THE INTEGRATION OF WIRELESS SENSOR NETWORKS, REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS FOR AUTONOMOUS ENVIRONMENTAL AND ANIMAL MONITORING

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ABSTRACT

The environment and agriculture issues are becoming extremely important and are facing many challenges. It is believed that wireless Sensor Networks (WSNs), Remote Sensing (RS), and Geographic information Systems (GIS) are three key enabling technologies to address those urgently challenging issues. Although extensive research has been conducted on individual technologies, their seamless integration to solve complex environmental problems has never been done before. This paper provides a provision and design for the multi-disciplinary integrated autonomous monitoring system. The integration will provide a powerful tool for optimal, profitable, and sustainable management of environment and agriculture and thus bring significant scientific and social benefits.

KEYWORDS

Wireless sensor Networks, Animal Monitoring, Remote Sensing, Geographic Information Systems, Data Dissemination

1. INTRODUCTION

Environmental and agricultural issues, such as climate change, water shortages, food safety, and rising food prices have caused serious global societal, economical, and political concerns. Humanity depends on the environment and agriculture for survival. Optimal, profitable, and sustainable management of land and water is critical. These requirements can be better addressed through using the integrated emerging and established technologies of Wireless Sensor Networks (WSN), Remote Sensing (RS) and Geographic Information System (GIS).

WSN is regarded as one of the most important technologies in the 21st century. If we consider the Internet as connecting human beings through computers, the wireless sensor networks will connect human beings with the physical world. With the advances of microelectronics, the intelligent low-cost low-power small sensor nodes can be developed to sense almost anything which is of human's interest (e.g. the phenomenon of hazardous volcanoes and earthquake). A sensor network consists of a large of number of sensor nodes which are densely deployed and connected through wireless links in a self-configured and self-organised manner [1]. Such sensor networks would enable numerous new and exciting applications and bring another technology evolutionary wave to penetrate to every aspect of our lives (e.g. home, health, environment, military, agriculture, transport, manufactory, entertainment).

Environment and animal monitoring is a natural application for WSN. Cheap, smart devices networked through wireless links and connected intimately with the physical environment can enable detailed and localized data collection at scales and resolutions that are difficult or impossible to obtain through traditional

instrumentation. Many networked systems have been successful developed for such applications. These systems have brought significant benefits to the scientific and social communities.

RS is a technology for acquiring and interpreting images from aerial or satellite platforms and can complement WSN to acquire information about habitat and landscape conditions. Through a GIS, we can query, process, graphically represent and analyse the information obtained from WSN and RS. The seamless integration of these technologies will provide an efficient and powerful tool for measuring and understanding the dynamic physical world.

This study takes feral camel management in Australia as a practical example. There maybe as many as one million feral camels in Australia and the population is doubling every eight years. Camels have significant impacts on pastoral production, environment and cultural values. They are Australia's emerging worst vertebrate pest in the desert. There is an urgent need for an effective and practical cross-border camel strategy.

This paper describes a framework for the application of the integrated technologies of WSN, RS and GIS to the study of important environmental and agricultural problems. The system aims to achieve autonomous monitoring of wildlife and livestock animals' movement, welfare and environmental impact in long term, over long distance. The system will provide not only a solid evidence base for the development and delivery of a camel management plan in Australia but also a general solution for the domain of applications in environmental management and animal agriculture. The solution addressing urgently challenging environmental and agriculture issues will bring significant scientific and social benefits.

The paper is organised as follows. In section 2, we give a brief overview on the uniqueness and need for efficient feral camel management in Australia. In Section 3, we describe the framework or architecture for integrated autonomous animal and environment management system. Finally we summarize and conclude the paper in section 5.

2. ENVIRONMENTAL AND AGRICULTURAL IMPACTS OF FERAL CAMEL

There maybe as many as one million feral camels in Australia and the population is doubling every eight years. Camels have significant impacts on pastoral production, environment and cultural values. They are Australia's emerging worst vertebrate pest in the desert.

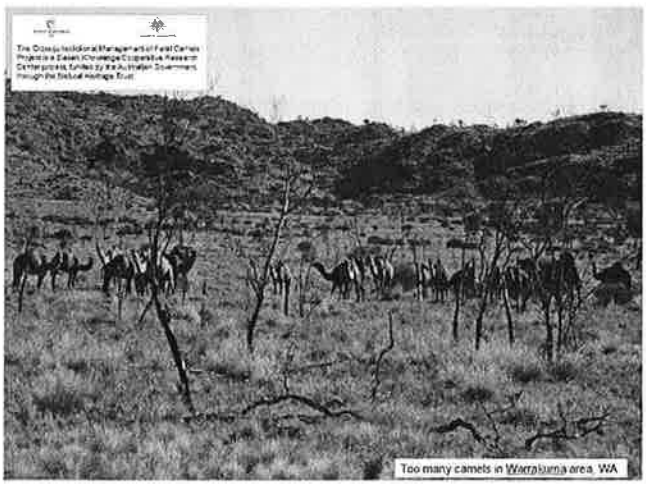

Figure 1. Over-populated Feral Camels in Australia

There is an urgent need for an effective and practical cross-border camel strategy. The Desert Knowledge Cooperative Research Centre (DKCRC) with its nationwide partners developed a project entitled "Cross-jurisdictional Management of Feral Camels to Protect NRM & Cultural Values" for this initiative [2][3].

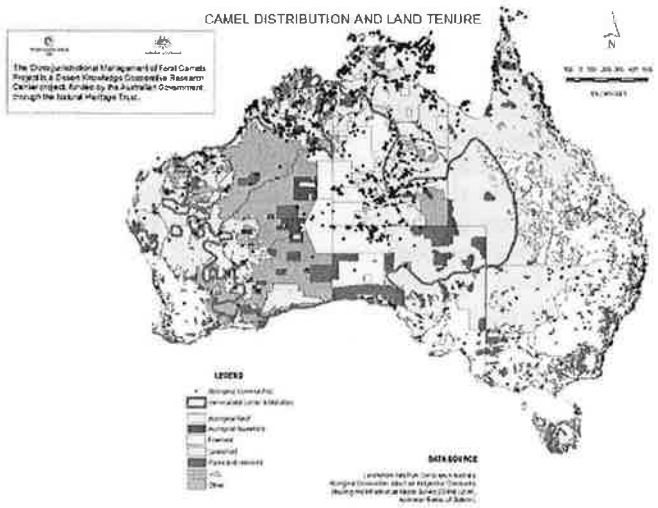

Figure 2. Camel Distribution and Land Tenure

3. DESIGN OF INTEGRATED AUTONOMOUS WILDLIFE MONITORING SYSTEM

To achieve the goals, it's critical to obtain timely and quantitative information of camel's movement, population and impact. However, feral camels have very large population, are highly mobile across a large portion of arid Australia. It is no doubt very challenging to dealing with them using traditional methods. Therefore a new approach utilising new ICT technologies must be developed.

This study aims to jointly use WSN and Geographic Information System (GIS) technologies to develop an innovative embedded networked system, which will automatically monitoring feral camel's movement and distribution in long term, over long distance. The system will provide a reliable and much-needed tool for camel management. The system will not only contribute to provide a solid evidence base for the development of a practical camel management plan but also assist to deliver the management plan. The system includes the two major components:

3.1 Embedded Sensor Devices and Hybrid Networked System

The development of new system will focus on assisting to quantify: 1) the environmental impact of animals (or pests, e.g. feral camels in Australia); 2) impact of climate change (draught, heat) on animals' welfare. It can not only track the movements of a single/group of animals online but also monitor specific behaviour which is relevant to the quantifications. This study will contribute to Australia's economic, social and environmental well being. It will also contribute towards the funding objective of promoting the participation of Australian researchers in strategically focused, leading edge science and technology.

3.2 Application Software for Real-time Visualization and Analysis of Comprehensive Environmental, Geographic and Animal Information

The new software will provide animal scientists with an easy-to-use visualization and data analysis system. It will integrate geographic information, including remote sensing images, topographic and thematic maps as well as information from wireless sensors. Through data processing, the system can visualize, quantify and analyze useful animal and environment information. Such dynamic information may take long time to gather and can hardly keep it frequently updated using any other method. It will significantly improve the efficiency

and capability in monitoring and analyzing animals' behaviors. The system architecture is illustrated in Figure 3.

The system will be built based on NASA World Wind, a virtual globe-based 3D visualization platform for integrating multi-source heterogeneous geospatial data sets [5]. World Wind has integrated a lot of ready-to-use high-resolution satellite images provided by those servers maintained by NASA. These images include a globe low-resolution image Blue Marble built in when the client is installed. High-resolution images such as Landsat 7, MODIS are online served by NASA servers. Supported by SRTM DEM data with highest resolution 90 meters, users can view the mountains and canyons in the whole globe from the sky or simply simulate a long distance flight from anywhere of the earth.

World Wind is an open source software platform. It has two versions developed by Java and C# respectively. High-end users can not only customize the client to a new interface, but also integrate any static or dynamic location-related information, in local machine or provided by a services. World Wind provides integration mechanism with standard Web Map Service (WMS). In this paper, we create a web service of real-time animal information detected by sensor network and this service is integrated into World Wind for visualization and analysis.

Spatial analysis service is built in the system for quantity information of animals' behaviors. For example, given a time interval, the animals' historical moving routes, frequency, velocity, etc., can be analyzed and the result can be overlaid and highlighted on the client's interface. More complex spatial analysis services, such as correlation analysis of the animals' behaviors with the environmental changes, can be customized according to theoretical models.

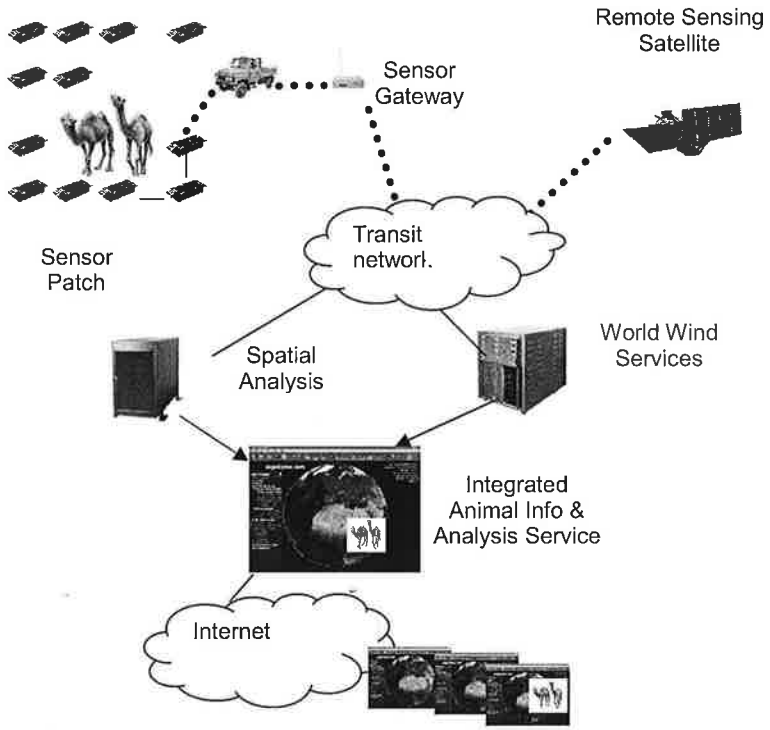

Figure 3. Architecture of Integrating Real-time Animal Information with World Wind

4. CONCLUSION

Through integrating the emerging and established ICT technologies, this multi-disciplinary study aims to develop a practical tool to achieve optimal, profitable, and sustainable management of environment and

agriculture. Through achieving autonomous visualised online monitoring of animals and dwelling environment, the system developed will provide a solid evidence base for environment and animal agriculture management and thus help develop optimal, profitable, and sustainable management plan and practice. It will transform environmental management and animal agricultural industry and bring enormous potential benefits for scientific communities and society as a whole.

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