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Intelligent Outdoor Spaces

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Abstract. There are a number of recent wide area wireless sensor networks applications focused on environmental monitoring. However, there is just a few of them that aim to connect the data collecting and processing power with approaches and technologies of ambient intelligence. In our paper we intend to go further on with the ideas how ambient intelligence used in wide manner in connection with wireless sensor networks throughout the open natural environment could be beneficial not only for early warning in case of possible disasters, but also as a supporting tool for people located from various reasons in various outdoor areas. These can be hitchhikers, hikers on difficult mountains tracks, or even workers in an exacting outdoor workplace (i.e., coal mine). An idea of a large-scale ambient intelligence system based on a wide area wireless sensor network is presented, where the system could be able of monitoring the environment, evaluating the collected data and, if necessary, informing the workers in the environment about possible threats and possibly giving some hints for their rescue using their mobile devices. Such "intelligent outdoor spaces" could use already existing and matured technology of both wireless sensor networks and ambient intelligence with a clear benefit for people situated there.

Keywords. Ambient intelligence, wide area sensor networks, environmental applications, outdoor spaces, early warning.

Introduction

First ideas about Ambient Intelligence used in a large scale manner firstly appeared in [1]. In addition to incorporating intelligence in sensor nodes within a wide area wireless sensor network, the authors of [1] proposed to upgrade this vision to the next level where these geographically distributed intelligent sensor networks would become intelligent sensor resources accessible to the users anytime-anywhere. In our earlier papers [2] and [3] we started with some contemplations related towards possibilities of using large-scale ambient intelligence approaches and applications in a number of environmental problems.

In this paper we intend to go further on with the ideas how ambient intelligence used in "large-scale" throughout the open natural environment could be beneficial in supporting people located at various outdoor places. We present here some contemplation about possibilities for outdoor large-scale ambient intelligence focused on such outdoor spaces, where a wide area wireless sensor network will be able, apart from its monitoring role, also of evaluating possible threats from the

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environment and sending early warning information, if not starting a supporting rescue action for people situated at various places in the monitored environment.

1. Problem Definition

The environmentally oriented wireless sensor networks [4] are in our opinion matured enough to become a basis for more complex support of various outdoor activities. As Efstratiou [5] pointed out, wireless sensor networks are more and more seen as a solution to wide area tracking and monitoring applications, but, these networks are usually designed to serve a single application and collected information is commonly available to one authority, usually to the owner of the sensor network. According to [5], the vision for the future generation of sensor networks is of a world where sensing infrastructure is a shared resource that can be dynamically re-purposed and reprogrammed in order to support multiple applications. Furthermore multiple sensor networks (possibly owned by different authorities) can be combined in a federated fashion in order to create a more complete picture of the world.

We certainly share this opinion and propose an idea of a complex ambient intelligence system over a wide area wireless sensor network implemented in a potentially risky natural environment (mountain areas, surface mines, seashores, river basins or water reservoirs, forests, etc.) that will perform the following tasks:

- monitoring the usual hydro-meteorological parameters of the environment (air pressure, temperature, humidity, soil moisture, etc.),
- monitoring indications of possible threats (seismo-acoustic signals, smoke, water on unusual places, etc.),
- monitoring appearance and movement of animals and human beings in the area,
- evaluating the data collected from the sensor network and identifying possibly dangerous situations,
- identification of possibly endangered human beings in the area under monitoring,
- attempting to contact the persons in danger possibly via their mobile devices and starting to provide all the necessary information and knowledge support aiming to help them to escape from the dangerous situation (including eventual alarming of a rescue squad.)

An AmI system working over such a sensor network will be able of evaluating all the data collected and decide about possible active intervention in the environment aiming to help people located at outdoor spaces under threat.

2. Related Works

Outdoor oriented applications of Ambient Intelligence approaches should be prevailingly based on recent achievements in the area of wide area wireless sensor networks. Let us describe shortly a couple of related works oriented on this area.

Tremendous effort has been devoted recently to the area of sensor networks and their important applications, as mentioned in [6]. A wireless sensor network is usually a combination of low-cost, low-power, multifunctional miniature sensor devices consisting of sensing, data processing, and communicating components, networked through wireless link. In a typical application, a large number of such sensor nodes are deployed over an area with wireless communication capabilities between neighboring nodes.

There is a number of works dealing with technical possibilities of sensor networks. The book [6] lists a number of results, oriented on context-awareness of sensors and sensor networks. The idea behind is, that if sensors could know more about their own context, then they could adapt their behavior and function only when needed and to the extent adequate to the current circumstances. This aspect can be important also for power consumption by the sensor. A lot of work has been done by [7], [8] or [9], a useful book on sensor networks is [10].

For instance, Cardell-Oliver and her colleagues [7] proposed a novel reactive soil moisture sensor network that reacts to rain storms in such a way, that frequent soil moisture readings were collected during rain (approx. every 10 minutes), but less frequent readings (once a day) were collected when it is not raining. The network includes a node with a tipping bucket rain gauge sensor and, in another part of the landscape, a group of nodes with soil moisture sensors. The node monitoring rain is separated from the nodes monitoring soil moisture, and yet these nodes need to share information, whilst minimizing the time spent sending, receiving and listening to messages.

Among a number of recent interesting environmental applications, we can mention the FieldServer Project [11], and the Live E! Project [12].

The FieldServer Project is oriented on development and networked applications of so-called Field Servers. A Field Server [11] is a wireless sensor network that will enhance the monitoring of environmental factors by allowing sensing nodes to be located at precise locations in fields, reducing overhead installation costs, and allowing for real-time data collection. For instance, in Japan, Field Servers were developed for applications at farms. They produce real-time images for security guards, and environmental data for farming. Agronomists, physiologists, and ecologists can exploit high-resolution real-time images in order to react on any specific situation that could appear in the environment. Many types of Field Servers have been developed up to now.

The second example, the Live E! Project [12] is an open research consortium to explore the platform to share the digital information related to the living environment. Using the low cost weather sensor nodes with Internet connectivity, a nationwide sensor network was deployed [12]. The network has accommodated more than 100 stations. The application of this weather station network is intended for disaster protection/reduction/recovery and also as educational material for students.

One of the most significant drivers for wireless sensor network research is environmental monitoring. Its potential will not only enable scientists to measure properties that have not previously been observable, but also by ubiquitous monitoring the environment and supplying the related data to relevant supervising bodies, they can create a basis of early warning systems for various environmental disastrous situations and their management. As [13] points out, the relatively low cost of the wireless sensor networks devices allow the installation of a dense population of nodes that can adequately represent the variability present in the environment. They can provide various risk assessment information, like for example alerting farmers at the onset of frost damage. Wireless sensor networks based fire surveillance systems were designed and implemented, as well. They can measure temperature and humidity, and detect smoke following by early warning information broadcasting [14]. Sensors are able to consider certain dynamic and static variables such as humidity, the type of fuel, slope of the land, the direction and the speed of the wind, smoke, etc. They also allow determining the direction and possible evolution of the flame front.

In our earlier papers [15], [16] and [17] we started with some contemplations related towards possibilities of using ambient intelligence approaches in water management. According to Yang [18], watershed management administers water resources within a watershed for different water users. The ultimate purpose of watershed management plan is to maximize the profits of different users meanwhile reducing the possible conflicts that might occur between them. Watershed management can be very efficiently modelled using multi-agent systems, nevertheless, there is just a few works taking into account also catastrophic situations (see, e.g., [19]).

However, apart from other similarly serious environmental disasters, floods are responsible for the loss of precious lives and destruction of large amounts of property every year, especially in the poor and developing countries. A lot of effort has been put in developing systems which help to minimize the damage through early disaster predictions (see, e.g., [20]). On the other hand, as drought periods, opposite to floods, cause lot of damage every year as well [21], also this problem deserves high effort. Interesting solutions to the problems can be found e.g. in [22], [23], or [24].

3. Proposed Approach

In order to support a person's activities outdoor, her/his geographic location must be identified as an important contextual information that can be used in a variety of scenarios like disaster relief, directional assistance, context-based advertisements, or early warning of the particular person is some potentially dangerous situations. GPS provides accurate localization outdoors, although it is not very useful inside buildings.

Based on ideas presented by Iqbal and others in [1], we can think about *Large-scale Ambient Intelligence* as a large set of geographically widely distributed intelligent sensor resources with the main purpose of increasing significantly intelligence of various segments of real nature. By a smart sensor resource we shall mean a kind of ambient artefact, namely a combination of an advanced sensor with ubiquitously computing and communicating processor integrated with the sensor. They purpose will be given by their main tasks, so that a number of their specific types could be possible. Let us mention a couple of them:

- smart water level guards;
- smart soil humidity sensors;
- smart forest fires guards;
- smart wind velocity sensors;
- and a couple of others.

Speaking about *guards*, we shall mean special kind of intelligent sensors applicable namely for early warning purposes in such cases, when e.g. the water level increase achieves some given gradient, or when temperature in a segment of a forest overreached the given level. In such a case the intelligent sensor resource will communicate a kind of alarm which will be propagated through whole sensor network and immediately elaborated further on by the responsible parts of the network.

Multi-agent architectures seem to be applicable here, as it is common in the case of large networks of sensors. We can tract various types of intelligent sensors and guards as agents with appropriate level of intelligence, recent dispatchers or even dispatching centres can be modelled as supervising agents (e.g., river basin management dispatching centres or fire brigades dispatching centres, etc.).

Outdoor acting person's support should provide relevant and reliable information to users often engaged in other activities and not aware of some hazardous situations that he or she could possibly encounter. There are only a small number of attempts to solve the related dangerous situations that can be described using the following scenario:

A user appears in a natural environment performing her/his working mission, a kind of leisure time activity (hiking tour, mountaineering, cycling, etc.), or because of being an inhabitant of the area. A sudden catastrophic situation (storm, flash flood, debris flow, etc.) could put the person in a risky, if not a life endangering situation. The "intelligent outdoor space" based on a federated wireless sensor network is ubiquitously monitoring the area and estimating the possible appearance of a dangerous situation. If necessary, the network will proactively broadcast an early warning message to the user, offering her/him related navigation services supporting escape from the dangerous situation. This message can be delivered via a mobile device of the user, if the user subscribed it prior to entering the outdoor area, but the cases without subscription should be solved as well.

In the literature, there is only a little works oriented on a kind of a service to the potentially endangered persons in a natural environment; however, this service is never such complex as in our scenario.

For instance, there are some attempts of preventing children from potentially dangerous situations in an urban environment. Probably the first ubiquitous system to assist the outdoor safety care of the schools kids in the real world is described in [25].

A number of papers are devoted to various solutions for tourist assistance, mainly oriented on context-aware tourist navigation on their routes. The usual approach is in deployment of intelligent agents, which collectively determine the user context and retrieve and assemble a kind of simple information up to multi-media presentations that are wirelessly transmitted and displayed on a Personal Digital Assistant (PDA). However, these tourism oriented applications are usually deployed for the navigational purposes, without having capabilities of warning the user from potentially dangerous situations that can appear during their routes.

As an example of an in a sense similar system we refer to [26]. The deployed sensor network aimed to assist the geophysics community, and in contrast with at that time existing volcanic data acquisition equipment the used nodes of the sensor network were smaller, lighter, and consumed less power. The resulting spatial distribution greatly facilitated scientific studies of wave propagation phenomena and volcanic source mechanisms. Certainly, we can imagine a number of potentially dangerous situations that can endanger people working closely to the volcano. Enhancing the purely geophysical sensor networks by the features mentioned above could improve the safety of working near the volcano.

Another example belongs also to the area of potentially dangerous workplaces. The result of [27] seems to be one of those attempts that aimed directly at developing a sensor networks for monitoring possible dangerous situations (gas explosion) in a large yet closed environment - a coal mine in China. In this system also a localization of miners in the coal mine is implemented, however, there is no possibility how to start some rescue actions by the system itself, by processing the results supplied by the network nodes automatically. Nevertheless, the experience with this sensor network in a Chinese coal mine is good and inspirational, according to [27].

In order to design some solution for outdoor spaces we can imagine a number of sensors acting as various kinds of guards. Let us present some examples, which are technologically feasible and frequently used in large-scale wireless sensor networks:

- water level guards, monitoring surface water level, or even groundwater level and watching over potentially dangerous or at least unusual situations.
- water quality guards, monitoring surface and groundwater quality and watching over possible contaminations or pollutions.
- air pollution guards, monitoring air quality, watching over possible pollutions.
- wind velocity sensors, monitoring wind velocity and watching over potentially dangerous situations.
- soil moisture sensors, measuring level of soil humidity, e.g. in forests, or in a river watershed, aiming at monitoring the degree up to which is the land segment saturated by water, and measuring the capacity of further possible saturation.

Of course, other kinds of intelligent sensors integrating ubiquitous monitoring (computing) of measured parameters with ubiquitous communication with other sensors – agents – in the area are possible as well.

We believe that the main application area for large-scale ambient intelligence will be any kind of prevention, connected with early warning facilities. Such areas as fire prevention, water floods prevention and early warning, or accident prevention in urban traffic could be clear candidates.

In water floods prevention area we can imagine the usage of the following agents:

- water level monitoring agents;
- land segments saturation (moisture) guards;
- water reservoir handlers;
- supervising agents.

The concept of our solution to the problem e.g., water floods, could consists of the following steps:

- Establishing a large-scale wireless sensor network, consisting of, e.g., water level guards, completed by a number of sensor sub-networks, composed from soil moisture guards, situated in those land segments that are already known as critical from the soil saturation point of view.
- The established large scale wireless sensor network will be embedded in a multi-agent architecture, where the particular sensor sub-networks of various types will play roles of group of agents in the multi-agent architecture.
- The special roles are assigned to manipulating agents, as are, e.g., water reservoir handlers, or river weirs manipulators.
- The whole system can be designed as hierarchical, as there could be a number of concentrators (agents collecting the data) as well as messages from the

groups of agents defined in the previous steps. These concentrators then communicate mutually as well as with the supervisor that is an agent with the task of evaluating the data as well as messages.

- Further on, the supervising agent will evaluate the messages from the lower level agents, and after judging the level of their importance it will start a respective action, or a whole sequence of actions, adequate to the situation appraised.
- The supervising agent will communicate also with localization agents, which are responsible for keeping information about the people localized in the monitored area. If the supervising agent evaluates the whole situation as dangerous for localized people, it will then send a request to the communicating agents to send an urgent message to the PDA's of the monitored people with a hint what to do in order to escape from the danger.

Similar solutions can be imaged also for other dangerous situations that are likely to appear in an outdoor space. These will be elaborated in a detail further on in other publications. Some our work in this direction has been already published in [3], [15], [28], or [29].

4. Conclusions

In the paper, after a short analysis of various recently used approaches, we presented an idea of a large-scale ambient intelligence application over a wide environmental sensor network aiming at monitoring and possibly early warning in cases of threads from the monitored outdoor environment. The system should be primarily focused on outdoor workplaces and workers acting there, however, it could be beneficial for all the people located in the monitored outdoor space. Their mobile devices can be naturally used for communicating with the monitoring system, with a possibility of prescription the desired messaging or warning service. The idea of just described intelligent outdoor spaces is in further development recently. We hope, that such intelligent outdoor spaces could become reality in the short time, contributing thus to saving many lives of potentially endangered people.

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