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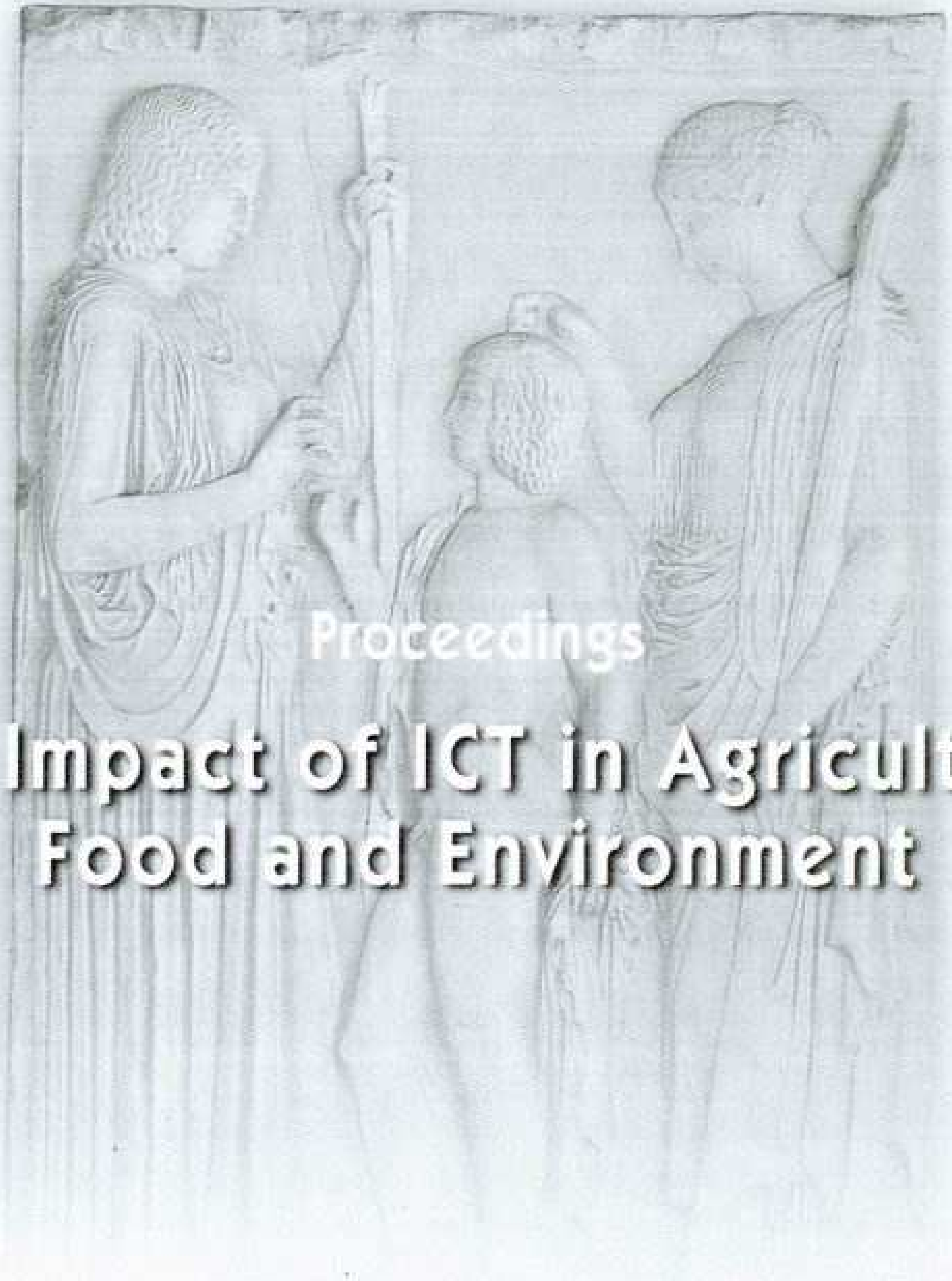

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A Decision Support System for Insect Identification and Forest Protection: A Case Study of Pine, Fir and Chestnut Forests

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Abstract

A forest, as a major component of an ecosystem, plays a very important role in soil protection, air quality, flood reduction etc. It also plays a significant economic role for rural areas and for the national economy as whole.

Forest health depends on many factors, such as biological, physical and anthropogenic. During recent decades, in particular, its health continuously weakens because of the extreme meteorological phenomena and increase of wildfires. As a consequence, its sensitivity to secondary attacks by insects and fungus increases rapidly, since the latter find convenient expansion conditions. However the budget for forest health is not satisfactorily high, and this often results in forest degradation.

This paper is concerned with the description of a Decision Support System (DSS) to protect forests from insects. It contains an Expert System that enables identifying more than forty distinct insects, either from some stage of an insect's life cycle or by the damage that insects cause to trees. Once an insect identification is completed, the system can recommend an appropriate treatment, aiming at reducing expansion of insects and minimisation of a possible forest damage. The system is enhanced with photos and drawings that assist the user in the precise and quick identification of an insect. It can be used either by experienced people, such as extension officers, or by inexperienced users such as forest owners. Moreover, it can be used for education or training purposes. One major advantage is that the DSS integrates in one module knowledge from diverse areas, as opposed to the distribution of knowledge in different sources.

INTRODUCTION

Forests, as a major component of terrestrial ecosystems, play a significant role to the environmental stability and to the maintenance of convenient and healthy conditions for the life on earth. They act as carbon dioxide and noxious gasses sinks and also as dust filters, with their involvement in the process of oxygen recycling (Tsekos and Koukouli 1976). They also prevent soil erosion by reducing the raindrop velocity and water flow (Papamihos 1985) as well as the air velocity. Finally, forests also play an important role to the local and national economy, much greater than is usually estimated.

Forests suffer from mistreatment in many places around the world for reasons of immediate economic development, in the form of over-logging, overgrazing or deforestation. This is also true in Greece and it is combined with destruction caused by fires. Indeed, in recent decades fires represent the most important reason for forest degradation in Greece, in conjunction with extreme meteorological events and environmental pollution that makes forests vulnerable to secondary attacks by pathogens and insects (Manion 1981, Freier and Beatz 1984, Kailidis 1986). In particular, it is the great loss of fir forest that is attributed to environmental changes and to secondary attacks by insects and fungus (Kailidis 1984). Yet the extensive deadening of fir trees in central Greece has not yet been explained satisfactorily. Regarding insect attacks, their diagnosis in the early stages is very significant because, after expansion, forest managers can do too little. This is due to two major reasons: Firstly, any treatment is then very difficult and expensive to be applied in large forested areas. Secondly, even if there is an effective treatment, the side effects of its application may be unacceptable.

Insects are usually present in small populations in a forest and constitute, with all the other organisms, the ecosystem, without any significant impact to the forest. There are periods however, during which their population increases rapidly, over the ordinary levels. Then the stability of the ecosystem is disturbed. At a consequence, a high economic damage occurs. For this reason, an early diagnosis of the insect species, either from some stage of its lifecycle or from the damage it causes to forest, is crucial. In practice the cause is identified too late, once the damage is already significant. This happens because it is difficult for the personnel in charge of forest protection to attribute the damage, to correct insect, and to predict the size of the damage. Given however that Expert Systems (ES) can emulate human experience in certain areas, several applications of them have been developed in forestry (Schmoldt 1987a; Schmoldt 1987b; Schmoldt 1987c; Schmoldt 1988; Schmoldt and Martin, 1989;Potter et al ,2000) that assist in the diagnosis and in the handling of such problems.

To confront with insect attacks to a forest, a Decision Support System (DSS) is proposed in the present paper , which can help non-experts in the early identification of insect attacks. The software runs on a PC. Alternatively, it can be run over Internet. No additional laboratory equipment is required. This way, insects are identified either from some stage of their lifecycle, with a satisfactory degree of confidence, or by the damage they cause on the trees. Consultation, to face attacks, can be provided. Predictions of possible dangers can also be made. The prototype implementation considers fir, specifically Chestnut and Pines, but it can be expended to any other specie. The DSS is also useful for training and educational purposes as well as for operational purposes. The relevant knowledge remains stored in a knowledge base and it can be easily be updated.

THE KNOWLEDGE BASE

As is well known, the reliability and acceptability of an ES depends mainly on the quality of knowledge contained in the Knowledge Base (KB). The quality of knowledge depends heavily, amongst others, on the Knowledge Acquisition (KA) procedure. In our case particular attention was paid to the accuracy of the description of the symptoms that can be observed and to their association with a specific insect as well as to the identification of an insect by its characteristics. The knowledge was acquired from a forestry expert. It was also complemented by the use of related literature during the KA procedure such as books, scientific journals and photographs of either insects and the damage they can cause to a forest. The insects per tree that can be identified by the DSS are given in Table 1.

Table 1. The insects per tree which can be identified by the system

PINE	
1. LYMANTRIA MONACHA L	**CHESTNUT**
2. MONOPHLEBUS HELLENICUS	1. ZEUZERA PYRINA L.
3. DIPRION PINI L.	2. BALANINUS ELEPHAS GYLL
4. HYLOBIUS ABIETIS L.	3. LASPEYRESIA SPLENDANA HB
5. MONOCHAMUS GALLOPROVINCIALIS OL.	4. PAMMENE FASCIANA
6. BLASTOPHAGUS PINIPERDA L.	**FIR**
7. ORTHOTOMICUS EROSUS	1. RESELIELLA PICEA SEITH
8. THAUMETOPOEA PITYOCAMPA SCHIFF.	2. PYTIOKTEINES CURVIDENS GERM.
9. DENDROLIMUS PINI L.	3. PHAENOPS KNOTEKI REITT
10. PISSODES NOTATUS F.	4. TRYPODENDRON LINEATUS OL.
11. RHYACIONIA BUOLIANA SCHIFF.	5. CACOECIA MURINANA HBK
12. PANOLIS FLAMMEA SHIFF.	6. SESIA CEPHIFORMIS Ochsh.
13. BLASTOPHAGUS MINOR HTG.	7. CRYPHALUS PICEAE RATZ
14. BUPALUS PINIARIUS L.	8. PYTIOKTEINES SPINIDENS REITT
15. NEODIPRION SERTIFER GEOFFR.	9. RHYACIONIA MARGAROTANA H.S.
16. DIORYCTRIA PINEAE STGR	10. AGEVILLEA ABIETIS HUDAULT
17. DIORYCTRIA SPLENDIDELA H.S.	11. MINDARUSABIETINUS KOCH.
18. POGONOCHAERUS PERROUDI MUSL.	12. ARGYRESTHIA FUNDELLA F.R.
19. PYTIOGENES CALCARATUS	13. ACANTHOCINUS RETICULATUS RAZOUM
20. DIORYCTRIA MENDACELLA STGR.	14. DIORYCTRIA ABIETELLA SCHIFF
	15. SIREX CYANEUS F.
	16. PISSODES PICEAE ILL.
	17. GRAPHOLITHA RUFIMITRANA Hs.
	18. RHAGIUM INQUISITOR L.
	19. UROCERUS GIGAS L.

For the development of the DSS we used EXSYS Professional, Ver. 5.1.0, an expert system development tool. In this tool, knowledge is represented in terms of IF-THEN-ELSE rules. Such a representation is very common in diagnostic expert systems. IF is followed by a list of conditions. The THEN and ELSE statements concern the appropriate action or conclusion. To build the KB, the user has to declare the *qualifiers* with their possible *values* and the *choices* as well. A qualifier is an entity that can take one or more values. A *qualifier-value* pair forms one condition of the rule or a conclusion that it is not final one. To formalise the KA procedure, we recorded all the qualifiers and their values in registration sheets. A *choice* is a possible final conclusion. For the system to be able to reach a conclusion, even in the case of inadequate facts that do not allow for a secure identification, we added more than one rule with the same conclusion but with less confidence factor. In accordance with the conditions of the rule, the conclusion is associated with a confidence factor, which is a measurement of the reliability of the conclusion. A typical rule is illustrated bellow:

```
                  qualifier                         value
RULE:
  If   kind of the forest specie is                 fir
  and  the stage of life cycle of insect is larva
  and  the body of larva  has colour light red like rust
  and  the body of the larva has shape light pressed
  and  [LARVA_LENGTH]>=3
  and  [LARVA_LENGTH]<=4
THEN:  RESELIELLA PICEAE  SEITH. - Confidence=8/10
  and  DISPLAY("C:\WINEXSYS\RESELI-1.TXT")
```

The first *then part* of the rule is a *choice* that corresponds to a specific insect. The second part, `DISPLAY("C:\WINEXSYS\RESELI-1.TXT")`, is used to display the appropriate consultation, stored in a text file, that concerns the identified insect.

To assist the user in confirming the appropriate symptom or characteristic or finding, a large number of selected images (stored in PCX files) are associated with a certain *qualifier-value* pair. Hypertext files are also called to give additional textual and graphical information.

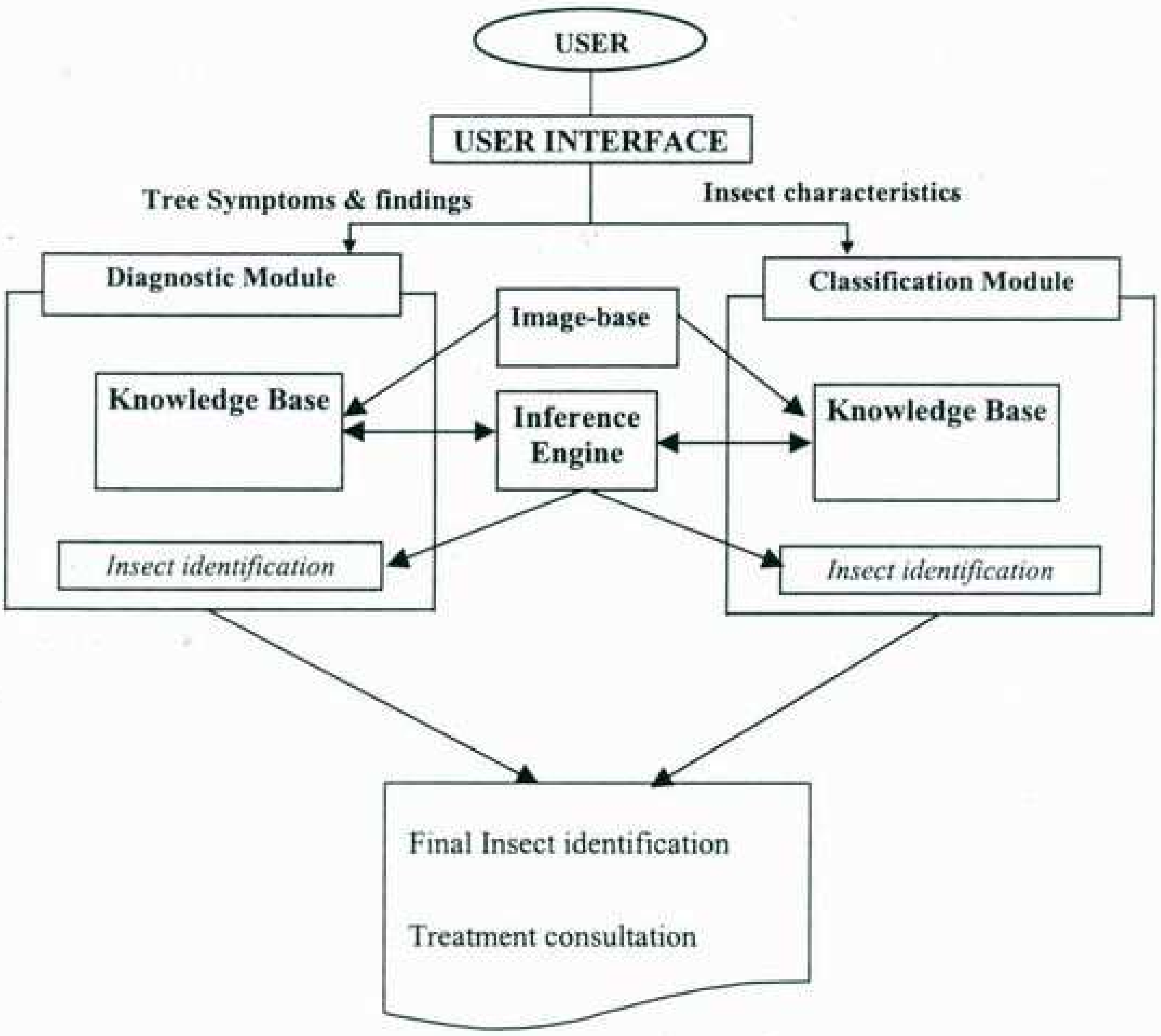

Figure 1. The architecture of the system.

The KB of the system contains about 150 rules. For each kind of tree it actually uses two distinct KBs. The first KB is a *classification* one, that helps the user in identifying the insect according to specific entomological characteristics. In this KB, for each insect and for each phase of its life, there are a number of identification rules. The second KB helps in identifying the insect from the damages it causes to the trees of the forest or from findings that the user can observe in the forest. The architecture of the system is illustrated in figure 1.

INTERACTION BETWEEN THE SYSTEM AND THE USER

Although EXSYS uses both backward and forward chaining inference methods, we use only backward chaining, which fits the diagnostic procedure. At the beginning of the session the kind of forest is chosen by the user. Next, he can opt the way of identification: either according to the insect's characteristics or the findings. The user can select both. In such a case the system initiates the inference by asking the user questions that concern the insect itself. The questions are associated with characteristics of the insect such as:

- the stage of life cycle
- the colour of its body
- the colour of its wings
- its length etc

If the user selects the findings in the forest the system initiates the inference by asking questions concerning the damages that occurred in the forest. If the system reaches a conclusion it displays it to the user with the associated treatment or consultation.

CONCLUSIONS & DISCUSSION

Although the system is still under evaluation, the first results show that, generally, it is reliable for both options of insect identification. Its advantages can be outlined as follows:

- The use of photos and diagrams enhance its friendliness.
- There is no need for complementary use of complex instruments.
- Due to the above, it can be used by forest personnel of a medium level of education.
- It performs fast insect identification either by some stage of the insect lifecycle or by the damage that insects cause to a forest.
- It incorporates diverse knowledge, which should alternatively be found in different sources.
- It can easily be updated.
- It is proper for training and educational purposes on forest protection.
- It can be used in the field.

After completion of the evaluation, the system will be available for use over Internet. Further work includes its extension by the inclusion of more trees and insects.

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