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House of Representatives Standing Committee on Agriculture, Fisheries and Forestry

Inquiry into the Impact on Agriculture of Pest Animals

National ICT Australia

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NICTA was formed by the Federal Government (Department of Communications, Information Technology and the Arts and the Australian Research Council) and its consortium partners; the Australian Capital Territory Government, the New South Wales Government, the University of New South Wales and the Australian National University.

The national laboratory is based on facilities in Sydney and Canberra. With an emphasis on use-inspired fundamental research, NICTA's research capabilities are focussed in the areas of infrastructure technologies, intelligent systems, software engineering, human machine interaction and foundations.

Introduction

This submission is concerned with detection and reporting systems applicable to new and established pest animals based on the use of wireless sensor networks.

It provides details of research currently underway to develop detection and monitoring sensor networks for use in the Kakadu National Park and which will track the movement of cane toads as part of a biological control program. The cane toad is a recent arrival that poses a direct threat to many species. While the cane toad's direct threat to agriculture may not be as apparent as its threat to native species the problems associated with tracking the movements of pest animals are comparable.

The use of wireless sensor networks under a deployment strategy that takes account of both techniques in adaptive learning technology and knowledge of pest animals can provide a monitoring solution that is free from the need for extensive human intervention. Moreover, it can provide not only more powerful control data but can also generate significant new knowledge to support ecological research and control objectives.

Wireless Sensor Networks

Established monitoring techniques suffer from two fundamental problems that affect their use in wide area high impact pest detection and control. The first problem is a high level of human intervention. This can hamper any detection strategy if the presence of humans is detectable to the animal under study. Human involvement also introduces physical limitations and scope for human error in observation.

Species monitoring by wireless sensor networks has been undertaken successfully in a study by researchers from the University of NSW. This was based on the use of sound recognition software to undertake a census of native frog species.

The system was based on the deployment of 16 independent sensors (PLEB) that recorded the rainfall, temperature and frog calls. The PLEB comprised a 25MHz Intel 486 central Processing Unit (CPU), memory storage capability, solar panel for power and a microphone. Calls detected by the PLEB were matched against a spectrogram of the unique call for 22 species that were stored on the system.

While the software system used in this study provides an important tool for monitoring the impact of cane toads on native species it is limited in its use because of the cost of each PLEB. More significantly as there is no coordination between the individual PLEBs the system is limited to detection data and cannot be used to infer more valuable knowledge such as the direction or rate of movement for the pest species.

At a cost of $1,000 per PLEB the deployment of sensor networks used in this model over a sufficiently wide area to allow valid biological and environmental study would be prohibitively expensive.

Research Objectives

To overcome these limitations a significantly different approach to sensor network technology must be developed that is capable of satisfying the following objectives:

- track the direction of pest animal migrations
- determine growth and movement of pest animal in a region
- infer the impact on flora and fauna of the pest animal
- establish vocalisation techniques to measure change in predator and prey population and competitors
- pinpoint the regions inhabited by the pest animal to allow appropriate controls to be introduced
- reduce or eliminate human intervention in the tracking process through the development of robust, scalable and long life sensors
- develop and deploy instrumentation that is inconspicuous and will not disrupt the area under observation.

A detection and monitoring system that satisfies these criteria would have wide spread application in pest animal detection and monitoring. It will be particularly relevant to Australia's wide geography.

Cane Toad Detection

The current demonstrator project for a wireless networked sensor system is the deployment of a network of inexpensive lightweight sensors capable of monitoring, tracking and characterising the impact of cane toads in Kakadu National Park.

The ideal system is one that presents the following characteristics:

- supports sensing over a wide area
- energy efficient
- robust in the presence of networking, data transmission and sensing errors
- efficient in data processing
- capable of data storage
- a high degree of detection accuracy
- capability to point the location of cane toads or other pest animal within a required degree of accuracy

To achieve this, sensors must have the capability to sense and interpret information, log data and transmit data to a central facility. In turn the central facility must receive sensor reports that will allow biologists and ecologists to track and monitor the growth and impact of cane toad populations.

The key to the use of large scale sensor networks is in the combination of:

- an effective and efficient sensor deployment strategy
- incorporation of domain knowledge related to the pest animal, including behavioural characteristics (activity periods), rate and manner of movement and preferred habitat into the system

Deployment of Wireless Sensor Networks

A three tiered clustered wireless network deployment was chosen for this application. This comprised:

1. Micro nodes that were light weight, low cost and densely distributed sensor nodes
2. Macro nodes that were sparsely distributed PLEBs because of their higher cost
3. Base stations that were more sparsely distributed than Macro nodes and were the link between the sensor network and the wired network

The sensor nodes were deployed in dense sensor patches that are widely separated. Individual sensor nodes communicate and coordinate with one another in the same geographic region. Sensor patches are typically small compared to the area under survey.

Domain knowledge allows the sensor network to be pre-programmed to be alert or idle according to the behaviour of the cane toads. Detection of the pest animal by vocalisation occurs at the micro node. Each micro node has an effective detection range of 20m.

At the micro node each vocalisation is sampled and a spectrograph created which is matched against the specific characteristics of the pest species. The distinctiveness of species vocalisation allows background noise such as rainfall, wind and vocalisation from other fauna to be disregarded. Where there is a match then the target species location is estimated using techniques known as time division on arrival.

Adaptive Learning

The first deployment of a sensor network of the scale required for monitoring Kakadu national park or a large scale agricultural belt will rarely if ever be correct. To manage this problem a Bayesian network capable of learning from previous deployments is used to adapt successive deployments.

A Bayesian Network is a graphical model that encodes probabilistic relationships among variables of interest and can be used to learn causal relationships and gain understanding of a problem even when all data entries are not known. Through the study of domain knowledge a set of variables relevant to the pest animal are identified. In the example of cane toads these include factors such as:

1. access to water in the near, medium or far vicinity
2. availability of food resources depending on vegetation characteristics
3. transport corridors available to the pest animal including roads, pathways, water and opportunistic travel such as vehicle hitch-hiking
4. influence of climatic variation on behaviour

Using this set of variables the probability of the pest animal being present in a particular location can be established. The probabilities are revised on the basis of sensor detection and the validity of the corresponding variable may change. This evidence is propagated through the network according to an algorithm that distinguishes superior and inferior nodes. As original assumptions and probabilities are revised the deployment can be reconfigured for maximum effect.

Cost

The deployment of a sensor network of the kind discussed here is not without a cost. The direct costs associated with the three tiered network are:

1. Micro nodes which cost a few cents each
2. Macro nodes which cost several hundred dollars
3. Batteries

Technical limitations on the macro node mean that each can support only a limited number of micro nodes and this is a major factor in system cost. To instrument the area of Kakadu some 9600 sensor nodes would be required. While this may appear a large number it takes no account of the influence of the adaptive learning capability.

On a simple direct cost basis the deployment of a tiered system over a region the size of Kakadu National Park compares very favourably with a system based on PLEBs only and is more comparable to the cost of simpler but less effective sensor nodes.

	Cost of Sensors ($m)	Cost of PLEBS ($m)	Total Cost ($m)
Only PLEBS	O	8680	8680
ONLY sensor nodes	4.32	0	4.32
Tiered Architecture	4.32	5.0	9.32

In any deployment the impact of the adaptive learning algorithm on the system would mean that the tiered architecture would require significantly fewer sensors than have been calculated. This is because the system makes more effective use of domain knowledge and benefits from hotspot identification through the adaptive learning technology which is not available in a deployment based on sensor nodes only.

Conclusions

The deployment of a distributed, multi-tiered wireless sensor network for the purpose of monitoring pest animal movement through a regional is feasible and offers better biological/ecological outcomes than traditional methods of pest animal monitoring. Although 90% of Kakadu is habitable by cane toads knowledge of their behaviour suggests that they will concentrate in areas offering better habitat and food resources.

However, even through the reduction of deployment to so-called hotspots significant problems of uncertainty remain. The model developed considered the impact of variables such as water, food, neighbouring zones, transport corridors and seasonal variation. To deal with these influences an adaptive learning algorithm was developed that can identify zones that might be future hotspots. The algorithm allowed the deployment of the network to be updated to improve its effectiveness while bringing down deployment costs.

The approach to sensor network deployment and adaptive learning described above has been developed in a specific application related to pest animal impact on a valuable ecological environment. It is equally applicable to a wide range of similar applications where wide area monitoring of a pest animal is required. The capacity of the system to adapt to environment and habitat variables makes it particularly valuable.

In this study we have focussed on the detection and monitoring of a particular pest animal through vocalisation. The application of sensor networks can be extended to a range of pests using this technique. Further adaptations may use visual identification or some other signature. By linking the sensor network to other technologies the functionality could also be extended from detection to actuation of a control technology.

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