EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

Exploratory Workshop Scheme

Standing Committee for Physical and Engineering Sciences (PESC)

ESF Exploratory Workshop on

FOUNDATIONS OF AUTONOMIC COMPUTING FOR TRAFFIC MANAGEMENT SYSTEMS

Durham (UK), 14 – 16 April 2010

Convened by:

Dr. Apostolos Kotsialos[1], Professor Margaret Bell[2], Dr Haibo Chen[3], Professor Lee McCluskey[4] and Professor Omer Rana[5]

[1] School of Engineering and Computing Sciences, Durham University, UK
[2] Dep. of Civil Engineering and Geosciences, Newcastle University, UK
[3] Institute for Transport Studies, Leeds University, UK
[4] School of Computing and Engineering, Huddersfield University, Huddersfield, West Yorkshire, UK
[5] School of Computer Science, Cardiff University, UK

SCIENTIFIC REPORT

1. Executive summary (approx. 2 pages)

In this workshop, eighteen (18) participants from ten (10) European countries came together to discuss the perspective of using the autonomic computing (AC) paradigm for the design of traffic management systems. The meeting was organised by the School of Engineering and Computing Sciences of Durham University and was held at the premises of Gray College at the Holgate Conference Centre. Accommodation for the participants was provided by Collingwood College, which is walking distance away. The meeting was held from Wednesday April the 14th to Friday April the 16th. Presentations were given on the first two days of the event. The third day was dedicated on discussing potential collaborations and research directions.

The venue provided an excellent environment for academics from computer science and traffic engineering to interact and exchange ideas. The workshop's administration was delegated to Event Durham, which is a Durham University organisation set up deliberately for handling efficiently events like this. Indeed, the delivery of support services from Event Durham provided a comfortable environment that allowed participants to focus on the tasks at hand. One negative event that affected the workshop on the afternoon session of the 15th and the morning session of the 16th was the volcanic eruption in Iceland which resulted to prolonged disruption of travel due to the closure of the European air space. This was particularly pronounced in the UK, for which air travel is the main mode of international transport. The participants had to make new travel arrangements as soon as possible booking other means of transport. The wireless network facilities provided in the conference room proved valuable and supported the participants' efforts. The morning session of the 16th was less affected, as the situation became clearer. Furthermore, two of the participants, Dario Ticalli from Italy and Shantenu Jha from the USA, did not make it to Durham because of the air space closure. The volcanic eruption did have a negative impact as it took precious time of concerned and stressed effort to find alternative ways of return trips.

The workshop itself focused on one of the main problems that modern day system operators are faced with, that of increased complexity of the administrative and decision making tasks. Diverse and heterogeneous software/hardware systems require highly complicated operational procedures. The difficulty of administrating large systems in an efficient, safe and timely way is compounded by the need to implement high-level policy requirements, which have to be elaborated and applied at the lower system level. As a result of this growing trend, the real-time requirements, most often than not, surpass the operator's human capabilities. The intrinsic difficulties of management of large and complex systems, has lead Computer Science (CS) to propose the Autonomic Computing (AC) concept.

The AC paradigm lends itself from the field of neurophysiology and more specifically from the Autonomic Nervous System (ANS). The ANS is responsible for the vegetative functions of the body, such as hormone secretion and blood flow regulation. In the case of the human body, the autonomic elements are responsible for the involuntary decisions made, while in the AC paradigm, they are responsible for decisions made at a higher policy level. The role of the human operator/manager is that of providing mission critical statements and success performance criteria; subsequently, the autonomic system takes the appropriate actions by self-configuring and self-optimising to meet the policies efficiently, and by self-healing to maintain and sustain the policy in view of changing conditions and context.

The control/information actions in the context of traffic management are a result of the understanding of the network conditions, as they are captured in the information relayed by the road sensors, and the translation of the objectives, policies, regulations and procedures operators must follow. It is human intelligence that intervenes, or expected to intervene, between the high level layers to the lower level of control actions, either in an anticipative or reactive manner. It is exactly at this point where the vision of autonomic transport systems comes into the fore. As the number of sensors, sophistication of control/information devices, and network spatial extension, increase from the one side and operator user needs becomes more diverse and complex, on the other, the AC approach to system design and development provides an answer for future traffic management systems. Thus, one of the main objectives of the workshop was to bring together experts from the fields of AC and traffic engineering to discuss ways autonomics can be used to tackle traffic flow problems.

The programme was structured in such a way so as to facilitate the interaction of the researchers from the two communities. In both days principles, case studies, tools, methods and problems encountered on both areas were discussed for the mutual benefit of researchers from these two areas. In other words, there was an effort to provide the background of traffic engineering and autonomic computing to the participants so as to blend and initiate cross-discipline understanding. The second day was concerned with more detailed discussions on traffic and transport management problems and how autonomics can be used to address them. In the morning session of the 16th (third day), there was a wider discussion on how to come up with concrete plans for further research collaboration and opportunities available. A preliminary task allocation for pursuing specific avenues was agreed.

The workshop's agenda included

- The articulation of the autonomic traffic management systems vision as a subject of further research and development.
- The identification and prioritisation of elements/applications in the Traffic Control Centre (TCC) that may become autonomic.
- The design and development of a roadmap for achieving the autonomic properties for those TCC components.
- The suggestion of interdisciplinary research projects directions.

It also aimed at identifying ways of using advanced modelling, control, optimisation, data processing, identification and prediction methods within the autonomic systems design approach exploiting the substantial and extensive work that has already been performed at a national and European level.

The overall conclusion was that the emergence of new technologies in terms of knowledge based systems advantages and of personalised hardware devices has created an opportunity for the development of traffic management systems that are able to adapt to both traffic conditions and changing user requirements hiding at the same the complexity of the associated decision making processes from network operators and road users. Hence, there is a general need to drive the development of traffic control, demand management and surveillance systems both from the bottom-up and from the top-down point of view towards novel design approaches that will endow those components with self-* autonomic properties.

2. Scientific content of the event

The meeting opened with the welcome and presentation of ESF by Apostolos Kotsialos of Durham University. Subsequently the following presentations took place (they are available at the site http://www.dur.ac.uk/autonomic.traffic/workshop.htm).

- The first technical presentation was given by Lee McCluskey and had the title "Background to The ARMS Working Group", which aimed at providing information on the previous effort of the informal research group that has initiated the discussion on autonomic traffic management systems in the UK. The motivation behind the ARMS group was summarised and the key drivers towards autonomic traffic management systems were discussed. These include the fact that there are many different systems in the UK with low level of interoperability, lot of management, software maintenance and configuration problems exist in deployed systems. Network operators suffer from information overload and reduced situation awareness. Therefore, the perspective of developing self-aware autonomic traffic management systems is particularly appealing and timely. In computer science language, this calls for systems that are not just reactive, but deliberative. Recent advantages in goal directed planning, semantic services and ontological engineering allow for the design of novel and innovative systems.
- Omer Rana gave a presentation on the "Principles of Autonomic Systems Design", which provided the context of autonomic computing and its comparison with other systems design approaches. It was argued that current programming, methods and management tools are inadequate to handle the scale, complexity, dynamism and heterogeneity of emerging systems. Hence, the need for self-configuring, self-healing, self-protecting, decentralised and heterogeneous architectures that can support autonomic system design. The goal of autonomic systems design is to build self-managing systems that address these requirements using high-level guidance, driven by more general policies. Two approaches for engineering self-adaptive properties were identified. The top down approach, whereby the overall system goals need to be achieved through the modification of interconnectivity or behaviour of system components and is realised through a system manager. The bottom up approach where the system components' local behaviour needs to be aggregated, without the intervention of a centralised system manager, in order to generate some overall system behaviour. It was agreed that real life applications are based on a mix of these two approaches. A coupled data fusion simulator based on autonomic systems design was presented as a case and analysis and its relevance to traffic management was discussed.
- Apostolos Kotsialos gave a presentation entitled "Traffic Management Needs and Perspectives". This presentation was for the benefit of participants with computer science background. The different types of road networks were presented (urban, motorway and mixed) along with the traffic management infrastructure in use, i.e. the Traffic Control Centre (TCC). The TCC's structure was analysed for its different subsystems that reside within it and outside at the field. The traffic surveillance and traffic control problems were briefly reviewed highlighting related issues in order to illustrate how they are embedded into the traffic control loop. A review of enabling emerging technologies was given along with possible broad directions of research. Two possible directions were identified and put forward for discussion: a) the deployment of autonomic systems with reference only to the IT infrastructure used by TCCs and b) the use of autonomic systems design principles as a paradigm for developing novel traffic management systems. These two directions are bound to cross each other, especially with the use of new personalised technology for traffic management purposes. A number of issues to be resolved were identified pertaining to the meaning of self-* properties for each particular system and high level policy disaggregation to meaningful sets of actions. Finally, the anticipated differential advantages of autonomic traffic management systems were discussed. These include complexity hiding, policy-centric operation, efficient use of resources (computing and

traffic), optimised adaptation to changing conditions and requirements, and ability to reason with system internal dynamics and the environment.

- Lee McCluskey gave a presentation entitled “Autonomic Traffic Systems: A Case Study”, which was concerned with the use of artificial intelligence for air traffic control. Based on available knowledge sources (training manuals, operational manuals, software tools and documentation, air traffic control personnel etc), part of the system requirements were encoded. These were to maintain separation between aircraft over the Atlantic Ocean in an expressive, structured logic, which contained related knowledge (airspaces, time, aircraft spatial positions, etc). The kernel of this specification was written using logic axioms. The main outcome of this work was related to validation and maintenance of Complex Theories (ontologies, domain models and formal specifications) which require automated tool support to identify bugs and help remove them. Such “theories” are not written like programs to allow systematic testing but are designed to decrease the semantic gap between a model and what is modelled. This approach has showed the potential for automated refinement/maintenance/configuration, assuming system knowledge is encased in a theory, i.e. the engineering of autonomic self-* properties.
- Ivana Dusparic gave a presentation entitled “Multi-Policy Optimization in Decentralized Autonomic Urban Traffic Control”. Its purpose was to introduce decentralised autonomic systems based on multi-agent self-organisation. Such systems are able to manage themselves guided by high-level policies without central control or a global system view (bottom up approach). Global behaviour arises from local actions and interactions between agents. Because of the dynamic nature of the operating environment, not all possible behaviours can be predefined and actions pre-empted. Hence, learning needs to be incorporated in the system architecture, such as reinforced learning. This allows for heterogeneous multi-policy self-optimisation using heterogeneous agents for conducting operations. The urban traffic control problem (junction control) was considered as an example of this approach. Q-learning, W-learning and Distributed W-learning were discussed for the problem of urban network junction control and a case study from the city of Dublin was presented.
- Haibo Chen gave a presentation entitled “Traffic Monitoring/Surveillance”. It aimed at a more detailed discussion of the traffic surveillance problem and its various subcomponents. The different sensor technologies used in practice were reviewed. These include infrastructure based sensors, i.e. inductive loops, video image detectors, acoustic, optical, infrared, microwave and radar devices; vehicle based sensors include GPS devices, transponders and cell phones; ad hoc vehicular networks were also considered. Based on these sensor technologies, traffic monitoring systems have been developed in the field, both for urban and inter-urban (motorway) networks. A review of real life system implementations provided a discussion of monitoring systems’ functionality. Traffic forecasting was discussed with emphasis on the application of neural networks using self-organised maps. The incident detection problem was considered based on auto-associative neural networks. A top-down autonomic computing architecture was proposed, whereby different surveillance tasks and related applications are assigned to different components of the TCC.
- Margaret Bell gave a presentation entitled “Environmental Aspects of Traffic Management”. This presentation aimed at addressing one of the most important aspect of traffic management, that of the traffic’s environmental impact. Vehicles are one of the main sources of CO_2 emissions contributing to global warming. Hence, the environmental consequences of traffic management actions cannot be neglected

from the effort of developing and designing autonomic traffic management systems. Since these are envisioned as policy-centric, understanding environmental policy is essential. The background of EU and UK environmental policies was discussed. Motorway and urban road network environmental traffic management goals were outlined with reference to the fundamental diagram of traffic, i.e. the flow-density relationship that characterises those networks. A number of scenarios concerning air quality in urban areas were reviewed. The use of demand management, gating and cascading methods were discussed as ways for improving environmental conditions. It was shown that achieving the goals set out by environmental policies is a highly complicated task presenting one of the main research challenges for autonomic systems.

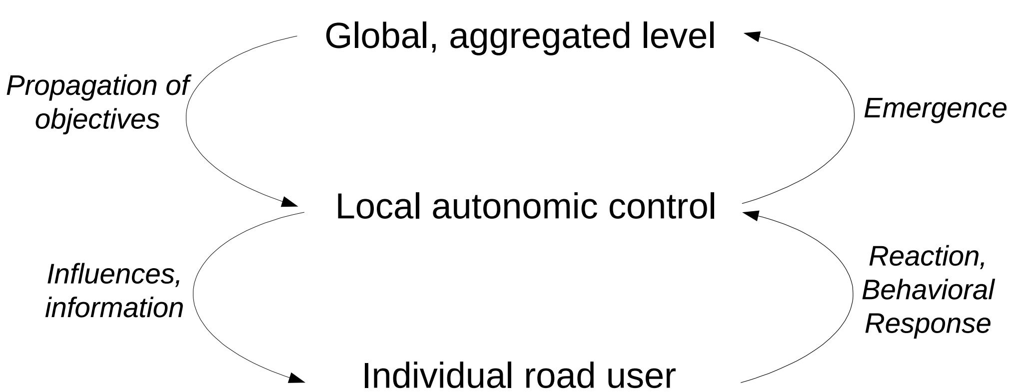
- Apostolos Kotsialos gave a presentation entitled “Traffic Management Policies and System Architecture”. The purpose of this presentation was to discuss autonomic traffic control systems design approach from a top down perspective. A review of general possible policy statements that may be followed was given in order to support the high level policy-centric character autonomic systems should have. Against changing requirements and in the effort for complexity hiding, autonomic systems should be able to select the appropriate mix of traffic control measures (bearing in mind their requirements) and the appropriate control strategy that will be used to determine the control measures’ operation. Alternative policies will result to alternative mixes of control measures and corresponding control strategies. Two examples were given, one for coordinated ramp metering and another for route guidance. Adopting different policies, for these two cases, meant different problem formulations, which require specific solution approaches from optimisation and control theory. It was argued that from a top down perspective, the design and development of autonomic control systems requires new and novel problem formulations. The requirement of self-* properties results to more sophisticated and complex problems, which will have to be addressed by use of well-founded tools from control and optimisation theory. Another issue to be resolved is that of identifying the control loops in an application that will be deliberately targeted to become autonomic. Endowing them with self-* properties is not straightforward as their meaning depends on the nature and level of the control loop. Finally, it was put forward that there is already a large body of work on intelligent transport systems architecture and software standards, at national and EU level. The effort for the development of autonomic systems should use this background to the maximum possible degree.
- Markos Papageorgiou gave a presentation entitled “Overview of Traffic Control Strategies”. This presentation was concerned with a detailed discussion of the different traffic control measures. The traffic system is treated as a dynamic system with certain capacity properties. The different control measures for managing traffic are junction signal control, ramp metering, route guidance and variable speed limits. These are used for protecting the road infrastructure from the detrimental effects of congestion. Each control measure’s principle of operation was explained in detail and results from real life and simulation-based investigations were reported. Isolated, coordinated and integrated traffic control strategies were discussed as well as fixed and reactive strategies. The binary nature of the variables, the large problem dimension, the measurement difficulty and the real-time constraints pose a formidable challenge even for the application of just a single measure in a coordinated fashion. It was argued that modern day systems tend to become technological giants with a child’s brain. This is one of the motives behind the initiative for autonomic traffic management systems, as the technology that allows the orchestration, automation, adaptation and deliberative responsiveness, is available. Technology, however, is not

enough. It is an enabling factor whose potential needs to be tapped in order to design, develop and implement highly intelligent, efficient and robust systems.

- Frances Brazier gave a presentation entitled "Dynamic Adaptive Systems of Systems Design". This presentation was concerned with an agent-based approach for designing autonomic systems. Agents are autonomous objects that can be reactive or proactive. They often display intelligent behaviour with the ability to learn and reason with their own state and the state of their environment. They can reason about reliability, credibility, integrity, quality of service, risks, penalties, liabilities and thresholds. Based on this approach, an autonomic manager responsible for an autonomic element can be considered a specially designed agent. Learning can be embedded into their structure, processing information from their interactions with other similar or dissimilar agents. Interactions range from one-to-one to multi-to-multi agents and also can take place between agents and available finite resources. This brings to the fore a multi-agent systems and service oriented architecture, which can be used for autonomic systems design. Middleware platforms can be developed to support simulation and emulation of large scale heterogeneous agent systems used for modelling road traffic networks. Application examples of this approach were given, including distributed energy management and supply chain logistics. Research challenges for this design approach include actor-agent systems, where the human is in the loop (participatory systems); governance design for robustness, reliability, trust and security; interaction design negotiation protocol strategies and mechanisms.
- Bart De Schutter gave a presentation entitled "Multi-Agent Control of Traffic Networks". This presentation was concerned with challenges and opportunities multi-level multi-agent control presents for road traffic networks. A combination of multi-level control with intelligent control agents using supervisors for achieving coordination was suggested. This supports a hierarchical control structure with agents operating at the lower levels with fast system dynamics and the supervisors at the higher levels, with slower dynamics and wider geographical coverage. Agents and supervisors include both vehicles and infrastructure based systems. For this intelligent vehicle-infrastructure system a number of issues regarding area controllers were discussed, including how to divide a real physical system and assign agents to it, how to determine subgoals in order to optimise an overall goal and how to resolve possible conflicting actions. Distributed model predictive control was proposed as an efficient method to be employed by agents, which are responsible for a single subnetwork. This approach tries to tackle the complexity problem through multi-level structuring of spatial and temporal division. Autonomic systems can support and make more efficient and robust the coordination mechanisms within the different levels.
- Daniel Borrajo gave a presentation entitled "Planning and Learning in Traffic Management", which aimed at presenting planning and learning technologies for the purposes of traffic management. The traffic control problem was discussed from the perspective of Artificial Intelligence. Given a domain model, a well-defined problem, a set of goals and corresponding metrics, the planning problem is that of obtaining a set of actions that achieve those goals or a subset of them. As autonomic systems need to be aware and adapt to their environment, machine-learning approaches were discussed, including supervised, unsupervised, and reinforcement learning. It was noted that using planning and scheduling technologies requires a lot of work on knowledge formulation and reuse. Learning methods can alleviate this task by acquiring more accurate domain models and by the use of heuristics to guide search for solutions in complex problems.

- Eric Van Berkum gave a presentation entitled "Multi-objective decision aid for traffic management". Its aim was to provide a view of decision support problems for traffic demand management. With personalised enabling technology available, traffic demand methods are becoming more reactive and short-term oriented. As autonomic traffic management systems will have to address competing objectives and conflicting metrics, this presentation provided an overview of the decision support system requirements. Different objectives to be optimised include safety, delays, CO_2 and NO_x emissions and noise. The use of bilevel optimisation was described as a way of achieving a compromise between optimising system objectives (system optimum) and optimising individual objectives (user optimum).
- Iisaki Kosonen gave a short presentation entitled "Urban Street Traffic Management Based on Real-Time Micro Simulation and Multi-agent Fuzzy Logic". This elaborated on using traffic simulation in real time traffic simulation to feed with data fuzzy controllers. An example of this kind of model based traffic management was given for junction control in an urban network.
- Todor Stoilov suggested ideas from a paper (co-authored with Krasimira Stoilova) entitled "Potential formal models for autonomic computing applications". In this paper, an analysis of the potential formalism used in hierarchical systems theory is performed, addressing the autonomic computing system design. Self management of the overall autonomic system can be achieved by influencing the local resources and the goals of the local computing subsystems.
- Franziska Klügl provided the following summary and research ideas.

  In the workshop, we identified a hierarchy of systems that can be managed based on autonomic management and control: Examples for these systems are e.g. data collection and analysis using an adaptive selection of data sources for generating up-to-date traffic information or the autonomic control of the traffic lights at one junction or for ramp metering. These systems provide services and may be functionally distributed (different services) or geographically distributed ((partial) urban network, highway network, etc.). From the point of view of a computer science and multi-agent systems researcher, two (related) research challenges can be identified. They can be summarized in the following figure (inspired by Frances' drawing).



Clearly, there are prerequisites for the following two research issues that should be covered by research issues from e.g. control theory (development of an atomic autonomic control system for the different "services" in isolation).

1. Multi-Level Integration of autonomic sub-system control to a high-level autonomic control

An open research question in the general area of multi-agent systems consists in the question of how to dis-aggregate a global high-level objective for directing lower level autonomous agents. That means, how a high-level objective, such as “optimize the signal control so that no road user has to wait in the urban network when heading towards the highway” can be mapped into lower level actions or behaviours. A number of sub-systems, each with autonomic control is involved in this high-level objective: a number of signals on a particular arterial leading towards the ramps, ramp metering, a data analysis service for the urban network, a data analysis service for the highway, maybe even a travel demand prediction model. These sub-systems are organized in a particular way (not necessary a hierarchy). The question is now: how to derive lower level abstract objectives for each of these sub-systems so that they are still able to exhibit autonomic control on its own and in coordination with its neighbours, required services, etc.? What happens if the autonomic control of the overall aggregate system requires a re-organization of its sub-systems, for example replacing the loop-based data gathering by a gps-based data analysis? What happens to the de-composition of the high-level objective, if a sub-system fails? What information needs to flow from the global to the sub-system level when we have a geographic distribution, respectively a functional distribution?

Assuming that the sub-systems of the overall autonomic management traffic system under considerations all work in an autonomic way following the given de-composed high-level objectives for the overall system, how can we ensure that the behaviour and decision making of the sub-systems really emerges to fulfil the high-level objective? This closes the loop from the whole-system objective to the local objectives and back. How the self-* properties of the overall system are affected by the self-* operations of the sub-systems adapting their behaviour to fulfil their partial objective in a different way? How can we avoid un-intended side effects of objectives? How to engineer an autonomic system, which self-* properties are depending on the autonomic control of sub-systems? What do we explicitly need in addition to the sub-system control? Social laws for self-adaption? Commitment strategies for self-configuration?

2. Taking into account the behavioural response of the road users

The larger the traffic systems with autonomic control are, the more important it is to pay attention to the road users reaction towards given information or directives. This basically means to extend the notion of online real-time control to a wider/larger system level. If we are about to develop an autonomic control of a complete urban network, road users adaption in route decision making has to be included in the simulation models that form the basis for on-line testing the different multi sub-system optimization. Also, when giving traffic information, the reaction of the road users to this information has to be integrated into the information given. Otherwise the displayed information might not be valid any more in the moment of display. Also for the implementation of new high-level objectives that are resulting in e.g. moving the location of a congestion – as in Margaret’s example – needs to consider potential user reactions to the new position of the jam. Otherwise it could happen that the road users adapt their behaviour in a way that negates the intended effect of the measure – thus the high-level objective cannot be fulfilled with the current plan any more. This might involve generating better prediction models of road users, and the integrated use of multi-agent systems, machine learning and planning technology.

3. Assessment of the results, contribution to the future direction of the field, outcome
Indicating what was learned and the new research objectives identified as a result of the workshop is an important part of this section. However we would also like to see in this section which concrete actions (if any) you plan as a follow up - this can be for instance the intention to submit a proposal for a ESF Research Networking Programme or an action under the Framework Programme; or else to set up an informal network, to publish proceedings, or to start a web forum...

- Autonomic traffic management systems aim at providing traffic monitoring and control services to the users (network operators, drivers and application within the computing environment of a TCC) in a centralised or decentralised manner, in such ways so as to guarantee high levels of service. Through the explicit engineering of self-* properties they aim at addressing the high complexity of decision making challenges related to congestion amelioration and reduction of negative environmental impact. As systems they are policy-centred, and flexible with respect to operations, which are employed in support of a range of possible objectives.
- For the field of traffic management, autonomic systems design can be applied at different system levels and the corresponding control loops. The meaning of the self-* properties at each level and application is case specific and requires detailed specifications. The autonomic computing approach can be generalised to a technology engineering design approach, which may lead to different kinds of planning, estimation, prediction and control problem formulations related to traffic management.
- Autonomic traffic management systems can be developed using both top/down, bottom/approaches and combinations thereof.
    - Top-down approach to systems development: overall system goals are to be achieved through the modification of interconnectivity or behaviour of system components – realized through a system manager.
    - Bottom-up approach to systems development: local behaviour of system components needs to be aggregated (without a centralized system manager) to generate a desired overall system behaviour.
- Planning and scheduling technologies can be used in conjunction and support to traffic monitoring and control algorithms and systems. This creates the requirement of knowledge formalization and reuse.
- Learning methods can alleviate this task by acquiring more accurate domain models and efficient heuristics to guide the search in complex problems such as in traffic control problems.
- Applications in
    - traffic control (all control measures);
    - traffic monitoring;
    - demand management;
    - cooperative vehicle/infrastructure systems;
    - decision support systems for network operators;
    - environmental monitoring and policy supporting control systems.
- Multiple objectives, from travel efficiency to environmental efficiency maximisation can be addressed through the paradigm of autonomic systems design.

A number of actions was decided for follow-up.

- Based on Terry Mulroy’s input during the Friday morning session, it was decided to submit a proposal for the COST framework.

- It was agreed to submit a EUROCORES proposal at ESF. This has been submitted by the time of this report.
- To submit a proposal in Future and Emerging Technologies of the FP7 framework.
- It was agreed that A. Kotsialos will organise a session on autonomic traffic management system at the IFAC Symposium on Control in Transportation Systems that will take place in Sofia in 2012.
- A group on autonomic transportation systems has been set up in LinkedIn to promote further discussions and networking among the participants.

4. Final programme

The final programme as was realised is as follows.

<u>Tuesday 13 April 2010</u>

Afternoon Arrival

Evening free

<u>Wednesday 14 April 2010</u>

09:30-09:40 Welcome by Convenor

09.40-10.00 Presentation of the European Science Foundation (ESF) (Apostolos Kotsialos)

10:00 – 10:30 The ARMS working group (Lee McCluskey)

10:30 – 11:00 Coffee break

11:00 – 11:30 Principles of autonomic systems design (Omer Rana)

11:30 – 12:00 Traffic management needs and perspectives (Apostolos Kotsialos)

12:00 – 13:00 Discussion

13:00 – 14:00 Lunch

14:15 – 14:45 Autonomic Computing case studies (Lee McCluskey)

14:45 – 15:15 Autonomic Computing case studies (Ivana Dusparic)

15:15 – 15:30 Coffe break

15:30 – 16:00 Traffic surveillance systems (Haibo Chen)

16:00 – 16:30 Environmental aspects of traffic management (Margaret Bell)

16:30 – 17:00 Discussion

18:00 Dinner

<u>Thursday 15th of April 2010</u>

09:30 – 10:00 High-level policies and traffic management systems architecture (Apostolos Kotsialos)

10:00 – 10:30 Road network traffic control (Markos Papageorgiou)

10:30 – 11:00 Coffee break

11:00 – 11:30 Multi-agent and knowledge based systems (Frances Brazier)

11:30 – 12:00 Multi-agent control of traffic networks (Bart De Schutter)

12:00 – 13:00 Discussion

13:00 – 14:00 Lunch

14:15 – 14:45 Deliberative planning and learning, reinforced learning and scheduling (Daniel Borrajo)

14:45 – 15:15 Decision support tools for road network traffic management (Eric Van Berkum)

15:15 – 16:15 Discussion

18:00 Dinner

<u>Friday 16th of April 2010</u>

09:30 – 10:00 Summary of workshop results

10:00 – 12:30 Discussion on future actions and follow-up activities

12:30 Lunch

Afternoon Departure

5. Final list of participants (name and affiliation is sufficient; the detailed list should be updated on-line directly)

Convenor
Dr Apostolos KOTSIALOS
School of Engineering and Computing Sciences, Durham University, UK.

Co-Convenors:
Prof Margaret BELL, Department of Civil Engineering and Geosciences, Newcastle University, UK.
Dr Haibo CHEN, Institute of Transport Research Studies, Leeds University, UK.
Prof. Lee MCCLUSKEY, School of Computing and Engineering, Huddersfield University, UK.
Prof. Omer RANA, School of Computer Science, Cardiff University, UK.

Participants:

Prof. Daniel BORRAJO, Departamento de Informática, Universidad Carlos III de Madrid, Spain.
Prof. Dr Frances BRAZIER, Faculty of Technology Management and Policy, Delft University of Technology, The Netherlands.
Prof. Bart DE SCHUTTER, Delft Center for Systems and Control, Delft University of Technology, The Netherlands.
Dr Ivana DUSPARIC, School of Computer Science and Statistics, Trinity College Dublin, Ireland.
Prof. Tom HOLVOET, Department of Computer Science, Katholieke Universiteit Leuven, Belgium.
Dr Franziska KLÜGL, Modeling and Simulation Research Center, School of Science and Technology, Örebro University, Sweden.
Dr. Iisakki KOSONEN, Department of Civil and Environmental Engineering, School of Science and Technology, AALTO-University, Finland.
Dr René MEIER, School of Computer Science and Statistics, Trinity College Dublin, Ireland.
Mr Terry MULROY, Transportation Planning (International) Ltd, UK.
Prof. Markos PAPAGEORGIOU, Dynamics Systems and Simulation Laboratory Department of Production Engineering and Management, Greece.
Dr Michal PECHOUCEK, Department of Cybernetics, Faculty of Electrical Engineering, Czech Technical University, Czech Republic.
Prof. Todor STOILOV, Hierarchical Systems Department, Institute of Computer and Communication Systems, Bulgarian Academy of Sciences, Bulgaria.
Prof. Eric VAN BERKUM, Centre for Transport Studies, Department of Civil Engineering Faculty of Engineering Technology, University of Twente, The Netherlands.

6. Statistical information on participants

The participants came from the following countries:

United Kingdom	:	5	(27.6%).
The Netherlands	:	3	(16.5%).
Spain	:	1	(5.6%)
Ireland	:	2	(11.1%)
Greece	:	1	(5.6%)
Sweden	:	1	(5.6%)
Finland	:	1	(5.6%)
Bulgaria	:	1	(5.6%)
Belgium	:	1	(5.6%)
Czech Republic	:	1	(5.6%)
International organisation	:	1	(5.6%)

Due to the volcanic ash cloud, one participant from Italy and another from the USA were not able to attend. In total, there were participants from 10 European countries.

Female participants	:	4	(22.2%)
Male participants	:	14	(77.8%)

The participants can also be divided into two categories, those with a transport/traffic engineering background and those coming from computer science.

Transport/traffic engineering	:	9	(50%).
Computer science	:	9	(50%).

Age Bracket

21 – 30	:	1	(5.6%)
31 – 40	:	7	(38.9%)
41 – 50	:	4	(22.2%)
50 –	:	6	(33.3%)

Participants' short biographical notes

Dr Apostolos Kotsialos (convenor)	Dr Apostolos Kotsialos is a lecturer at the School of Engineering of Durham University. He received his engineering degree from the Department of Production Engineering and Management of the Technical University of Crete, Greece. During his postgraduate studies he has worked extensively on the problem of modelling and control of traffic in motorway networks. Since 1996 he has been involved in numerous transport telematics research projects funded by the EU, such as DACCORD, TABASCO, OMNI, SMART NETS, RHYTHM and EURAMP. During these projects he developed control strategies based upon feedback and model predictive approaches. He joined Durham University's School of Engineering in September of 2005. His research interests include forecasting, production planning and control, traffic flow theory and control and transportation / logistics.
Prof. Margaret Bell (co-convenor)	Margaret Bell is Professor of Transport and the Environment and was instrumental in setting up the instrumented City research Facility that boasts £3m of equipment and historic data sets dating back twenty years. She is a member of the Research Council's Peer Review Colleges, Chair of the Smart Environment Interest Group of the ITS (UK) and was named Commander of the Order of the British Empire for services to sustainable transport in the Queen's 80th Birthday Honours List. Her research has been mainly in the field of traffic and environment monitoring, modelling management and control. Professor Bell's research work has included ageing of traffic signal plans, development of congestion measures, forecasting air quality and duration of incidents with neural networks and fuzzy logic, evaluation of demand management strategies and traffic control policy on the environment.
Dr Haibo Chen (co-convenor)	Dr Haibo Chen is a Principal Research Fellow in the Institute for Transport Studies (ITS), which is the largest university-based transport teaching and research organisation in Europe, having over 90 staff actively involved in a variety of transport activities, operations and development. Dr Chen has over twelve years experience in applying advanced statistical and mathematical techniques (e.g. artificial intelligence, multivariate analysis, data fusion and mining etc) in the broad field of traffic, emissions and

	air quality modelling and policy intervention in real-time (e.g. congestion classification, incident detection, journey time variability, and emissions and air quality estimation etc). He has worked on projects for incident detection and traffic forecasting, in which he also investigated the effects of missing values and gaps in real-time traffic data on network performance forecasting. This work led to the real-time implementation of traffic flow and journey time prediction on the M25 motorway by the Highways Agency UK, and to the transferability study of the methods developed in urban real-time traffic information systems.
Prof. Thomas Lee McCluskey (co-convenor)	Thomas Lee McCluskey is Professor of Software Technology in the Department of Informatics. He obtained a PhD in machine learning and automated planning while working as a lecturer in computer science at the City University in 1989. In the early 1990's he led a team of academics at the City and Huddersfield Universities on the 'Faroas' project (`formalization and animation of requirements for oceanic aircraft separation'). The team performed knowledge engineering for the National Air Traffic Services, successfully formulating a model (the CPS) in many-sorted first-order logic of separation criteria for aircraft management over the North Atlantic, and a tools environment, which could auto-generate a program for predicting conflicts in flight plans. He has led projects, which developed meta-tool technology to automatically validate and self-maintain formulations of knowledge.
Prof. Omer Rana (co-convenor)	Omer Rana is a Professor of Performance Engineering in the School of Computer Science at Cardiff University, and the Deputy Director of the Welsh eScience Centre. He holds a PhD in Neural Computing and Parallel Architectures from Imperial College, London, and works in the areas of high performance distributed computing, multi-agent systems and Data Mining. He has published over 150 papers in peer reviewed, international journals, workshops and conferences. He is on the editorial board of the new book series on Autonomic Systems from Birkhauser publishers (Switzerland), and was formerly on the steering committee of the IEEE/ACM International Conference on Autonomic Computing.
Prof. Daniel Borrajo	Daniel Borrajo is a Professor of Computer Science at Universidad Carlos III de Madrid since 1998. He received his Ph.D. in Computer Science in 1990 and B.S. in Computer Science both at Universidad Politécnica de Madrid. He has published over 150 journal and conference papers mainly in the fields of problem solving methods (heuristic search, automated planning and game playing) and machine learning. He has been the PI and/or participated in over 30 research projects and networks funded at all levels (regional, national and European). He has been the Conference co-chair of the International Conference of Automated Planning and Scheduling (ICAPS'06), Chair of the Spanish conference on AI (CAEPIA'07), PC member of conferences as IJCAI (senior PC at IJCAI'07), AAAI, ICAPS,

	ICML, or ECML. He has advised 11 PhD thesis, and currently member of ICAPS Council. He has also been Dean of Computer Science studies, Department Chair and adjunct to the Academic Vice rector.
Prof. Frances Brazier	Prof dr Frances Brazier is a full professor within the Faculty of Policy and Management, at the Delft University of Technology. Her chair, Engineering Systems Foundations, and her group, the Dynamic Adaptive Systems Design Group, focus primarily on the design and (self) management of large scale distributed autonomous (adaptive) interactive systems in dynamic environments. The social and legal requirements for the design of autonomous systems (as the basis for acceptance), the values that are of key importance are an inherent part of design. Energy management and transportation management are examples of domains of application in which technology and policies for distributed (re)configuration and self-management are being explored, have been explored. Agent middleware (AgentScape), developed within the group, provides the technology needed to design and study the behaviour of a large scale system through large-scale simulations and distributed emulations. AgentScape development is currently supported by an international consortium led in cooperation with Thales R&D, within the context of D-CIS, with both industrial and academic partners. Frances Brazier holds a MSc in Mathematics and a doctorate in Cognitive Ergonomics from the VU Amsterdam. She began as a researcher at the VU within the Department of Cognitive Psychology, moved to the Department of Artificial Intelligence where she was promoted from assistant, associate to full professor in 2000. She (and her group) moved to the Department of Computer Systems within the same faculty in 2005, and in 2009 to Delft University of Technology. Parallel to her academic career she co-founded the first ISP in the Netherlands: NLnet. She is still currently a member of the Board of NLnet Labs. As vice chair of EurOpen, an umbrella organisation for 22 national UNIX users' groups, she was responsible for the initiation of EUnet, the European network at the time. She has been a member of a large number of international programme committees, reviewing committees, PhD committees, has published significantly in the areas of Autonomous Systems, AI, Multi-Agent Systems, Distributed Systems, E-government, Web Services, and HCI. She was a member of NWO's Advisory Committee in Computer Science (NWO is the National Science Foundation in the Netherlands) for 5 years, chaired the I-Science GLANCE programme. She is currently a member of the editorial board of "AI in Design and Manufacturing" and Birkenhauser's Autonomic Computing series.
Prof. Bart De Schutter	Bart De Schutter received the degree in electrotechnical-mechanical engineering in 1991 and the doctoral degree in Applied Sciences (summa cum laude with congratulations of the examination jury) in 1996, both at the K.U.Leuven, Belgium. The subject of his PhD thesis was "Max-algebraic system theory for

	discrete event systems". After obtaining his PhD degree, he was a senior research assistant of the FWO-Flanders at the ESAT-SISTA research group of the K.U.Leuven. In 1998 he transferred to the Control Systems Engineering group of the Faculty of Information Technology and Systems of Delft University of Technology, The Netherlands. In 2003 the control groups of Delft University of Technology merged into the Delft Center for Systems and Control (DCSC). Currently, Bart De Schutter is a full professor at Delft Center for Systems and Control (DCSC) department of Delft University of Technology. In 1998 Bart De Schutter was awarded the Richard C. DiPrima Prize for this PhD thesis. In 1999 he has received the triennial Robert Stock Prize for PhD theses in Exact Sciences at K.U.Leuven. In 2003 he obtained a VIDI grant on the topic of multi-agent control of large-scale hybrid systems from the Dutch Technology Foundation STW. Bart De Schutter is associate editor for Automatica and for the IEEE Transactions on Intelligent Transportation Systems. He is also coordinator of the European FP7 STREP project Hierarchical and distributed model predictive control of large-scale complex systems (HD-MPC).
Dr Ivana Dusparic	Ivana Dusparic is a Research Fellow in the Distributed Systems Group at Trinity College Dublin. She received a B.Sc. degree in Applied Mathematics/Computer Science from La Roche College, Pittsburgh, PA in 2001, M.Sc. by research in Computer Science from Trinity College Dublin in 2005 and has recently defended her Ph.D. thesis in the same university. Her research interests include self-organizing learning algorithms, autonomic computing and intelligent traffic control.
Prof. Tom Holvoet	Prof. Tom Holvoet is an associate professor of the computer science department at the KULeuven (Belgium), where he received his PhD in 1997 on engineering open distributed software. He is part of the DistriNet labs, a research group of 73 researchers with elaborate experience and expertise in distributed software and security. He is leading a task force that specifically works on self-adaptive (autonomic) and self-organising distributed systems, coordination, multi-agent systems, software architecture and middleware. The research is application-driven in that it is directly linked to real-world use case scenarios, including traffic monitoring and management, logistics - warehouse logistics as well as multi-modal logistics (e.g. inland shipping, road transportation). Since 2000, he has been a co-author of over 150 scientific publications and is actively involved in programming committees of high-ranked conferences as well as discussion-oriented workshops, and is a frequent reviewer for journals (incl. JAAMAS, ACM-TAAS, Transp.Res.-C, IJARAS (member of editorial board), Computers in Industry. He is promotor of a Strategic Basic Research project on traffic management and simulation, coordinator of a Strategic Basic Research project on 'distributed collaborative systems for logistics', coordinator of a R&D project on 'software architecture

	for warehouse logistics', promotor of two consecutive fundamental research projects on 'decentralized and autonomic, manufacturing control'.
Dr Franziska Klügl	Dr. Franziska Klügl (PhD, computer science in 2000, University of Würzburg, Germany) is currently Associate Professor (Docent) in Information Technology at Örebro University, School of Natural Science and Technology, Sweden. She leads the Multi-Agent Simulation Group at the Modelling and Simulation Research Center of the Örebro University. Within her research on the methodological basis and application of multi-agent systems, she is managing the development and extension of the generic SeSAm modelling and simulation system. Her research interests include multi-agent simulation and systems and their application in biology, geography and traffic, visual programming and human-computer interaction. Dr. Klügl has published more than 80 papers and articles in scientific journals and conferences. She was co-organizer of the last four ATT (Agents in Traffic and Transportation) workshops and co-edited two books in this area. She was program chair of the European Workshop for Multi-Agent Systems 2008, program co-chair of the German Multi-Agent System Conference 2005 and publication chair of AAMAS 2008. She is member of the steering committee of ALA (Learning and Adaptive Agents) and of the board of EURAMAS.
Dr. Iisakki Kosonen	Iisakki Kosonen received his M.Sc. in 1989 at the Helsinki University Technology (TKK), Department of Electrical and communications Engineering. The doctoral degree in 1999 was at the Department of Civil and Environmental Engineering. Kosonen has been working at the TKK/Transportation engineering since 1988 and currently as docent and teaching researcher. His main teaching and research activities are related to the Intelligent Transportation System as well as to traffic simulation and control. Kosonen has been working abroad at the Nottingham Trent University (NTU, 1997), Los Alamos National Laboratory (LANL, New Mexico, 1998) and Kungliga Tekniska Högskolan (KTH, Sweden, 1996-2003 part time).
Dr René Meier	Dr. René Meier is a Lecturer in Computer Science at Trinity College Dublin. His interests as a researcher in distributed systems cover a variety of overlapping topics related to very large-scale, context-aware mobile and pervasive computing systems as well as to self-organizing systems. These include context-aware and location-aware services, self-organizing peer-to-peer systems, and programming models and middleware architectures for global smart spaces with a special focus on their application to intelligent transportation systems. Research activities include the development of a novel transportation architecture for Dublin City Council as well as architectures for service-based automotive computing as part of Lero – the Irish Software Engineering Research Centre. He is an editorial board member for the Mobile and Pervasive computing community of IEEE Computer Society's on-line magazines home, Computing

	Now, and an Associate Editor for the IGI International Journal of Ambient Computing and Intelligence. Recently, he served as the General Chair for the International Symposium on Vehicular Computing Systems.
Mr Terry Mulroy	Terry Mulroy has over 35 years experience in the field of transportation engineering with particular emphasis on transport policy, urban transport and traffic systems management. Mr Mulroy has directed the projects in respect of work in many historic towns and cities and pioneered work in traffic calming and lorry management. His early career was spent designing and implementing traffic management schemes in the London area. He was appointed Study Director for the West Midlands Area Multi Modal Study and Specialist Advisor on the Midlands to North-West Multi-Modal Study. Recently, he has project managed the street running and tram/traffic operational control for the Metro Midland Line 1 Extension, Wednesbury to Brierley Hill and Understanding Traffic Signs Research Project for the DfT. As Chairman of the Transport Vocational Group, he has developed the National Transportation Qualification on behalf of ICE, IHT, IHIE and CILT, and is currently on the Steering Group for the EuroRAP Mass Action Road Safety guidelines project.
Prof. Markos Papageorgiou	Markos Papageorgiou was born in Thessaloniki, Greece, in 1953. He received the Diplom-Ingenieur and Doktor-Ingenieur (honors) degrees in Electrical Engineering from the Technical University of Munich, Germany, in 1976 and 1981, respectively. From 1976 to 1982, he was a Research and Teaching Assistant at the Control Engineering Chair, Technical University of Munich. He was a Free Associate with Dorsch Consult, Munich, Germany, (1982–1988), and with Institute National de Recherche sur les Transports et leur Sécurité (INRETS), Paris, France (1986–1988). From 1988 to 1994 he was a Professor of Automation at the Technical University of Munich. Since 1994 he has been a Professor at the Technical University of Crete, Chania, Greece. He was a Scientific Advisor of INRETS (1988-1997); a Visiting Professor at the Politecnico di Milano, Italy, in 1982, at the Ecole Nationale des Ponts et Chaussées, Paris, France, from 1985 to 1987, and at MIT, Cambridge, MA, in 1997 and 2000; and a Visiting Scholar at the University of Minnesota in 1991 and 1993, University of Southern California in 1993, and the University of California, Berkeley, in 1993, 1997, and 2001. He is the author of the books Applications of Automatic Control Concepts to Traffic Flow Modeling and Control (New York: Springer, 1983) and Optimierung (Oldenbourg, 1991; 1996); co-author of the book Optimal Real-time Control of Sewer Networks (New York: Springer, 2005); the editor of the Concise Encyclopedia of Traffic and Transportation Systems (New York: Pergamon, 1991), and the author or co-author of over 300 technical papers. His research interests include automatic control and optimization theory and applications to traffic and transportation systems, water systems, and further areas. Prof. Papageorgiou is the

	Editor-in-Chief of Transportation Research-Part C and an Associate Editor of various other journals. He received a DAAD scholarship (1971-1976), the 1983 Eugen-Hartmann award from the Union of German Engineers (VDI), and a Fulbright Lecturing/Research Award (1997). He is a Fellow of IEEE (1999). He was the first recipient of the IEEE Outstanding ITS Research Award (2007).
Dr Michal Pechoucek	Prof. Michal Pechoucek is a head of Agent Technology Center and a deputy head of the Department of Cybernetics, Czech Technical University in Prague (CTU). He is a full professor in Artificial Intelligence at CTU. He graduated from CTU and the University of Edinburgh and completed his Ph.D. in Artificial Intelligence and Biocybernetics at CTU. Michal Pechoucek is an author of more than 150 journal papers and conference contribution. His work is cited by more than 140 SCI listed citations. Michal Pechoucek has acted as a principal investigator on more than 20 research projects funded by AFRL/EOARD, ONR, CERDEC/US ARMY and FAA. Besides, Michal Pechoucek has collaborated with international industries such as Rockwell Automation, BAE Systems, Cadence Design Systems, TSystems, Denzo and others. Michal Pechoucek is a visiting/honorary member of Artificial Intelligence Application Institute, University of Edinburgh, is member of the Advisory board of Center of Advanced Information Technologies at State University of New York. He is also a member of the Board of directors of European Association for Multi-Agent Systems. Michal Pechoucek has been awarded Fulbright fellowship for 2011 to spent his sabbatical at the University of Southern California.
Prof. Todor Stoilov	Prof. D.Sc., Ph.D Todor Atanasov Stoilov is a senior researcher, computer scientist with experience in project management. Educational records: 1973 – Technical University Sofia -Electrical Engineer-Automatics; 1979- defending PhD degree; 1989-Associated professor in Bulgarian Academy of Sciences; 1998-defending D.Sc. (Doctor of Sciences degree, which is a higher scientific achievement according to the national legislation); 2000 – Full professor in Bulgarian Academy of Sciences (BAS). He has more than 200 publications, including 4 monographs in the area of computers and communication networks, wireless transmissions, modeling, optimization, traffic management; transport system management, on-line control. Applied activities: Management and participation in projects and contracts-more than 30 national funded projects from state and industry organizations (Ministry of Sciences, Ministry of Industry, State agency of transport, information technologies and communications). Participation and management of Bulgarian teams in International projects, funded by the EC under several programs: INCO-COPERNICUS program, project FRETRIS 096183 (1996-1999, Freight Road Transport Information System); project EDIPA 977076 (1998-2000, Electronic Data Interchange between Port Administrations); FP5-IST project

	REGNET, IST-2000- 26336 (2001-2003, Regional Network of Culture Heritage), FP6-IST project VISP IST-2004-027178 (2005-2010, Virtual Internet Service Provider); projects under the frameworks of programs SOCRAT, LEONARDO. Todor Stoilov is a professor in Institute of Computer and Communication Systems, affiliated to Bulgarian Academy of Sciences. He is a head of Department “Hierarchical systems”. His activities are concentrated on the implementation of information technology solutions in different domains: system management, automation, transportation, financial investments. Particular interests are in computer networks, computer sciences, software technologies, control systems, optimal resource allocation. His professional experience is a background for current educational and teaching activities, applied in several Bulgarian Universities.
Prof. Eric Van Berkum	Eric van Berkum (1959) received his MSc (1984) degree in Applied Mathematics at the University of Twente and his PhD (1993) degree in Civil Engineering at Delft University of Technology. His PHD project was about the impact of traffic information on route and departure time choice. After a short career (1985-1988) as a software engineer at Cap Gemini, he was a consultant at Goudappel Coffeng from 1988-2009. There he worked mainly in the field of transport modelling and travel behaviour, and headed Innovation and Product Development for close to 15 years. In 1998 he became a part time professor in Traffic Management at the University of Twente. Since 2009 he is a fulltime professor Transport Engineering and Management and also heads the Centre for Transport Studies at the University of Twente.