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A New COST Action: Autonomic Road Transport Support (ARTS) Systems

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Mobility of people and goods is a key challenge for the future. Transport is one of the world's largest industrial sectors, yet challenges and frequent failures of road transportation networks are well known, with the cost of congestion alone estimated at Euro 100 billion in the EU[1].
Systems of road traffic flow are affected by the outcome of individual driving decisions, often assisted by personalised navigation and information-providing devices. This combined with the complex topology of the network and the random occurrence of capacity reducing events make for a complex system. Within this system control centres utilise a range of assets (traffic signal, variable speed limits, re-routing etc) to help optimise the flow of network traffic with respect to a range of rules, regulations and policies relating to efficiency, safety and environmental criteria.

Over the past 30 years or so, ICT has been applied with a certain amount of success by highways authorities and urban traffic controllers to support traffic management. The application of ICT to Transport has led to what is termed Intelligent Transportation Systems (ITS), though these systems generally do not embody intelligent properties in the AI sense. There have been some use of AI in traffic support [2], for example the application of ANPR in number plate recognition, or the use of A*-inspired algorithms in routing algorithms. Most notable is the widespread success over the last 20 years or so of adaptive traffic light algorithms, for example in SCOOT systems (http://www.scoot-utc.com/). These systems sense traffic flow and adapt signal control plans for collections of traffic lights in order to optimise traffic flow through junctions. In general, stakeholders in the traffic support area (consultants, equipment suppliers, transport authorities) have embraced new developments in ICT, and are well disposed to the deployment of AI techniques. Further, the level of interoperability and data representation is relatively high compared to some public sectors, and is characterised by the widespread use of the “UTMC” (http://www.utmc.uk.com/) by local authorities in the UK. UTMC is essentially an interface specification at the relational database level for data interchange, used to connect up the wide range of data flowing through control centres.

Road traffic controls and surveillance systems can be viewed as forming large scale, heterogeneous, control systems, complicated by the dependencies on human behaviour. To effectively “manage” or enable the “optimisation” of such a socio-technical system is a daunting task, exacerbated by rising public environmental and operational expectations. Recent technological advances (eg novel ramp metering control, variable speed limits, surveillance interpretation, and road user information systems) have led to incremental improvements in the performance of road transportation networks; taken as a whole, however, the effect is more management controls, more surveillance data, and more complex and demanding goals than current operator-centric systems can manage. Quite apart from the ability for trained human experts to make informed decisions and plans in such complex, real time systems, the cost of configuring, managing and them is enormous. Current and planned related EU initiatives in areas such as “Smart Cities” appear to make even greater demands on IT, and in particular demand complex, intelligent software-intensive systems within their infrastructure.

A recently-approved COST (European Cooperation in Science and Technology) Network on Autonomic Road Transport Support (ARTS) Systems is being set up to explore the potential of embedding "autonomic" properties into the design of transportation systems. Autonomic Computing was launched around ten years ago by IBM [3] and can be viewed as a challenge to embed desirable self-managing intelligent properties into large systems to cope with the problems of their inherent complexity. The potential benefits of autonomic systems are in helping solve the core problems of engineering road transport support (RTS) systems: their costly configuration and maintenance, high operating complexity, suboptimal operation, and the problem of embedding and maintaining safety and environmental conditions within the operational parameters of the controlling system. Autonomic Computing integrates ideas from several areas of AI including automated reasoning, machine learning and automated planning, and implementations often draw on distributed AI technologies such as intelligent agents.

There has been little research into the many challenges of implementing autonomic behaviour in transportation systems, and what has been done has been carried out in a range of fragmented research areas. Some recent pilot studies concerning RTS technologies use agent-based technology [4,5,6,7]. Utilising a more centralised notion of self-maintenance, theory refinement algorithms for automatically evolving a requirements model of air traffic control criteria was developed in work sponsored by the UK NATS [8]. Concentrating on self-organization is the focus of “Organic Computing”, a large cooperative research effort sponsored by the DFG [9]. Its goals are the development and control of emergent and self-organising technical systems. In the area of Organic Computing several projects have investigated the feasibility of adaptive, intelligent traffic light controllers and their ability to self-organise, e.g. to form progressive signal systems [10].

The challenge of embedding autonomic properties into RTS infrastructure is great, and will be tackled effectively only if a co-ordinated, continent-wide set of experts can be mobilised. The Action will initially focus on community building: with an initial start of 31 member institutions representing 14 countries in Europe, it will explore the application of AI techniques to large, complex control systems, in particular those techniques with the potential to embody autonomic behaviour in systems supporting road transport. Research in related disciplines tends to follow one paradigm or be embedded within one particular framework. The primary focus of the COST Action will be to provide the scientific environment for a concerted effort towards the analysis and development of techniques for engineering autonomic behaviour in RTS systems. Surveying the literature on Autonomic Computing, there are a range of architectures and techniques used both from Computational Intelligence area and from classical AI. Hence the Action will encourage research groups to consider a range of architectural approaches, taking into account the heterogeneous, embedded, spatially distributed nature of the area, and the enormous amount of data and knowledge that RTS systems currently have available. Embedding autonomy into a system requires building into the system the semantics of its own functions, so that it can have some measure of self-awareness. The idea of embedding meta-data within systems is now well established and is fundamental to the development of the semantic web and its associated service-oriented and semantic technologies, as well as the widespread use within the scientific community of ontology and supporting tools. Hence, a major theme within Network is how to harness service-oriented and semantic approaches to enable such behaviour as dynamic system configuration from primitive components. For example, how can current ITS technologies be “wrapped” into services that can be subject to automated assembly and control, in response to high level traffic policies? The benefits of this approach are that it hides the complexity of individual components (and makes them easier to maintain), while allowing new or changed high level policies to automatically deliver new and alternative mixes of control services.

The ARTS Action includes experts from several areas of computer science, engineering and mathematics, to bring together those with complementary backgrounds. With a focus on architectures, methods and models for ARTS, the Network will build on past research and development within ITS, and lessons learned from previous pilot studies in AC, to provide insights into appropriate platforms and methods for engineering ARTS systems. The Action will organise workshops, industrial-facing seminars, training schools. and develop a road map and demonstrator systems in order to build up the critical mass of a research community.

While intuitively appealing, resources aimed at embedding autonomic properties into systems still require a business case, or an objective argument for who will benefit from ARTS, and in what measure. The Action intends to identify and quantify the scope, nature and potential pay-off with respect to financial, environmental and safety criteria, and look at the overall question of return on investment of autonomic systems within the transport area. Some transport areas may be considered more naturally amenable to autonomic techniques, such as local and regional control centre planning support, and real time traffic control. Applications such as automated incident detection may be considered as more problematic, as human judgement may always be superior in determining causes for alarm. Other applications, and emerging technological and organisational ideas, such as cooperative and infrastructure systems, vehicle to vehicle enabled traffic support and demand management, need to be investigated from an ARTS standpoint. One particularly vexed question is that of the wider implications of the introduction of self-managing systems with respect to national legal and regulatory frameworks for Transport, and EU legal frameworks. For example, issues of liability need to be considered in the context of whether and in what way future ARTS systems might limit human intervention.

Another interesting perspective that the Action will explore is from a Human Factors viewpoint. The era of personalised information systems for road users makes it necessary for road traffic support systems to take into account road user reactions, and anticipate road user adaptation to controls. Investigation of participatory and mixed-initiative systems, where a human operator is in the loop, will need to be investigated. Wherever the interface occurs, it will be set at a high level: the owner sets out goals, policies or service levels that the system must follow, and the system translates these into its system functions resulting in a change of behaviour. Hence, where and how the Human is interacting with an autonomic system is a crucial issue. What kind of behavioural responses and issues will autonomic systems provoke? This is tied up with the issue of identifying the scope of potential application of autonomics: for example, do self-managing properties apply to all the controlling embedded software systems, or do they encompass the integrated hardware and software as well?

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