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Multi-Agent Based Anti-Locust Territory Protection System

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Abstract

Locust invasion still remains danger to crops and vast unused fields in certain parts of the world. This problem is also relevant to Kazakhstan. Every year the government allocates 16 million USD to control locusts’ population, and prevent damages that they cause after its intrusion.

The aim of this paper is to define the concept of developing an anti-locust multi-agent territory protection system (ALMATPS), which consists of heterogeneous robots such as unmanned aerial vehicles (UAV), ground robots (GR) or unmanned ground vehicles (UGV) (there is no different between these two terms, both can be used). These heterogeneous robots collaborate with each to achieve the main goal using the agent based modeling (ABM).

1. Introduction

Invasion of locusts is a catastrophic natural disaster which leads to devastation of crops and major agricultural damage.

Locust, in zoology, is a name for certain migratory members of the short-horned grasshopper family (Acrididae). Locust and grasshoppers belong to the same family Acrididae in the Orthoptera Order, which also includes crickets

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Keywords: locust control; agent based modeling; heterogeneous robots; HARMS;
and long-horned grasshoppers (see Fig. 1(a))

\[\text{Locust} \quad \text{Grasshopper} \]

(a) Different types of insects belonging

\[\text{Cock} \quad \text{Long-horned grasshoppers} \]

(b) Life cycle of the locusts to Acridida Family

Fig. 1. (a) Different types of insects belonging to Acridida Family; (b) Life cycle of the locusts

Usually locusts live separately, but sometimes they join into swarms. This phenomenon was studied by many scientists and they discovered that locusts form swarms under certain environmental circumstances, as heat, dry climate, lack of vegetation, water, etc.

Lone locusts are very calm and usually avoid one another, which is called the solitary phase. When the locusts become crowded, they undergo a radical behavioral shift from calm to a more active phase called the gregarious phase (see Fig. 1 (b)). During this phase, the locusts become more active, cannibalistic and move toward each other, forming the destructive swarms for which locusts are infamous around the world.

Occasionally, they make long-distance migrations and in such cases it can build up to huge populations. As their population increase, they need more and more food.

According to the Food and Agriculture Organization (FAO) of the United Nations (UN), the three considered species – the Italian Locust (CIT), the Moroccan Locust (DMA) and the Migratory Locust (LMI) - are present in the entire Caucasus and Central Asia (CCA). The largest area suitable for CIT is located in central and northern Kazakhstan (see Fig. 2).

Fig. 2. Distribution areas of the three main locust pests

From Fig. 3, we can observe that the largest amount of infested areas belong to Kazakhstan. Presented statistics and the vast territory of the expansion of locusts justify the importance of developing an anti-locust territory protection system in Kazakhstan. In order to reduce the cost and damage significantly, locust swarms should be detected during an outbreak or early upsurge stages and abolished before reaching an unmanageable state, when their populations expand into full-scale plagues.
In this paper, we present the new concept of fighting against locusts, applying the methods of precision agriculture/farming (PA or PF)\(^\text{15}\).

To avert the threat of plague outbreaks locally, regionally and interstate, aggregations of locusts are sprayed with chemical or biological pesticides from the ground and the air\(^\text{16}\). The collapse of the Soviet Union in 1991 led to a significant decrease in locust monitoring and preventive treatments resulting in a need to spray 8 million hectares in Kazakhstan in 2000 to prevent major crop losses\(^\text{17}\). The chemical pesticides may have harmful effects on human health and environment. Thus, using PA/PF methods in ALMATPS will reduce the damaging effects of using chemicals pesticides to the environment, since it aims directly to the detected areas of locust habitat.

Nowadays there are many information systems that help countries suffering from locusts’ plagues by forecasting locusts’ growth period, such as African Real Time Environmental Monitoring using Imaging Satellites (ARTEMIS)\(^\text{18}\), Reconnaissance and Management System of the Environment of Schistocerca (RAMSES)\(^\text{19}\) and Schistocerca WARning Management System (SWARMS)\(^\text{20}\). All of these systems use images from satellites, as Terra-MODIS and SPOT-VEGETATION\(^\text{21}\), to study necessary ecological conditions, mainly green vegetations. These systems were developed and implemented by FAO of the UN with the help of different space organizations such as The National Aeronautics and Space Administration (NASA)\(^\text{22}\), The Centre national d'études spatiales CNES\(^\text{23}\), The Swedish National Space Board (SNSB)\(^\text{24}\), etc. In 2002, Kazakhstan adopted the system based on experience with the Desert Locust Information Service (DLIS)\(^\text{26, 27}\), developed by FAO, the Natural Resources Institute (NRI) and the University of Edinburgh: SWARMS at FAO-HQ, and RAMSES at country level\(^\text{25}\). The system was named the Kazakhstan Locust Information Management Tool (KLIMT). It was designed for three main locusts’ species that are spread in Kazakhstan. KLIMT was supposed to maintain a database that allowed to build maps, retrieve information on surveys and pesticide treatments against locusts, as well as statistical tables for any given time period and area (14 oblasts’ of the country). Several technical workshops in CCA on locusts revealed that, currently, updating the database by seasonal information is being carried out only in 4 oblasts (Almaty, Karagandy, North Kazakhstan and Zhambyl), although at the beginning the database was set up in 14 oblasts. Mapping and analysis of Geographic Information System (GIS) information were not conducted by the Republican Methodological Center of PhytoSanitary Diagnostics and Forecasts, despite the fact that it was responsible for locust monitoring since 2003. Thus, the outdated software and unfilled database led to uselessness of KLIMT\(^\text{25}\).

In this regard, Kazakhstan should apply new methods and technologies of forecasting and controlling the locust invasion.

The proposed concept of the entire locust control system is based on four main levels (see Fig. 4).

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* oblast – a type of administrative division in Kazakhstan (region), analogous to “state” or “province”.

**Fig. 3. Infested areas (ha) from 2006-2014 years**
The hierarchy of the system is presented vertically downwards. The first level is the Satellite level that distinguishes the regions of locusts’ habitat. It is supposed that with the help of FAO, it is possible to re-establish GIS systems and set up special centers which will allow gathering necessary information from satellites used by DLIS. Extracted satellite images will provide information on the locust habitat (especially, vegetation). Satellite images make it possible to identify damaged vegetation caused by the growth and reproduction of locusts in that particular area. However, it is still not enough to fully control the locusts, as it is difficult to identify locusts’ oriental migration from satellite sensing images because of their small size. Thus, we need the second level – Airplane/helicopter level, which is also called a monitoring level. With the help of satellite data, the regional centers will send monitoring airplanes and helicopters along with UAVs/drones on the board to the detected areas of locusts. In case it is necessary to observe the locust habitat more precisely, UAVs/drones will be released from airplanes/helicopters. The third level is the UAVs/drones level, where they will help direct the UGVs in the areas of locust invasion. The fourth level is the UGVs/robots level. The mission of the last level is to exterminate the locusts in their solitary stage.

The next section presents the ABM of the concept, focusing on the development of the last two levels (Levels 3 and 4). The paper ends with the summary of highlighting the importance of the project.

2. Model of the concept

This section presents the description of the two lower levels (Levels 3 and 4, skipping Level 1 and 2) and their communication with each other, since we are developing the system from bottom to top.

Organization of the joint work of group of UAVs/UGVs is established using the ABM28.

In order to model the communication between heterogeneous robot groups, we use Communication among Human, Agent, Robot, Machine, and Sensor (HARMS) or HARMS model30.

Some objects of ALMATPS system, namely, UAVs and UGVs, will have their own agent. Thus, the system will be considered as a large MAS and the task allocation between agents will use multi-agent approach model29,31.

The system workflow is as follows:

1. After detecting approximate areas of locust habitat, airplanes/helicopters release UAVs/drones to the territory.
2. During prototype experiments of our study, quad rotors have been used to define the exact location of locusts, and send massages to the Command Center (see Fig. 5). Quad rotors not only define the exact areas, but also determine the direction of locusts’ movements. Although, this level can consist other UAVs such as hexacopters, flying wing type UAVs, coaxial/helicopter type UAVs also could fall in this category.
3. Then the Command Center will send the UGVs and necessary robots to the area, taking into account the direction of locusts’ movements (see Fig. 6).
4. The UGVs/robots eliminate locusts immediately (see Fig. 7).
5. The UAVs continuously observe and examine the area and send the information to the Command Center, which updates the UGVs/robots with the received information from UAVs.
The presented workflow can be seen as a business process of the entire system. Each object of the system has its own task and set of characteristics.

Thus, this workflow illustrates the process of accomplishing the two lower levels of the system.

3. Concussion and future work

Locust invasion is a serious problem for crop fields and vast pasture areas. The development and establishment of the ALMATPS will improve the territory protection from locust plague not only of a particular country, but of other bordering countries as well, due to the migratory nature of locusts.

The paper proposes the concept of the multi-agent based anti-locust territory protection system. The layers of the system have been defined, focusing on its lower levels that contain heterogeneous unmanned vehicles/robots. Also, the communications of the objects in the system have been described. As a future work we are planning to consider communication between the levels adopting the MANET (Mobile Ad hoc Network), MESH or Ad-hoc networks.

It is assumed that the use of state-of-the-art technologies (ABM, robotic systems, etc.) and PA/PF methods increase the effectiveness of pest control systems, since there will be a unified database to track pest migration, and UAVs/UGVs and robots will accurately distribute harmful chemicals to the infected areas, causing the least possible harm to the environment.

The Address of the President of the Republic of Kazakhstan N.Nazarbayev to the nation on January 17, 2014, states that “During the second and subsequent five-year plans, we should establish the industries of mobile and multimedia technology, nanotechnology and space technology, robotics, genetic engineering, and future energy exploration......We need to ensure that our AGRICULTURE takes the path of innovations. This is our traditional industry......According to the Plan for the transition to the “green” economy by 2030, 15 percent of acreage will be
converted to water-saving technologies. We need to develop agricultural science and create experimental agro-innovation clusters,” and thus, the proposed project concept is considered to be innovative and it is supposed to be useful for the development of agricultural innovation clusters in Kazakhstan. Also, the prototype stated in the paper is the first step of a large-scale project that is to be applied for a governmental grant for its implementation.

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