Knowledge-Based Systems 22 (2009) 552–556

Contents lists available at ScienceDirect

Knowledge-Based Systems

journal homepage: www.elsevier.com/locate/knosys

An electronic tree inventory for arboriculture management

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ARTICLE INFO

Article history:
Available online 9 January 2009

Keywords:
Arboriculture management
Urban-forestry
GPS
GIS
PDA
Thermal imagery

ABSTRACT

The integration of Global Positioning System (GPS) technology into mobile devices provides them with an awareness of their physical location. This geospatial context can be employed in a wide range of applications including locating nearby places of interest as well as guiding emergency services to incidents. In this research, a GPS-enabled Personal Digital Assistant (PDA) is used to create a computerised tree inventory for the management of arboriculture. Using the General Packet Radio Service (GPRS), GPS information and arboreal image data are sent to a web-server. An office-based PC running customised Geographical Information Software (GIS) then automatically retrieves the GPS tagged image data for display and analysis purposes. The resulting application allows an expert user to view the condition of individual trees in greater detail than is possible using remotely sensed imagery.

1. Introduction

Changing land use, causing significant disruption to natural ecosystems, is a result of urbanization and modern farming practices. However, public interests, concerning how these changes affect daily life and limit sustainability for future generations are on the increase [15]. The main reasons for this include the improved air quality and environmental conditions, resulting in increased human wellbeing, associated with woodland areas. As a consequence, tree inventories for arboriculture management are an important tool in cataloguing existing and planned urban and rural environments.

Urban forests can be defined as groupings of trees and vegetation that are located within suburban and industrial areas. Understandably, such enclaves are regularly subjected to the influences of modern life. Restricted growing space and exposure to pollution means that urban trees are often under greater stress than their rural counterparts. These conditions render individual tress susceptible to pests and disease. According to Pauleit and Duhme [9] the subsequent management of such fragile infrastructure is challenging and requires up to date and accurate information. Fortunately, relatively cheap, geospatial tools including GPS and GIS are increasing in availability. Such technologies can form a platform for the recording, analysis, and reporting of arboreal data.

In an urban context a GIS-based method for locating potential tree-planting sites, based on land cover in Los Angeles, has already been introduced by Wu et al. [16]. In their system large, medium, and small trees are virtually planted within a metropolitan area using remote sensed imagery. Greater priority is given to larger trees as more environmental and social benefits are expected to result from them. Distance from impervious surfaces and crown overlap are employed as criteria to identify potential sites. The criteria are realised as decision-based rules that eliminate sites that are either too small or too close to existing infrastructure. Once populated with predicted planting sites, individual trees are counted and estimates of canopy cover are made. The approach is reported as producing improved estimates of potential planting sites than manual methods. Statistics derived indicate that residential land has the greatest potential planting sites while commercial and industrial land has the least. Urban tree analysis is also described by [7] and [3] in the literature.

In a rural context the movement of trees, on sloping land, as a result of continuous land erosion, has been studied by Ramos et al. [12]. In the system described multiple datasets were established using dual-frequency GPS receivers. The first set, consisting of waypoints located on stable ground so that their positions did not change over time, represented a control network. Subsequent sample sets where then captured at the base of individual trees. Once collected, each set was analysed using a commercially available GIS software package in order to establish its relative movement. Results obtained by the group confirm that some of the trees in question move between 2 and 4 cm a year. Importantly, land slope was reported as being between 2 and 5% while the time period between captures was approximately six months in duration. The mechanical tillage of land using modern agricultural practices was identified as a major cause of the phenomena. Carver

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doi:10.1016/j.knosys.2008.10.005

et al. [4] and Nemenyi et al. [8] also describe the analysis of trees in rural environments.

In this paper, electronic arboriculture planning and management is achieved using a GPS-enabled PDA, web-server, and open source GIS software. The adding of a dynamic layer facility to an existing GIS package means individual maps can be populated with accurately positioned waypoints linked to actual tree images. As a consequence, the application developed provides more realistic estimates of tree position than have been achieved using traditional arboreal assessment methods. Such methods include onsite visual inspection by a trained arboriculturist as well as remotely sensed imagery. The capture and interactive segmentation of thermal images described here is designed to provide a general assessment of individual trees health. The motivating factors for the adoption of such a machine intelligence approach, by agencies responsible for arboriculture maintenance, include reliability and the reduction of expensive labour costs.

2. Laptop data capture

To capture position data, a Mio™ A701 PDA with built-in GPS antenna has been attached to a laptop by means of Universal Serial Bus (USB) port. Conveniently, USB and FireWire ports allow connection to and the capture of images using a range of camera types. A direct connection between PDA and web-server is possible, however, the degree of pre-processing of image data required for transmission by this method was considered too computationally intensive. Therefore, whenever available, data is sent via the laptop by means of wireless network. If outside wireless network range, the laptop represents a convenient storage medium which can upload data when connection to a network is available. At present the capture of images requires mains electricity, however, portable generator or battery can be employed.

GPS coordinates are determined at the moment of image capture and represent latitude and longitude in degrees, minutes and seconds (DMS). Before being combined with image data, the DMS coordinates are transformed into Ordnance Survey British National Grid (OSGB) Easting and Northing. This is required because planet Earth is not a perfect sphere (the distance between poles is less than the distance across the equator) and accurate maps are based on the ellipsoid shape. Once transformed into the Airy Spheroid ellipsoid on which OSGB maps are based, individual tree locations can be plotted on maps that accurately describe the United Kingdom. The transformation between coordinate systems is achieved using the 7 parameter Helmert transformation described by [2].

A typical example of input to and output from the PDA is given in Table 1. As DMS cannot be converted directly into OSGB an intermediate coordinate system, decimal degrees (DD), is employed. Conversion between DMS and DD is achieved using Formula 1 and 2.

$$D_{\text{Lat}} = D_{\text{Lat}} + \frac{M_{\text{Lat}}}{60} + \frac{S_{\text{Lat}}}{3600} \tag{1}$$

$$D_{\text{Long}} = D_{\text{Long}} + \frac{M_{\text{Long}}}{60} + \frac{S_{\text{Long}}}{3600}. \tag{2}$$

Table 1
Example of DMS to OSGB conversion.

Form	Latitude	Longitude
Degrees, minutes and seconds (DMS)	52° 54′ 42.039″	−1° 11′ 2.172″
Decimal degrees (DD)	52.912	−1.184
Ordinance Survey (OSGB)	454,914 (Easting)	335,226 (Northing)

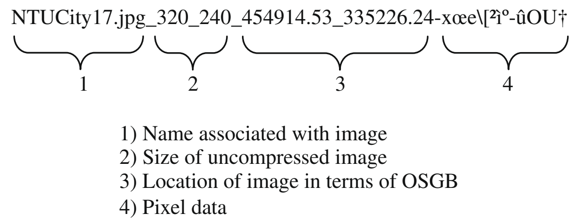

Fig. 1. Message format adopted for position and image data transmission.

Once transformed into the OSGB reference system, the resulting position information and raw type image data is formatted into a string. Fig. 1 illustrates the message format adopted.

Compression and decompression of image data, in order to reduce the length of individual messages, is provided by means of the zlib library [18]. Although the compression of image data has its own computational expense, its inclusion keeps the overheads of transmission between laptop, web-server and desktop application to an absolute minimum. Understandably, messages remain compressed whilst on the web-server and are only decompressed when retrieved by the desktop application. By saving images to the host laptop's hard drive, a user is given the opportunity to view captured images. As a consequence, poor quality images can be deleted before compression and transmission to the web-server.

3. Web-server application

The web-sever represents an interface between laptop and desktop applications. Based on the .NET framework, the web-server provides set and get services. Both set and get services make use of files saved to the web-server's hard drive. The set service allows the laptop application to add new records. Uncompressed records are appended to a text file while compressed records are appended to a data file. The get service, in contrast, allows the desktop application to retrieve records from the end of a file. If an error occurs during either the setting or getting of a record, an error flag is sent to the calling laptop application. The central storage of records using a web-server means that multiple data capture applications can run concurrently.

4. Desktop GIS application

To view and query captured tree data, a desktop application based on the Quantum GIS (QGIS) open source project [11] has been developed. A GIS application was chosen over a web-based application due to the former's ability to query layered data and spatially represent multiple layers within the same application.

Modifications made to the QGIS application are shown in Fig. 2. It was decided to employ an open source platform, as mainstream GIS applications are expensive commercial software. Access to source code also meant modifications could be made easily. The QGIS application represents mapping software that can be used to create, visualise and query geospatial information. A Windows distribution of the software was chosen because of its compatibility with existing institution software. It was also anticipated that intended users, arboriculturists, would be more comfortable with the Windows environment. Although the installation of QGIS is extensively documented, a number of technical problems were encountered. These problems were found to be a result of a conflict with the GNU parser generator package [1].

As illustrated in Fig. 3, to access dynamic layer functionality a range of new buttons and icons based on existing styles were constructed by the authors and integrated into the QGIS open source application. The new methods are grouped into a dynamic layer