described by Hill (2007) has been selected for its robustness in handling Swahili inputs. It is reproduced here below for ease of reference.

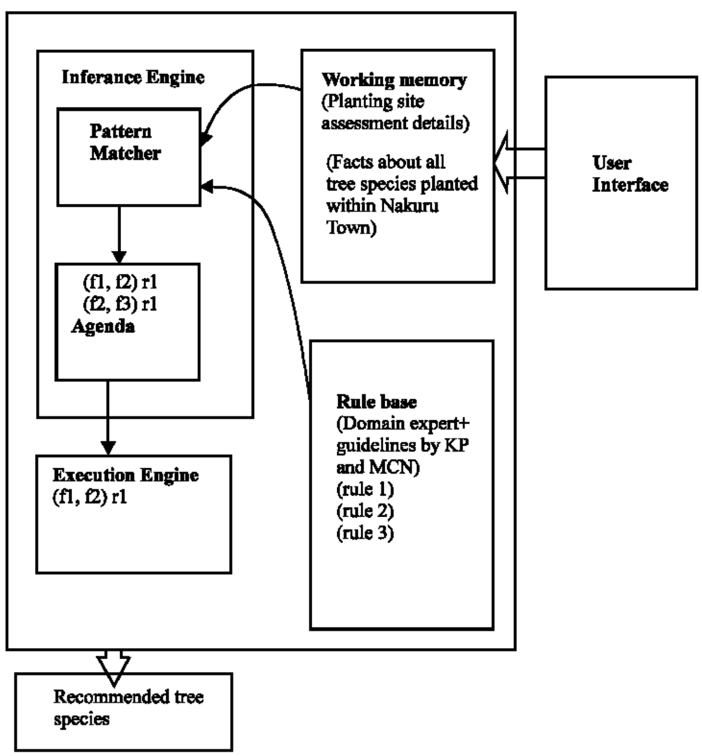

Fig. 5: Architecture of the model based on the Java Expert System Shell, adopted from Hill, 2007

Working memory/fact base: Jess's working memory is which similar to a database; it's filled with indexed, structured data. Most of the time, working memory is accessed by pattern matching from a rule. The working memory contains all details of tree species that can be planted within the urban centre where the study was conducted.

The deftemplate construct was used to describe the kind of facts that were stores in form of member variables called slots. As shown:

```
Deftemplate tree
    "A specific tree." (slot C_name) (slot S_name) (slot Texture) (slot Drainage) (slot Compaction) (slot Ph) (slot ConT ?) (slot Sun)
    (slot Drought) (slot Flood) (slot Mheight) (slot Mwidth) (slot Root) (slot Break) (slot Maint))
```

Facts of more than thirty five (35) different tree species were included in the working memory of the system. The facts construct was used to store details about tree in working memory as shown below.

```
(deffacts tree_types (tree (C_name "Mexican Ash") (S_name "Fraxinus pennylvanica")
(Texture nil) (Drainage nil) (Compaction nil) (Ph nil) (ConT? yes) (Sun full) (Drought yes)
(Flood yes)(Mheight 70) (Mwidth 50) (Root shallow) (Break yes) (Litter yes)
```

Rule base/knowledge-base: The rule base contained all the rules incorporated into the system. These were formulated based on information collected from the different stakeholders and the domain expert. The rules take the form of an if... then statement in a procedural language, but are not used in a procedural way since they are executed whenever their if parts (their Left-Hand-Sides or LHSs) are satisfied. This makes Java Expert System Shell (JESS) rules less deterministic than a typical procedural program.

Example of such a rule is illustrated below:

```
(defrule MAIN:odst (answer (ident odst) (text ?i))
(test (<(integer ?i) 20)
?t1<-(tree (Mheight ?x&:(> ?x 50)))
=> (retract ?t1)
```

The user interface design borrowed heavily from the verbal elicitation technique with questions being formulated based on a typical conversation between a tree nursery owner and a customer. The interface takes the end-user through an interactive dialog which is then dynamically synthesized from the "goal" of the system, the contents of the knowledge-base and the user responses. Some of the information about the urban site expected form the user includes soil texture, drainage, soil compaction, pH levels, soil contamination, sun light exposure, Exposure to extreme wind, surface run-off effects, planting conflicts (overhead lines, underground utilities, structures, street lights, signs) and levels of human activity.

RESULTS

Urban environments with varied planting characteristics were identified as test cases for testing and evaluating the prototype developed. Recommendations on tree for planting on the specific planting sites from different tree nursery owners and domain experts in urban forestry were recommended and compared with those of the Prototype.

In evaluating the prototype specific environments with varied characteristics within the urban centre were identified and selected as test cases. The specific details of the each environment were recorded and validated through the assistance of the Domain Expert. A set of questions and expected responses were prepared for each of the test cases for the evaluation purpose. The set of questions and responses for each test case were given to the officer of the urban Council environment section and selected tree nursery owners selected based on their expertise in the area of urban forestry. Recommendations made by each of them were recorded for each of the test cases and compared with those obtained from the developed system. The results obtained from the testing were accurate within the range of the expected, given the difficulty of identifying the most suitable tree for a given environment since even human experts would disagree about some of the tree selected for given urban environments.

A typical sample run of the prototype showing the interactive dialog between it and the user are shown in Fig. 6 while Fig. 7 illustrates the sample output inform of recommended tree species.

```
A KNOWLEDGE-BASED SYSTEM FOR SELECTION OF TREES FOR
PLANTING WITHIN NAKURU TOWN

Type your NAME and press ENTER> oloo
****************************************
Hello, oloo.
Welcome to the Knowledge-based System for selection of trees for urban environments.
The system contains knowledge on trees that can grow in Nakuru town
In assessing the planting site the following basic test need to be carried out on the soil
a)        Texture by feel technique = to identify soil type i.e. Clay, Loam, Sand
b)        Drainage Test for Drainage levels
c)        Screw Driver test for compaction levels
d)        Ph test to test acidity of alkalinity of the soils
Please answer the questions and I will recommend some trees for planting
***********************************

What is the texture of the soil?
VALID ANSWERS ARE:=>clay loam sand :loam

How would you rate the level of drainage at the site?
VALID ANSWERS ARE:=>poor moderate excessive :moderate
Is the soil at site compacted?
VALID ANSWERS ARE:=>yes no :no

What are the pH levels at the site? (acid 1.0-6.9) (alkaline 7.0-14.0)?
VALID ANSWERS ARE:=>acid alkaline :acid

Are there signs of potential soil contamination (unidentified material; past dumping, construction debris)?
VALID ANSWERS ARE:=>yes no :no

What is the expected sun light exposure at site(full>6hrs direct sun)(partial<6hrs sun or filtered light) (Shade<6hrs filtered light)?
VALID ANSWERS ARE:=>full partial shade :full
```

Fig. 6: Sample run of the system showing the interactive dialog between IT and the user

```
********************* RECOMMENDATION ************************

Number of tree(s) recommended: =24
COMMON NAMES: Flat-top acacia SCIENTIFIC NAMES:Acacia abyssinica
COMMON NAMES: Cordia SCIENTIFIC NAMES:Cordia Africana
COMMON NAMES: Markhamia SCIENTIFIC NAMES:Markhamia lutea
COMMON NAMES: Elgon Teak SCIENTIFIC NAMES:Olea capensis
COMMON NAMES: Madagascar terminalia SCIENTIFIC NAMES:Terminalia mantaly
COMMON NAMES: Mexican Ash SCIENTIFIC NAMES:Fraxinus pennylvanica
COMMON NAMES: Royal Poinciana SCIENTIFIC NAMES:Delonix regia
COMMON NAMES: Jacaranda SCIENTIFIC NAMES:Jacaranda mimosifolia
COMMON NAMES: Dichrostachys cinerea SCIENTIFIC NAMES:sickle bush
COMMON NAMES: Abyssinian Diospyros SCIENTIFIC NAMES:Diospyros abyssinica
COMMON NAMES: Silky Oak SCIENTIFIC NAMES:Grevillea robusta
COMMON NAMES: Whistling Pine SCIENTIFIC NAMES:casuarina equisetifolia
COMMON NAMES: Ekebergia capensis SCIENTIFIC NAMES:Ekebergia
COMMON NAMES: Nandi Flame /African Tulip SCIENTIFIC NAMES:Spathodea campanulata
COMMON NAMES: Tree Entada SCIENTIFIC NAMES:Entada abyssinica
COMMON NAMES: Podo SCIENTIFIC NAMES:Podocarpus falcatus
COMMON NAMES: Cape fig SCIENTIFIC NAMES:Ficus sur
COMMON NAMES: Podo SCIENTIFIC NAMES:Podocarpus latifolius
COMMON NAMES: Cedar SCIENTIFIC NAMES:Juniperus virginiana
COMMON NAMES: Avocado SCIENTIFIC NAMES:Persea americana
COMMON NAMES: Mexican/Kenya Cypress SCIENTIFIC NAMES:Cupressus lusitanica
COMMON NAMES: Prunus SCIENTIFIC NAMES:Prunus Africana
COMMON NAMES: Tasmanian blue gum SCIENTIFIC NAMES:Eucalptus globulus
COMMON NAMES: Croton SCIENTIFIC NAMES:Croton megalocarpus
```

Fig. 7: A sample output of the system with a list of recommended tree species

CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

This study presents the design and development of a knowledge-based system for selection of tree for planting in urban environments. Its design was based on a formalized approach to urban planting site assessment used by many domain experts in the areas of urban forestry. The system provides recommendations on tree for planting for specific urban sites similar to other systems developed but most importantly it doesn't incorporate a database approach that is common in many other system designs.

The knowledge-based system developed forms a basis for more research in the area of application of artificial intelligence in urban forestry and also proposes long term evaluation of tree planting initiatives based on recommendations of such developed systems.This would involve monitoring changes in the urban environment and state of the trees planted at different stages of their growth. Such information would increase the confidence levels of the using the prototype since subsequent factors likely to affect the trees would have been considered.

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