The Location and Positioning of Buried Pipes and Cables in Built Up Areas

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SUMMARY

There are currently more than four million kilometres of underground cables and pipes in the UK alone — a combination of water, sewer, gas, electricity and drainage. It is estimated that there are 1.5 million holes dug every year on UK highways and footpaths by utility companies so they can install new services and maintain existing ones.

In the UK, many of today's 'buried water and sewerage assets' were laid during Victorian times (up to 200 years ago) when accurate records of the location and depth of each pipe were not kept. Every time a company digs a hole it runs the risk of hitting one of these pipes, causing disruption to drivers and customers, or a live power cable, which in some cases can prove fatal for workers. Further to this, up until recently, the recording of the utilities' location was not carried out in an accurate or methodical manner.

Locating these underground assets is currently hit and miss — ground probing radar is widely used with some success but is slow and not reliable to the depths required, particularly in the UK's clay soils, and cannot locate newer plastic pipes.

Researchers in The University of Nottingham's Institute of Engineering Surveying and Space Geodesy are part of a £1 million, multi-partner four-year research programme called Mapping the Underworld, funded by the Engineering and Physical Sciences Research Council aimed at developing new solutions to solve these problems.

The initiative, involving seven universities across the country and support from industry, will develop new ways of detecting pipes and collating information from various sources on the location of underground utilities.

The academics at The University of Nottingham have been awarded a share of the funding to focus on how satellite technology could be used to access information on where utilities are buried and provide an accurate location to workers on the ground.

To work effectively, GPS technology needs to be able to make contact with four to five satellites orbiting the earth to obtain accurate co-ordinates — this can be a problem in built-up areas where large buildings and other obstructions can block the signals.

The IESSG will be researching how GPS can be integrated with other systems such as inertial navigation, pseudolites, locatalites, GSM, and GPS integrated with total stations in order to provide a reliable and accurate solution. Further to this, simulation software developed at the IESSG will be used to predict the future performance of a combined GPS, Galileo and GLONASS approach in such a difficult working environment.

In a separate £2.4 million project, funded by the Department of Trade and Industry, Nottingham researchers will be working with colleagues at Leeds University and other industrial partners.

The research will involve looking at the feasibility of producing a mammoth subterranean map of the UK, which would show where all of its buried assets are located.

The Nottingham researchers will be looking at how information from this map could be accessed by devices mounted on to machinery such as mechanical diggers, so utility workers could ensure they are not digging near to pipes or power cables before starting maintenance work. The research will also look at the use of 'augmented reality' technology, similar to 'virtual reality', which would overlay a computer-generated image of the utilities on the ground, so workers could 'see' where they are buried.

The following paper gives an overview of the work carried out to date as well as the vision of the research.

The Location and Positioning of Buried Pipes and Cables in Built Up Areas

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1. INTRODUCTION

In the UK, there are currently approximately 4 million kilometres of buried pipes and cables providing utility services. These are a combination of telecommunications, water, gas, sewerage, electricity and drainage. It is estimated that there are 1.5 million holes dug each year in the UK on highways and footpaths by utility companies so that they can install new services and maintain existing ones. This is in addition to road building and repair work carried out by the Highways Authority.

Over the past 25 years, the UK has seen an increase in traffic of 72%, with an increase in cars on the road of 14 million from 10 million in 1972. In addition, the amount of freight carried on the roads has increased by 69% since 1980. Latest Government figures forecast that road traffic will increase by about 40% over the next 20 years.

Congestion is an everyday part of our lives, and has many causes. Busy roads are very sensitive to small disturbances, such as accidents, weather conditions, traffic volume and road works.

One answer to enable these pipes and cables to be located is to map them on absolute terms e.g. using GNSS. This is simple enough for new pipes and cables being laid, but difficult to do so for those already underground. The combination of location devices such as GPS with detection devices such as Ground Penetrating Radar, Acoustics, and quasi-static fields is a way forward. In addition to this, the use of knowledge integration and pipeline-ground interaction can all add up to a combined system allowing the location of such utilities to become reality. However, this will be a mammoth task considering the amount of utilities in existence.

The following paper outlines two projects funded in the UK aimed at tackling the above issues, and focuses on the positioning aspect, and the ideas to be used in making GPS and future GNSS work in built up areas where the majority of utility location is an issue.

2. THE UTILITIES

Many utilities in the UK were laid in Victoria times when demands due to economic boom were large, with pipes in older cities being greater than 150 years old. Poor mapping techniques, and recording the pipe's location relative to a physical feature that no longer exists means that the exact location many of today's networks are unknown. In particular, their position relative to other pipes and cables.

In addition to this, many records do exist, but in a number of formats such as paper based, microfiche, and digital. Furthermore, the records that do exist are sometimes in-compatible between various companies, hence being able to position one company's pipes relative to another's cables is difficult.

Today, there is another boom in cable laying. The Government is actively promoting the use of broadband within the general population. Again, the fibre optic cables required for this are vast. Today there is well over 3 million km of fibre optic cables laid under the streets of the UK.

In 2001, the UK Government announced the target to have the most competitive and extensive broadband market in the G7 group of countries by the end of 2005. The DTI has commissioned research to benchmark the progress of the UK against the other G7 countries (Canada, France, Germany, Italy, Japan, UK and the USA), and also Sweden, Ireland and Australia [dti, 2006].

The UK currently has the most extensive broadband infrastructure in the G7 group of countries, with over 97% of households and businesses now able to receive broadband. BT announced in summer 2004 that it expects availability of broadband to rise to over 99% by the end of summer 2005. There are over 6 million subscribers in the UK and there are around 60,000 new connections each week [dti, 2006].

Many utilities are reaching the end of their design lives. National Grid Transco, for example, has a programme to replace all their iron mains within 30 metres of properties over the next 30 years [HSE, 2006]. Thames Water will replace more than 1,600 km of iron mains in London over the next 5 years.

The utilities companies are being pushed by the customers' demands. It is now difficult to place more utilities into the tight space under the streets of some of the older cities without the risk of damaging those already in place.

The increasing use of plastic pipes, however, is making detecting the utilities through geophysical techniques even more difficult.

It is common practice to dig a series of trial holes in order to locate the utility required, then to come back some days later to excavate the actual trench. This causes extra disruption as well as excavation costs.

3. ECONOMIC DISRUPTION

Due to the inaccurate data and location knowledge of buried pipes and cables, more excavation is carried out than would be required if the coordinates of these buried utilities were known. This is true for excavation as well as trenchless technology. The majority of utilities, in particular in built up areas, are buried beneath the roads. Therefore disruption and congestion is inevitable when excavation occurs. Due to the use of trial holes to find the utilities in the first place, and the fact that other utilities are sometimes damaged during the excavations, accurate knowledge of the locations of such utilities would be of great benefit.

This would reduce the direct, indirect and social costs associated with excavation. The social costs of congestion in the UK alone are estimated to be between £2 and £4 million per annum.

Further to this, the direct costs of trenching and reinstatement of approximately 4 million street openings per annum is estimated at approximately £1 billion per annum, and indirect costs of £3 billion per annum. From June 2008, the Traffic Management Act will require all with underground assets to give digital (GIS) asset location data on request [DFT, 2006].

Overall, the lack of real-time accurate knowledge of the utilities' location results in increased number and size of street openings, or of longer duration with an undesirably high number of "hits" on third party assets, over and above those caused by poor practice.

4. MAPPING THE UNDERWORLD

The UK's Engineering and Physical Sciences Research Council (EPSRC) announced in 2004 that it was establishing a programme as an initial attempt to start tackling the above issues. It organised a "sandpit" exercise, whereby invited academics, industrialists and EPSRC all got together in the Autumn of 2004 to think of ideas that could be put forward as research projects. The EPSRC put £1 million into the programme, and as a result four projects were funded, there being;

- Buried asset location, identification and condition assessment – a multi-sensor approach.
- Mapping and Positioning.
- Knowledge and Data Integration.
- Enhanced Methods of Detection of Buried Assets.

Further to this, a network programme was also separately funded;

- Mapping the Underworld Network.

The above projects bring together academics from Universities in Bath, Birmingham, Leeds, Nottingham, Oxford, Sheffield and Southampton. In addition to which, industrial companies, notably UK Water Industry Research (UKWIR) are also heavily involved with the projects.

The overall work will last for 4 years, and started in the Summer of 2005. In addition to the research work, the projects will organise workshops on regular basis in order to disseminate the findings and ideas. The project has a web page www.mappingtheunderworld.ac.uk, and further details about the work may be found here.

The overall aim of the project is to investigate the feasibility of several novel approaches, alongside greatly enhanced existing approaches, to be combined in a single multi-modal approach to the location, identification and condition assessment of buried assets. These include developing Ground Penetrating Radar, Acoustic, Quasi-static field techniques, interaction of the soil in previously excavated areas as well as the interaction of the soil with the utility and integrating their combined information with the location of the data. The devices will be surface based, whereby a suite of sensors will sweep across an area, as well as being pipe based, so that the sensors are taken through a water pipe and the surrounding utilities detected.

4.1 Mapping and Positioning

The overall objective of this sub-project based at the University of Nottingham is the research and development of a prototype positioning system to conduct precise 3D positioning at a centimetre level, using pseudolite and Locatalite transmitters, currently available commercial GNSS technology and GNSS simulators developed and available at the IESSG. A suite of algorithms and a software package for the data processing and simulation of GPS, Galileo and pseudolite measurements will be researched and developed. System validation will be conducted at Nottingham, as well as field trials with the remainder of the project teams.

The accuracy, availability and reliability of satellite based positioning are very dependent on the number of tracked satellites and their spatial geometry [Santerre, 1991]. One of the limiting factors in using GPS is the requirement of having direct line of sight with the satellites themselves and the GPS receiver. Most of the mapping of the “underworld” will be based in built up areas where line of sight to a sufficient number of satellites is not always possible. In addition, the presence of trees, as well as buildings, can cause masking issues, as well as introducing multipath errors.

This part of the project will research various means of improving the position availability, integrity and precision through a GPS based system, augments with other systems such as Galileo, GLONASS, INS, Locatalites and pseudolites. The reliable and accurate positioning of the overall system is an underpinning issue.

The overall aim of the project is to investigate the feasibility of several novel approaches, alongside greatly enhanced existing approaches, to be combined in a single multi-modal approach to the location, identification and condition assessment of buried assets.

5. VISTA

A second project called “Visualising Integrated Information on Buried Assets to Reduce Streetworks” (VISTA) has recently been funded by the UK’s Department for Trade ad Industry (DTI). This project brings together the University of Nottingham and University of Leeds, as well as UKWIR and 18 other organisations, including various utility companies, professional organisations, excavation companies and survey companies.

The research planed for this project focuses on enhancing and integrate existing legacy asset information, together with dynamically acquired accurately geo-referenced data in the street and develop novel techniques to display the resulting knowledge to digging teas and network planers.

One such visualisation idea is to use Augmented Reality. This was developed at the University of Nottingham as a means of visualising underground data such as utility location [Roberts, et al. 2002]. However, the visualisation is only as good as the source data, so if the source data is inaccurate, then the utility will be visualised in the wrong place. Such a high-tech AR system could give the excavator a false sense of accuracy, and he may well excavate without caution. Therefore, the accuracy, and an indication of the accuracy to the user, of such data is vital. Figure 1 illustrates a screen shot from an AR device used in the Yorkshire Water region [Evans, et al. 2003].

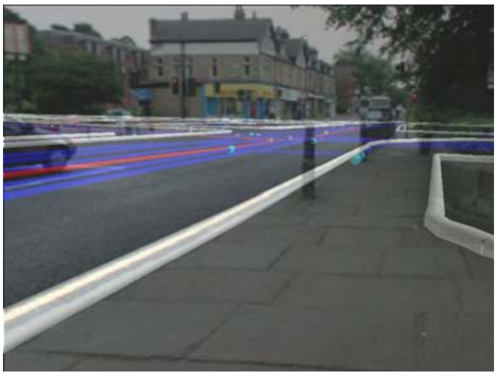

Fig. 1 A screen grab of the AR system used in Headingly [Evans, et al. 2003]

6. CONCLUSIONS

This paper has given an overview of two projects underway in the UK trying to tackle the issue of not having accurate information about the location of buried utilities. These projects are in their infancy, but the paper tries to make the reader aware of the issues raised, and possible direction to tackle the problems.

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BIOGRAPHICAL NOTES

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