AN INTERNET-BASED MONITORING SYSTEM FOR BEHAVIOUR STUDIES OF STINGLESS BEES

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ABSTRACT

Stingless bees have an increasing commercial importance for pollination inside greenhouses. Besides the ecologic interest, studies on their behavior and on the influence of abiotic factors such as air temperature and humidity on flight activity can help select the species more suitable for a specific condition. An Internet-based monitoring system to help these studies is presented. The instrumentation level uses a personal computer and a data acquisition board plus sensors for those two variables and for bees count. A database is build with these data and can be accessed locally or remotely via Internet using a Web Browser. The technology permits acquisition of more and better data than before and also allows sharing the results among researchers from different parts of the world in real time.

STINGLESS BEES AND THEIR IMPORTANCE

The insects from the *Apidae* family, sub-family *Meliponinae* are known as “stingless bees” because their sting is vestigial and is not effective. They are social insects living in colonies with several levels of social organization and can be found mainly in tropical and temperate subtropical climate regions. Among 400 species known, 300 are found in America, 60 in Southeast Asia, 50 in Africa, and 10 in Australia. (Velthuis, 1997).

Bees in general are important commercial and environmentally because they are the main pollinators of many crops and directly influence agricultural production, maintenance of ecological balance and reproduction and survival of many plant species. About 75 % of human food is based on plants that are pollinated by bees. (McGregor, 1972).

From the environmental point of view preservation and strengthening of plant species are related to the possibility of cross-pollination, which is responsible for the maintenance of genetic variability. This reproduction process depends very much on pollination agents such as wind and bees (Roubik, 1995). The interaction between flowers and bees is one of the most successful examples of association in nature, and there are cases of extreme specialization. Kevan (1999) discusses the role of pollinators as bioindicators of the state of environment.

From the economic point of view beekeeping and management of stingless bees for pollination of commercial crops has evolved significantly as an activity in some regions and shows good potential in many others. The search for new pollinators for agricultural use in the 80's was very successful with *Bombus terrestris* (a bumble bee), which proved to be a very important pollinator for tomatoes, eggplant and pimiento in greenhouses. (Velthuis, 1997). Heard (1999) reviewed the role of stingless bees as crop pollinators; Malagodi-Braga et al. (2000) review the use of stingless bees in greenhouses.

RESEARCH ON STINGLESS BEES

The need for effective yet not aggressive pollinators inside a greenhouse, where other insects are neither available nor desired is one of the reasons for the studies of stingless bees. Another reason is to propose conservation programs in order to guarantee their survival as species. Those studies aim at knowing their living habits, how they make their hives and nests, the conditions for building them, their geographic distribution, their floral preferences, and the conditions for flight activity.

The availability of flowers is one of the external factors that influence the flight activity and hence the growth of the colony, but other abiotic factors also interfere. Several authors studied the flight activity of stingless bees and its relation to abiotic factors. Hilário et al (2000) studied the flight activity of *Melipona bicolor bicolor*. Ten colonies were observed in laboratory from 1993 to 1995 in a total of 855 datasets. The methodology consisted of manually counting and registering the number of bees entering ad leaving the colony, the air temperature and humidity. The bees were counted for five minutes in thirty minutes intervals, from eight to eighteen o'clock. The results showed a positive correlation between flight activity and air humidity, and also a threshold for the beginning of the activity. The author was able to identify temperature and humidity ranges that favor external activities.

Heard & Hendrikz, (1993) studied two colonies of *Trigona carbonaria*, from 1986 to 1988 in a total of 368 observations. For five minutes each hour they manually counted the bees going inside and outside the colony and registered temperature, humidity, solar radiation, and wind velocity. The results showed that temperature and radiation have an influence on the activity. A daily pattern was also observed. According to the authors the results show that the species can be used as pollinator in regions of tropical and subtropical climate, where the temperature are above 18ºC and the solar radiation is above 15 Wm^{-2}.

Kleinert-Giovannini & Imperatriz-Fonseca, (1986) studied two colonies of *Melipona marginata marginata* and six colonies of *Melipona marginata obscurior*. In more than a thousand observations the authors manually colleted data from bees count, air temperature and humidity, wind velocity and a pattern for the climate (cloudy, sunny, partly cloudy, etc). They identified a positive correlation between flight and temperature and a negative correlation to air humidity. They also observed that although activity through the day approaches a normal distribution, there is no direct correlation to daytime and the decreasing of the activity at the end of the day even in good weather conditions possibly reflects a daily rhythm pattern.

Manual data acquisition is a bottleneck for these studies. It is strongly time consuming and demands qualified personnel. Consequently the studies have to be limited in time and that reflects on the amount of data obtained. Errors can occur in reading, registering, and on the transcription of the data to computers for processing, especially after long working periods.

DEVELOPMENT OF AN AUTOMATIC DATA ACQUISITION SYSTEM CONNECTED TO THE INTERNET

An automatic data acquisition system can minimize if not eliminate many of these problems. It can extend monitoring to a greater number of colonies, to other variables and to longer periods. As a consequence the quantity of the data can be significantly increased and their quality improved while researchers can dedicate their time to analyzing the results.

Based on that, an automatic data acquisition system was proposed and is being developed. It is aimed at monitoring colonies located in a laboratory or close to it. In this situation a personal computer and a data-acquisition board can be used as the basis for the instrumentation level. They collect data from sensors located inside the colonies and send them to another personal computer where these data are stored in a database. It also stores data from a weather station that is linked to that computer.

In order to allow sharing data in real time among the many researchers involved in the projects, some of them located in different states of Brazil, some of them from research groups in Europe and North America, it was decided to connect the system to the Internet. The system architecture can be seen in Figure 1.

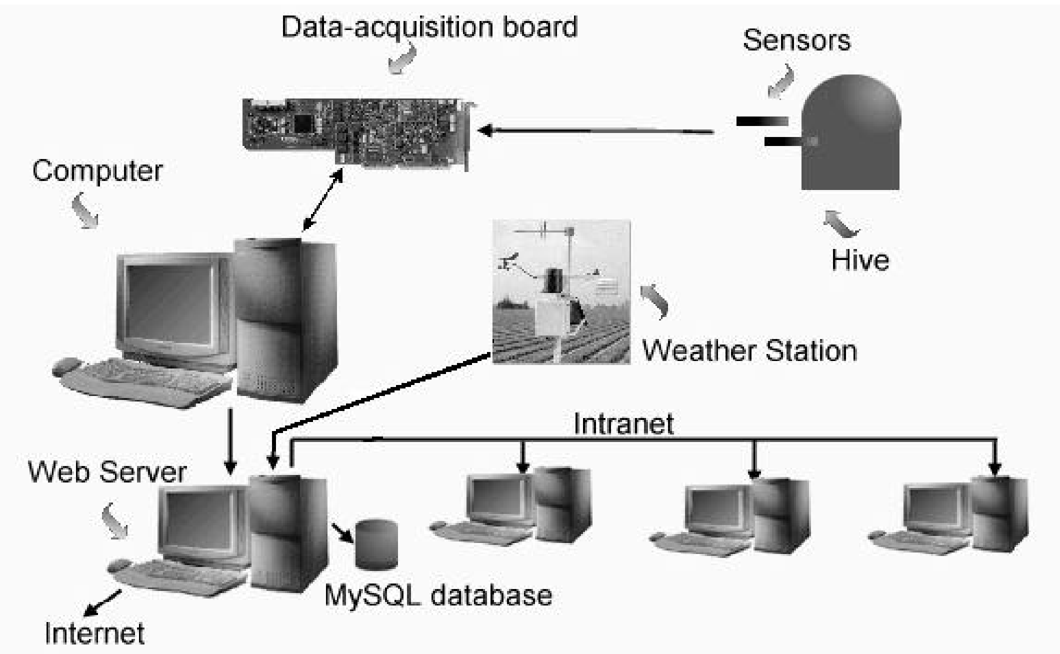

FIGURE 1 - Proposed system architecture

System description

On the instrumentation level the system is based on a data acquisition board (DAQBoard2000 - Iotech), which has 40 digital, 16 analog and 3 counter inputs, and is plugged in a PCI slot on the computer. Temperature sensors (LM 35 – National Semiconductors), humidity sensors (HIH-3605 Honeywell), and infrared optical sensors for counting bees are connected to it. A single board can handle sensors for monitoring up to 8 colonies. A file with data collected by that board and another file with data from the weather station (Davis) are sent to a second computer and are input to a database by a specific program.

A MySQL Server, a relational database management system, running under Linux OS, implements that database. It is integrated to the Apache Web server through PHP scripts. Those freeware software chosen as the basis for the system have good documentation on the Web, and all of them use TCP-IP as their network communication protocol. Figure 2.

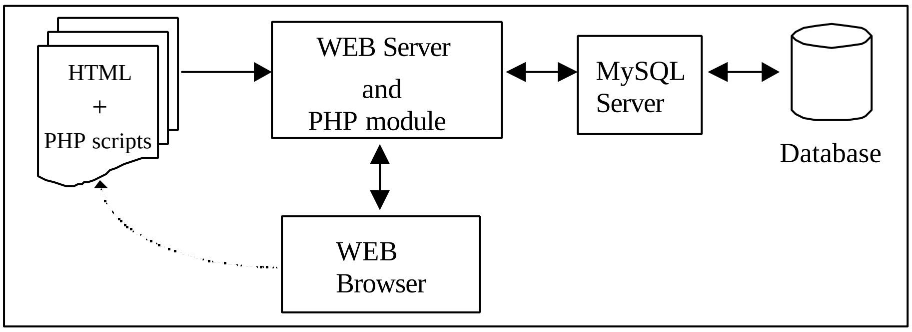

FIGURE 2 – Conceptual diagram of the Web interface software

There are two types of system users. A first type, the manager, must have access to manual data input on the database such as species, equipment, and colonies information data, that will form a cadastre. For that a data management and maintenance program written in Visual Basic implements the interface in an Intranet environment, which offers more security and efficiency since the possibility of interruption during the data insertion process is smaller. The second type of users, the end users, can only make queries on the database, and can't change its data. Web Browser was the technology selected for the implementation of the interface, because it is widely available.

In order to organize the information and to make it easier to input cadastre data by the manager, the program is structured in windows by data entity such as species, colony, localization, and equipment. The presentation of previously input information in combo boxes in windows with related entities is an additional facility.

Figure 3 shows an example window of the cadastre of the colonies studied at the BeeLab, University of São Paulo, Brazil. The manager can input, change and delete colonies filling the form on the screen, which has the following data fields: colony identification, species, localization, place of origin, arrival date, and start of data acquisition date. In this screen the fields "species" and "localization" are selected from combo boxes as mentioned.

The end user can access the same information through an HTML page as seen in Figure 4. The page is generated after the execution of a PHP script.

In another window the manager must relate each colony to its sensors (air temperature and humidity inside the colony, and bees count) and their position on the acquisition board. With that information the system is able to answer the user's queries with respect to a specific colony and a certain period of time, extracting from the database only the desired data. Data can be presented in tabular or in graphic form. Tables allow remote users to export data to a spreadsheet or other program to perform further analysis.

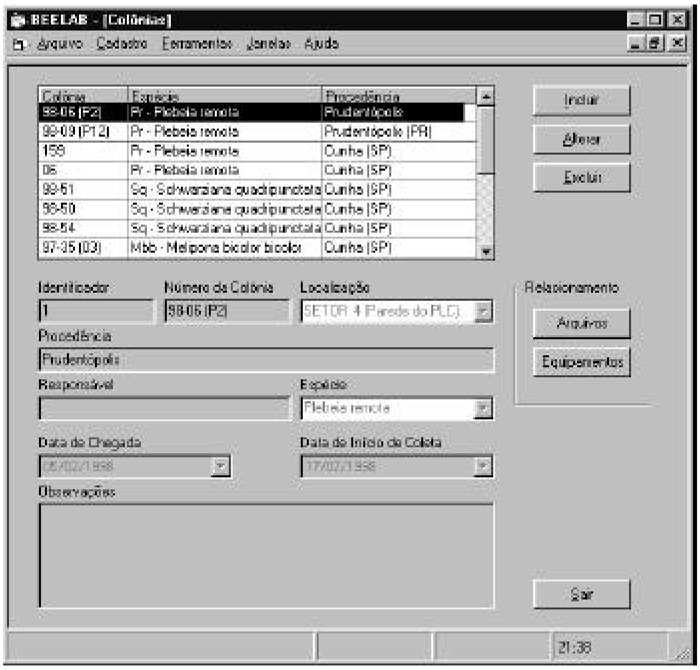

FIGURE 3 – Example window for the cadastre of colonies by the manager.

FIGURE 4 – Cadastre of colonies as seen by the end user on an HTML page.

The graphic form on its turn allows a better visualization of data but usually does not allow export. The graphic interface on the Intranet is implemented with Visual Basic and shows simultaneously two variables versus time. The variables can be selected among temperature, humidity and bees count. Two cursors can be used for measurements on the screen and the difference between values is displayed automatically. These features are not available yet for Internet users.

CONCLUSION

The system is a typical example of automation including instrumentation for data acquisition, structured storage in a database, and tools for queries and analysis. The use of a commercial data acquisition board was convenient because it was possible to concentrate on other issues such as the adequate sensors for the application. Although based on market modules and tools its integration has demanded a significant amount of engineering work.

With the new technologies it was possible to design and implement a system that expands the data acquisition capacity of the researchers and improves data quality. It also allows real time access to data beyond the confines of the laboratory, expanding it to any place where there is a connection to the Internet. This will strengthen interaction between researchers from different parts of the world, creating a virtual institute for research on stingless bees.

The software used has good portability and is available for Linux and Windows environments what gives another degree of freedom when choosing the platform for future work. For the future the Internet interface might include Java Applets to present graphics, animations and other calculations in order to explore better the system's data and to increase interactivity with the user. In this context the ".NET" infrastructure, by Microsoft, may be another solution. Both PHP and MySQL proved to be easy to use and compatible, and it was possible to dedicate more time to the project of the database than to its implementation. During the specification of the database it became clear that other important information related to the studies of the stingless bees might be included in a more comprehensive information system. This work is intended to be the first part of the development of such system.

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