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Location-aware system for olive fruit fly spray control

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ABSTRACT

Location awareness is essential for many Precision Farming (PF) tasks with strong spatiotemporal, environmental, public health and food safety characteristics. Nevertheless, its role is much more crucial in PF tasks with efficacy depending mainly on local climate conditions and the collaboration of users. A PF task with the aforementioned characteristics is the insecticide-bait ground spraying against olive fruit fly, the most serious pest on olive cultivations. It requires location awareness, so as to be more efficient, friendly for the environment and the domestic areas, and ensure olive products with low insecticide residues. This research proposes an innovative, integrated, Location-Aware System (LAS) suitable for the ground control of the olive fruit fly. The developed system enables rapid prototyping of Location-Aware (LA) services in an intelligent PF environment combining location sensing technologies with wireless Internet, Geographical Information Systems (GIS), and Expert Systems (ES). We focus on the functional and operational capabilities of the middleware architecture, on the design issues of the developed GIS, ES, and LA modules, as well as, on the factors and infrastructure that must be considered during the spraying process. Based on this framework we developed specific LA services, such as finding the area to be sprayed, estimating the amount of the spraying solution required, canceling the spraying process, etc. These services aim in a more efficient and environmental friendly treatment. To validate the LAS a moderate-scale experiment is performed showing that the proposed system is functional and operational. LAS consult effectively the tractor attendants on how to spray, by means of reducing spraying failures and minimizing the decisions that must be taken during spraying process. Preliminary results report that with LAS no over sprayings occur, sprayings are based on infestation risk, cultivation characteristics, and meteorological conditions. Finally, a safe distance from biological cultivations, environmental protected and domestic areas is kept, avoiding pollution of these areas with insecticide residues.

1. Introduction

Olive fruit fly (scientific name; *Bactrocera oleae* or *Dacus oleae* (Gmelin), Diptera: Tephritidae) is the most serious insect pest of olive fruits in the world. It affects the olive tree cultivation causing serious qualitative and quantitative consequences with economic impacts and monetary losses (Neuenschwander and Michelakis, 1978; Economopoulos et al., 1986). Even with the pesticide treatments that are applied every year to control the olive fruit fly population, the damage caused by this insect in the fruits, results in about 10–30% loss of the olive crop (Economopoulos et al., 1982; Michelakis, 1990; Economopoulos, 2002). Without treatment and under optimum climate conditions, for the development of the olive fruit fly, the insect could infect up to 100% of the olive fruits (Athar, 2005). Control of olive fruit fly depends on either killing the hatching eggs and larvae in the olive fruit or stopping the female from mating or laying eggs. This can be accomplished with broadcast foliar sprays, or bait spraying applications using different attractants in combination with insecticides, or with massive numbers of sterile male's release. However, in real pest management conditions, bait spray from ground is considered as the most effective treatment against olive fruit fly (Manousis and Moore, 1987).

In most cases, bait sprays from the ground are performed based on the sprayer attendants' experience. As a result spraying efficacy is limited, whereas environmental protection is not taken systematically into account. Global Positioning System (GPS) technology, still in its' first steps, is now used in order to monitor the tractors and find out any failures in the spraying process. Most studies are focused on monitoring (Liebhold et al., 1993; Lyons et al., 2002) or modeling (Kapatos and Fletcher, 1983) the olive fruit fly population and adjust the spraying areas according to their findings. To the best of our knowledge, no proper attention has been given so far on the improvement of the spraying process from the research community. Note that the spraying process has spatial and temporal characteristics, which must be taken into account for an appropriate distribution of the spraying solution. For example, tractor attendants must know during the spraying process the current

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local conditions, such as temperature, wind speed, insect population characteristics, density coverage of olive trees, etc., so as to apply the appropriate quantity of the spraying solution per area unit. As a result, the success of the spraying process depends on the cultivation characteristics, insect's population dynamics and meteorological conditions. Management tools are needed for the ground sprayings against olive fruit fly because in many cases, the efficacy appears to be very limited and/or the environmental protection is almost absent. The impacts on the environment, the food chain, the operators and the natural enemies of the pests could be reduced if the ground sprays were limited to those that are necessary and conducted in an appropriate and systematic way. Clearly, this problem has all the characteristics of a Precision Farming (PF) or Precision Agriculture (PA) application and in order to find an effective solution, it is necessary to look on the new technological advances and methods offered.

The main issue in any PF environment is to provide access to electronic agro-environmental (e.g. biological, climatic, meteorological, etc.) records, namely, a step in the direction of providing accurate and timely information to farmers for the support of decision-making. Note that farms are distinguished by the distributed nature of the information, the intensive collaboration and mobility of their personnel, as well as their need to access agro-environmental information occasionally. Obviously, the aforementioned provision has motivated the introduction of ubiquitous computing technology, assuming of course that the design scenarios for developing PF systems respond to particular conditions (i.e. soil or cultivation characteristics, meteorological conditions, number of users, etc.) and demands (i.e. solving a pest problem with a specific precision). For this reason, in this research, we suggest an iterative user-centered development method to understand the bait sprayings from ground and to envision and deploy appropriate scenarios, in which the main system components respond autonomously in accordance with the context. Examples, of possible scenarios in the problem of bait sprays from the ground could be to stop the spraying activity in case the temperature exceeds a threshold or to avoid the possibility of spraying nearby an environmental or domestic area.

In many real cases, a PF environment is saturated with heterogeneous computational and wireless communication devices (Zhang et al., 2002). In addition, any service offered has to be accessible to diverse and non-specialist farmers through simple, intelligent and effortless interactions. Thus, there is a need the system to be aware of the specialized context in order to provide information and services when the farmers need them. For example, PF utilizes new information and communication technology techniques to get localized environmental conditions of the farm through the use of satellite or aerial imagery, GPS and other means (Auernhammer, 2001). The information gained is utilized for taking decisions to make environmental safe and optimal use of resources and improve productivity and quality by making appropriate use of water, nutrients, pest management, etc.

The aim of this paper is to propose an intelligent Location-Aware System (LAS) that combines location sensing technologies with wireless Internet, Geographical Information Systems (GIS) and Expert Systems (ES), for monitoring and controlling olive fly pest problem in a ubiquitous PF environment. It contributes in:

- Supporting a generic Wireless Sensor Network (WSN) model for handling heterogeneous meteorological data, managed by a simple interface (Pontikakos and Tsiligiridis, 2007).
- Providing a middleware architecture design, that allows software agents to cooperate and communicate among themselves, disseminating and/or gathering the sensory data on the WSN.
- Developing an intelligent system that integrates Location-Aware (LA) services in a ubiquitous PF environment by means of combining GIS, ES and LA modules in order to improve the efficacy of bait sprayings from ground against the olive fruit fly and minimize the consequences in the natural environment. The developed modules support tasks like the countering measures selection and the alarm spraying levels.
- Reporting some encouraging preliminary results obtained from a moderate-scale experiment, which was carried out at the province of Laconia (Greece) in order to validate the proposed system under real ground spraying conditions.

The paper is organized as follows. Section 2 provides some background information by means of the description of the problem and the related work undertaken so far. Section 3 provides the underlying methods adopted and the tools used. Details about data acquisition, the proposed architecture and the description of the experimental site, the olive fruit fly population monitoring and treatment procedures, as well as the software tools used, are provided in this section. Some preliminary results obtained from the experiment are reported in Section 4. Finally, in Section 5 the main conclusions along with the future work are presented.

2. Background

2.1. Problem description

As already mentioned olive fruit flies affect the olive tree cultivation causing serious qualitative and quantitative consequences with economic impacts. The insect is monophagous and has three to five generations per year depending upon local conditions. The flies are very mobile and have the ability to seek out cooler areas of the orchard and urban trees. Its mobility and the fact that generations overlap, make the treatment of this insect a complicated task (Manousis and Moore, 1987; Mazomenos et al., 2002; Montiel and Jones, 2002).

The olive fruit fly control with insecticide-bait spraying applications from ground consists of two phases. The first phase is the monitoring of the pest population in order to take a decision to spray or not. The number of adults in traps (i.e. McPhail traps) and observations of larval stages in fruit samples are coupled with climatic data (temperature, relative humidity, etc.) to make predictions of damages and take preventive measures. The second phase is the spraying application process itself. It aims at minimizing the population of the adult stage of the olive fruit fly with the least impact for the environment and with the lowest cost. To achieve these goals several problems need to be solved concerning geospatial, meteorological, biological and other agro-environmental data that exist during the spraying applications.

The spray process takes place during the day using tractors. Each tractor covers one section of the spraying area. The insecticide-bait solution applies in a course spray or stream to a small portion of the tree. There is no need to cover the whole tree, because the adult flies are attracted to the bait, feed on it and die. During the spray applications several problems may arise:

- During the spraying process the meteorological parameters need not to exceeded specific thresholds, defined in advance. Note that the air temperature and wind speed values are usually unknown to the spraying attendant and therefore, the spraying could continue, even in cases the meteorological conditions are inappropriate.
- Usually, the sprayings cover large areas. Thus, it is difficult for the tractor attendants to memorize their spraying areas, and as a result over or under spraying may occur.
- The spray volume dependents on the coverage of olive trees. Nevertheless, the spraying attendant cannot easily determine the