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Dissemination plan for the project

Revision: 1.0, March 25, 2014

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Due date of deliverable: Month 12 (March 2014)

Actual submission date: March 31st, 2014

Nature: O. Dissemination level: PU

Funding Scheme: Small or medium scale focused research project (STREP)

Topic: ICT-2011 9.10: FET-Proactive 'Fundamentals of Collective Adaptive Systems' (FOCAS)

Project number: 600708

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Executive Summary

This document sets out the dissemination plan for the QUANTICOL project. The project has ambitions to see its research outputs and results disseminated widely in academia and beyond. We present here our plan to achieve this goal and review the progress on the plan which has been achieved in the first year of the project. This gives an insight into how we see the plan being developed and implemented in later years of the project.

- We discuss the various forms of dissemination which we will engage in, and our strategies for achieving impact through dissemination.
- We present our approach to dissemination outside the theoretical computer science community in domain-specific journals which are relevant to the case studies of the project.
- We reflect on the dissemination achieved in the first year of the project, putting forward concrete examples as indicators of the type of work which we will do in later years of the project.
- We explain how we see our dissemination activities being brought to different user communities with different interests and agendas. We explain the role of software demonstrators created by the project.
- We enumerate concrete examples of dissemination such as publications, articles in newsletters, publicity flyers, and others.
- We expound on the reach of our dissemination, identifying other research projects and other communities to whom we have presented QUANTICOL results.
- We present a chronological record of our working meetings with representatives of the smart system owner and operator communities responsible for collective adaptive systems day-to-day operation in practice.
- We detail planned dissemination events in later years of the project.

1 Introduction

This dissemination plan outlines the activities which the members of the QUANTICOL project will undertake, separately and together, in order to engage with three distinct user communities. These are:

- i) the scientific communities who are interested in formal methods, and quantitative modelling and analysis—these are our natural communities, where our previous work is known and where we have a wealth of expertise about venues and the nuances of the scope and interests of particular conferences and journals;
- ii) the FoCAS community, interested in all aspects of collective adaptive systems, and other scientific communities beyond our own, even including those which lie outside the discipline of computer science—here is where we are reaching further, and taking our results out to communities where our previous work is not known and we are less familiar with the subtleties of dissemination, expectations, interests, and scope; and
- iii) the smart city owner, operator and user communities beyond academia, the communities who experience the day-to-day effects of dynamic adaptive systems in cities—these communities are much harder again to reach than scientific communities because there are many fewer opportunities to have influence and access, and in consequence this requires different approaches to dissemination specifically targeted to these communities.

We address each of these communities in turn in Sections 2, 3, and 4 below.

1.1 Dissemination plan outline

From the project outset, the QUANTICOL project will actively seek out opportunities to disseminate to all identified constituencies and audiences. The pattern of dissemination which we plan to follow is illustrated in Figure 1.

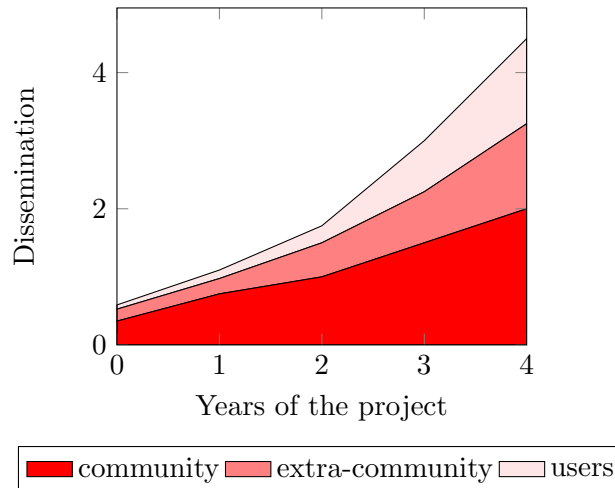


Figure 1: Planned dissemination plan for the QUANTICOL project to reach all audiences

This figure expresses our intended plan that dissemination outside our natural community will increase proportionally towards the later years of the project. We have formulated this plan in the foreknowledge that our work in early years of the project will lead to improvements in the modelling and analysis methods and techniques which are available to us. Technical advances in research methodology of this kind can be best appreciated in detail by experts within our natural communities of formal methods and quantitative modelling and analysis. Experts in these areas understand the demands of

this kind of technical work and they are well positioned to appreciate these technical advances as pure research contributions which they can apply in their own research, in addition to seeing the value of these technical advances and their potential areas of application.

In later years of the project we will be applying these advanced techniques to the project case studies and showing that they have allowed us to address the key modelling and analysis challenges which are specific to collective adaptive systems. We believe that this phase of the project will act as a springboard to allow us to reach beyond our own natural scientific community to communities in the broader FoCAS realm and beyond to areas of application which are difficult to predict in advance. Our efforts in the case studies of the project will give us access to publication contexts where the achievements in modelling are the primary theme of the publication and the detailed technical work making the modelling possible is the background theme.

We believe that, beyond academia, the smart city owner, operator and user communities will be most engaged by success stories where the insights which have been obtained through modelling and analysis have led to practical changes in the operation of collective adaptive systems, or to changes in their regulation and evaluation through the definition of key performance indicators, or via other measures and metrics. We believe that dissemination of this kind can happen only towards the end of the project when detailed and convincing case study models have been accepted by the smart city owner and operator community. This explains why dissemination of this kind increases most towards the end of the QUANTICOL project's four years of funding.

1.2 Dissemination of research

The QUANTICOL project will disseminate its research findings through the traditional channels for scientific work: peer-reviewed journals and conferences. Whether they are journals or conferences, we will target high-profile, international venues which have significant international visibility and high impact factors.

Both journal publications and conference publications are valued and esteemed by the project. Conference publications have the advantage of allowing more rapid dissemination of results, bringing them to the attention of other researchers in a timely fashion. Journal publications have the advantage of longevity and archival prestige, allowing the results of the project to influence others in later studies over a longer time span.

One aspect of publication of the work of the project received special consideration and discussion. We discussed whether our case study material (on smart grids and smart energy, bike sharing schemes, and public transport) should be presented in domain-specific journals for these areas (such as green energy journals or transportation journals). The project concluded that this should be decided on a case-by-case basis for each paper, encouraging authors to target domain-specific journals in this way, if the authors of the work believed this course of action to be best for a particular research contribution. In other cases the opposite decision would be the correct one: some more technical material resting heavily on the context and expectations of the theoretical computer science community would not be best appreciated by the reviewers and editors of domain-specific journals.

It is easy to under-estimate the difficulty of publishing in another community, with different technical vocabulary, different standards of evidence and proof, and different literature. The scenarios envisioned by the project included novel modelling and analysis techniques being divorced from the case study material, or coupled with the case study material. In the former case the risk is that the new techniques would be being presented in the absence of any application, and hence be unable to convey their full utility and value. In the latter case the risk is that they would be being presented to reviewers from other technical disciplines and domains outside theoretical computer science who would struggle to appreciate them fully.

Balancing these risks, and ensuring that the project publishes effectively both in theoretical computer science journals and in domain-specific journals, will require continued consideration and care. We will use the experience gained through the collective track record of the QUANTICOL project

members in inter-disciplinary research to ensure that the case study work is used effectively to exemplify the application of novel modelling and analysis techniques and that publishing of case study material in domain-specific journals outside computer science does not marginalise these research contributions.

1.3 Achieving impact through dissemination

A vitally important part of the dissemination of the project will be achieved not through publication, but through engagement. A well-written scientific paper will persuade a researcher to try a novel analysis technique or to start working within a different modelling regime but it will not persuade the operator of a complex energy supply or transportation system to adopt a new operational strategy. Impact of this kind requires not the one-way communication of a publication, but a two-way dialogue in which the (potential) adopter can ask questions, test assumptions, and probe into details of the work in a way which is not possible with peer-reviewed publication.

As a vehicle for this form of dissemination, the QUANTICOL project is creating a variety of software products to illustrate the ideas of the project and lower the barrier to accessibility for those who could be influenced by the ideas and the insights. A first example of this kind of dissemination is the visualisation tool for Lothian buses data discussed in more detail in Section 4.1. This software tool serves several purposes:

- it helps make the project researchers familiar in detail with the available data and both its potential and its limitations for predictive modelling;
- it provides a “middle ground” between modelling issues and operational issues, allowing researchers and system providers to have a meaningful dialogue on topics of common interest;
- it sparks the interest of system providers and system regulators, making them more inclined to engage with the QUANTICOL project and to contribute their advice, data and time, and to share their ideas and their problems; and
- it opens a dialogue with other parties who are interested in analysis and modelling of smart cities and helps to build bridges to other service providers and other modellers, as was the case with the DemoFest meeting, described in Section 4.3.

The QUANTICOL project has developed other modelling, verification and analysis tools such as mean-field model-checkers (as reported in TR-QC-01-2013) and statistical model-checkers (as in MultiVeStA [SV13]) and has used combinations of existing modelling tools to analyse case studies (as reported in TR-QC-02-2013).

1.4 Domains of discourse

The QUANTICOL project believes that different domains of quantitative discourse are appropriate for our most distinct dissemination communities.

Academic The primary domain of discourse here is *models, languages, and logics* together with abstract representations such as formal semantics, and abstract reasoning such as model-checking and mean-field approximation.

Industrial/user The primary domain of discourse here is *data, measurements, and evidence*, together with concrete representations such as simulations and visualisations, and concrete reasoning such as studies and exemplars.

These separations are not absolute—it is of course possible to conduct discourse with academics on data, measurements and evidence—but discourse with industrial and user communities via models, languages and logics is more difficult because it presupposes a shared background and technical understanding which is in practice very unlikely to be shared.

1.5 Types of dissemination

Evidently, different types of dissemination are appropriate for different audiences. Here we list the primary forms of dissemination activity undertaken by the QUANTICOL project.

- Publications — conference and journal publications provide a definitive record of the work done in the project and are one of the most lasting forms of dissemination, speaking to other researchers in related projects.
- Keynotes — invited talks and keynote presentations are an important form of dissemination because they convey the sense that our peers hold the work in high regard, and consider it to be valuable, and worthy of greater exposure.
- Presentations — technical presentations at conferences and workshops draw the audience in to the research, encouraging them to read a technical paper later, in order to understand the work in greater depth.
- Seminars — departmental and school seminars are valuable because the seminar speaker is speaking to professors and their students, and encouraging others to invest in learning about the QUANTICOL project.
- Tutorials — tutorials at conferences provide a rare opportunity to present our research work to our peers over a longer time-span than is allotted to a typical paper at a conference.
- Summer schools — summer schools are an important dissemination channel to PhD students and early-career researchers because the speaker has considerably more time to present (perhaps several hours or a day) and can give a detailed technical treatment of the work, helping to disseminate information about methods and techniques to the next generation of researchers.
- Workshops — early presentation of research at workshops can garner valuable insights from other researchers which shape the work and its direction; small, focussed workshops provide an opportunity for deep technical discussion with other academics working in the same area and addressing similar problems.
- Software — software modelling tools are a proven vehicle for disseminating theoretical ideas to other researchers, bringing the theory to life and allowing it to be applied to other problems, in other contexts; software visualisation tools are helpful in bringing data to life, supporting dissemination to industrial partners.
- Working meetings — working meetings are different in context from structured presentations at academic gatherings: there is an agenda, rather than a programme, and a fluid discussion in a dialogue rather than a lecture; industrial collaborators are more likely to be involved.
- Website — our website <http://www.quanticol.eu/> is an important form of dissemination because it provides a single, unified resource for the outputs of the project, including papers, technical reports, software and deliverables.
- Videos — a video presentation allows the researchers on the project to speak directly to other researchers, even those in other time zones and different parts of the world. The QUANTICOL project is hosting videos on its website currently including our own video introduction to the QUANTICOL project available at <http://blog.inf.ed.ac.uk/quanticol/video/> and has participated in video interviews at FoCAS meetings and video-recorded panels at ICT 2013.
- Three-fold flyer — the three-fold flyer prepared by the project provides a brief introduction to QUANTICOL and its case studies. The QUANTICOL three-fold flyer is illustrated in Figure 2.

Part of a European network

QUANTICOL is a European research initiative involving the University of Edinburgh, Scotland; Consiglio Nazionale delle Ricerche – ISTI, Italy; University of Southampton, England; Ecole Polytechnique Fédérale de Lausanne, Switzerland; and IMT Lucca, Italy.

The QUANTICOL project is a member of Fundamentals of Collective Adaptive Systems (FOCAS, www.focas.eu), a Future and Emerging Technologies Proactive Initiative funded by the European Commission under FP7.

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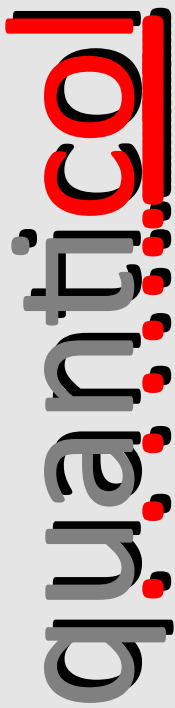









www.quanticol.eu









A Quantitative Approach to Management and Design of Collective and Adaptive Behaviours

EU FET Proactive Project, 2013–2017.
Grant number 600708.

www.quanticol.eu

Collective adaptive systems

Collective adaptive systems (CAS) consist of a large number of heterogeneous entities with decentralised control and varying degrees of complex autonomous behaviour. These entities may be competing for shared resources even when collaborating to reach common goals.

ICT-based CAS are at the core of the envisioned smart cities of the future and people are an intrinsic part of CAS: their actions and their feedback alter the behaviour of the system.

The QUANTICOL project

The pervasive but transparent nature of CAS, together with the importance of the societal goals they address, mean that it is imperative that thorough *a priori* analysis and verification of their design is carried out.

This should investigate all aspects of their behaviour before they are put into operation, including the timeliness of their response and their efficient use of resources.

The QUANTICOL project is developing innovative analysis tools to help to reason about collective adaptive systems during their design and while they are in operation.

Objectives

The main objective of the QUANTICOL project is the development of an innovative formal design framework with a specification language for CAS and a large variety of tool-supported, scalable analysis and verification techniques.

We are extending modelling and analysis techniques to meet the challenges of multi-scale systems.

These are often spatially heterogeneous systems and critical key parameters controlling their operation may be unknown or unknowable.

Application areas

We will exploit the technology developed in QUANTICOL to consider scenarios which might change the current provision of energy and transport services in cities, either on a shorter or longer term.

The development of our methodology will focus on the provisioning challenges of smart grids and smart urban transport initiatives such as bicycle sharing.

- An increasing number of large cities worldwide are using bicycle-sharing schemes to reduce vehicular traffic, pollution, and energy consumption.
- The research challenges here are the construction of efficient redistribution policies for vehicles and the creation of incentive mechanisms to improve load balancing within these systems.
- Cities where tourism plays an important economic role face operational challenges when they host major arts, sporting, or cultural events.
- Service providers will benefit from modelling tools which help them to plan their public transport.
- Electricity networks provide different challenges because of their multiple organisational scales, for example: local or large-scale production and decentralised consumption.
- Since the instantaneous supply of electricity must always meet constantly changing demand, operation of an electric power system involves a complex process of forecasting production and demand.




We will use mean-field analysis to provide heuristics for good suboptimal policies, in particular to account for spatial aspects and for systems incorporating electric vehicles.

Our science

Our techniques are based on the original combination of recent breakthroughs in stochastic process algebras and associated verification techniques, and mean field/continuous approximation and control theory.

The QUANTICOL design framework will provide scalable extensive support for the verification of developed models, and also enable and facilitate experimentation and discovery of new design patterns for emergent behaviour and control over spatially distributed CAS.

Open and accessible

The software that enshrines the design methodology will be made freely available through an open source license and will be supported by appropriate documentation available on the web.

Particular care will be taken to ensure that the results of the case studies are disseminated as widely as possible in the user community.

Figure 2: The QUANTICOL three-fold flyer has been distributed at ICT 2013 and DemoFest 2013 and other events, serving as a calling card for the project giving readers more information about the project and its aims as well as contact details.

2 Engagement with the scientific community

As previously stated, our engagement with the scientific community will largely proceed along traditional academic lines through the generation and publication of scientific papers and research results. We intend to publish in high-profile international conferences and the best quality journals.

2.1 Open access publication

Throughout the duration of the project we will endeavour to ensure that our publications are available via an *open access* arrangement (that is, they are freely downloadable by readers without payment of fees to publishers). There are two principal types of open access arrangements in widespread use:

Green open access: this is where the author's final version is available, without the publisher's markup and page numbering. This arrangement does not usually incur payment of fees to publishers.

Gold open access: this term applies when the publisher's final version is made available for free download. This arrangement often necessitates payment of fees to publishers to purchase this right.

In the QUANTICOL project we will prefer Green open access to Gold open access. We will also look for opportunities to publish in open access journals (for example, Logical Methods in Computer Science) where papers are distributed under a Creative Commons ShareAlike license. A similar arrangement is in place for publications in the Dagstuhl series.

2.2 Presentation of research results

The written word does not speak for itself. Presentations of research results in person at conferences, seminars, or other meetings are a vital tool for disseminating new ideas and new discoveries. Keynote talks and invited presentations are particularly important because they convey the sense that the work which is being presented is held in some esteem by the event organisers. Keynote speakers are typically accorded additional time in the programme and given a prestigious (often plenary) timetable slot.

Members of the QUANTICOL project have given many presentations, seminars, and keynote talks during the first year of the project.

- On June 3, 2013, Mieke Massink (CNR) gave a brief presentation of the QUANTICOL project at the 15th International Conference on Coordination Models (COORDINATION 2013) that took place in Florence as part of the 8th International Federated Conference on Distributed Computing Techniques (DisCoTec 2013). There were approximately 40 international delegates, mostly academic and mostly from the Formal Methods community.
- On June 22, 2013, Luca Bortolussi (CNR) gave an invited lecture about Fluid Model Checking techniques, partially developed within QUANTICOL, at the Bertinoro summer school on Formal Methods (<http://www.sti.uniurb.it/events/sfm13ds/>). There were approximately 30 people in the audience, predominantly PhD students coming from all over Europe.
- On June 25, 2013, Jane Hillston (UEDIN) gave a presentation of the QUANTICOL project to the Laboratory for Foundations of Computer Science lunchtime meeting. There were approximately 30 people in the audience, predominantly from the University of Edinburgh but several from other universities in Scotland.
- On 31st August, 2013, Jane Hillston (UEDIN) gave an invited talk at the 8th International Symposium on Trustworthy Global Computing (TGC 2013) in Buenos Aires, Argentina which

was essentially about the QUANTICOL project. There were approximately 30 people in the academic audience from around the world.

- On October 16, 2013, Vincenzo Ciancia (CNR) gave a presentation which included information about the QUANTICOL project in the Dagstuhl Seminar 13422, “Nominal Computation Theory”. The audience was made up of computer scientists interested in the recently born field of nominal automata, and a preliminary link was established during the presentation between this very abstract field and topological reasoning about (possibly infinite) behaviour of collective systems.
- On 10th February, 2014, Mirco Tribastone (SOTON) gave a seminar at the Dipartimento di Elettronica, Informazione, and Ingegneria of Politecnico of Milano, where he discussed some recent QUANTICOL results about the analysis of large-scale software systems¹.

2.3 Publications in journals and conferences

The publication plan for the QUANTICOL project seeks to promote the work of the project in many different scientific communities. We believe that disseminating the work of the project in many areas will help to increase its impact and influence.

The QUANTICOL project has published widely and prolifically in its first year, reporting on many different kinds of research contributions, including:

- an investigation of how stochastic process algebra can be combined with numerical analysis tools for the analysis of emergent behavioural aspects of collective adaptive systems [BLM13a];
- a study presenting our envisaged approach to the prediction and control of the behaviour of large-scale systems, based on formal methods for their rigorous and unambiguous specification, and an array of scalable and accurate underlying analytical tools [BDNG⁺13];
- learning and designing stochastic models from observations and requirements formulated in terms of satisfaction of temporal logic formulae, and recasting these in terms of learning and maximising an unknown likelihood function which can be numerically estimated at any value of the parameter space [BS13];
- using the Central Limit Approximation of Continuous Time Markov Chains to verify collective properties of large population models, describing the interaction of many similar individual agents [BL13];
- developing new approximate aggregation algorithms for large-scale discrete-state stochastic models, leading to an efficient derivation of an approximate marginal probability distribution over some of the model’s populations [PH13];
- inventing new bisimulation relationships between Markov processes characterising the notion of contextual lumpability for processes, and algorithms to compute these equivalences [HMPR13];
- developing accurate and scalable fluid approximations of systems in the presence of immediate actions, thereby avoiding problems of *numerical stiffness* which make intractable the stochastic modelling of software systems with activities of durations that are separated by many orders of magnitude [BT13];
- deepening our mathematical understanding of how systems with non-exponential service times behave under conditions of heavy load, by considering their limit behaviour [TT13];

¹http://www.deib.polimi.it/eventi/dettaglio.php?id_elemento=695&idlang=eng

- providing software tools to promote simulation results to statistical model-checking results through logics for property specification [SV13];
- extending and applying techniques from rewriting theory and constraint networks, leading to an algebraic approach to the design and transformation of constraint networks, inspired by *architectural design rewriting* [BLM13b, BCG⁺13];
- making foundational developments in the underpinning theory and semantics essential for defining the modelling languages used in the project [Cia13];
- making progress in our foundational understanding of the relationship between the discrete and continuous modelling regimes [BH13];
- developing constraint-based methods to describe features and run-time behaviour of systems, allowing for a variety of formal automated analyses of product families, ranging from consistency checking to model checking [tLP13]; and
- finding applications in other modelling domains beyond collective adaptive systems [GHS13, BBNS13].

One way to summarise this body of work is to examine the publication venues to get a sense of the audiences which the QUANTICOL project has reached in its first year. A summary histogram is presented in Figure 3.

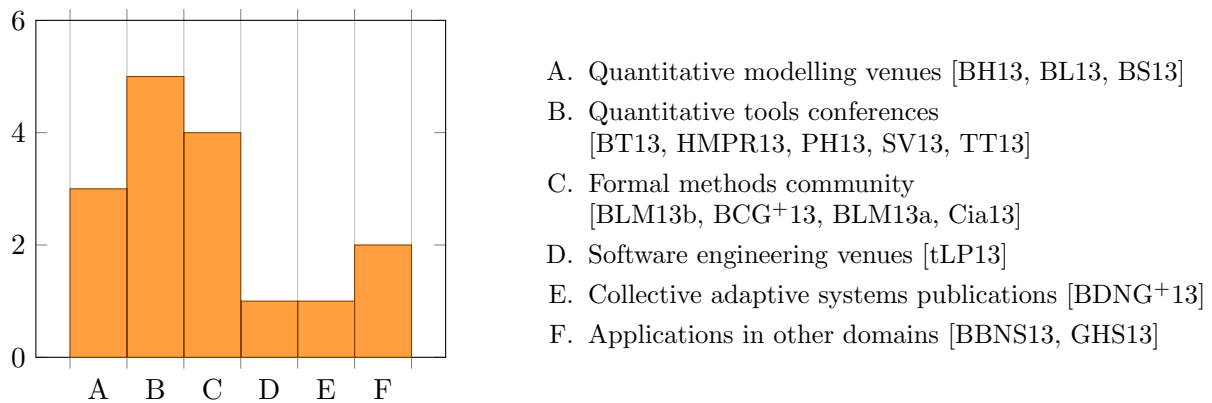


Figure 3: Histogram showing the distribution of QUANTICOL publications in different publication venues

2.4 Technical reports and preprints

Scientific publication can be a lengthy process, due to the rigorous reviewing and revision of published work and the inescapable delays incurred by the printing process and other material constituents of a well-managed publishing process. It is not uncommon for the delay between a paper being completed (from the author’s point-of-view, where they are making no other changes to the paper) to published (with all necessary publisher’s marks, assigned a Digital Object Identifier (DOI), and indexed in a repository) to vary from six months to two years.

In this setting, the QUANTICOL project wishes to expedite the dissemination of project outputs and has identified two preferred routes to making project results available to the wider community in a timely manner. The first is the publication of a technical report series for the project which allows the publication of work-in-progress and preliminary papers in advance of a formal publication.

The first technical reports in this series have now been published. The reports are available from the QUANTICOL web site at <http://www.quanticol.eu>.

2013:

- D. Latella, M. Loreti and M. Massink. *On-the-fly PCTL Fast Mean-Field Model-Checking for Self-organising Coordination*. Preliminary version. QUANTICOL TR-QC-01-2013. December 17, 2013.
- M.H. ter Beek, S. Gnesi, and A. Fantechi. *Chaining available tools to support the modelling and analysis of a bike-sharing product line: An experience report*. TR-QC-02-2013. December 20, 2013.
- M.H. ter Beek, S. Gnesi, and F. Mazzanti. *Model Checking Value-Passing Modal Specifications*. TR-QC-03-2013. December 20, 2013.

2014:

- V. Ciancia, D. Latella, M. Massink. *Logics of Space and Time*. TR-QC-01-2014. January 08, 2014.
- G. Iacobelli, M. Tribastone, A. Vandin. *Differential Ordinary Lumpability in Markovian Process Algebra*. TR-QC-02-2014. Feb. 04, 2014.
- D. Latella, M. Loreti, M. Massink, V. Senni. *Stochastically timed predicate-based communication primitives for autonomic computing - Full Paper*. TR-QC-03-2014. Feb. 05, 2014.
- R. Pakauskas, L. Bortolussi. *Multiscale Reductions of Mean Field and Stochastic Models*. TR-QC-04-2014. Feb. 05, 2014.

The second is through publication in a well-established preprint series. QUANTICOL papers are also disseminated via arXiv.org, a highly-automated electronic archive and distribution server which is an e-print service which is widely used in the fields of physics, mathematics, computer science, quantitative biology, quantitative finance and statistics. The following are examples of QUANTICOL-supported research leading to preprints which have been disseminated in this way.

- *On the Robustness of Temporal Properties for Stochastic Models*, Ezio Bartocci, Luca Bortolussi, Laura Nenzi and Guido Sanguinetti, arXiv:1309.0866, 3rd September 2013.
<http://arxiv.org/abs/1309.0866>
- *Incentives and redistribution in bike-sharing systems with stations of finite capacity*, Christine Fricker and Nicolas Gast, arXiv:1201.1178, 25th September 2013.
<http://arxiv.org/abs/1201.1178>
- *On-the-fly Fast Mean-Field Model-Checking: Extended Version*, Diego Latella, Michele Loreti, Mieke Massink arXiv:1312.3416, 12th December 2013.
<http://arxiv.org/abs/1312.3416>
- *Learning Temporal Logical Properties Discriminating ECG models of Cardiac Arrhythmias*, Ezio Bartocci, Luca Bortolussi and Guido Sanguinetti, arXiv:1312.7523, 29th December 2013.
<http://arxiv.org/abs/1312.7523>

The choice of whether to disseminate a new research output as a technical report or an arXiv preprint or to wait until the official publication is left to the authors of the work to decide on a case-by-case



Figure 4: The QUANTICOL project participated in workshop activities at the first FoCAS Inter-project meeting which ran from June 4th to 5th 2013 at the Centre for Genomics Research, Barcelona, Spain.

basis. No course of action is mandated by the project, but timely dissemination of work is encouraged in whatever form the authors think is appropriate.

3 Engagement with the FoCAS community and beyond

3.1 Public engagement

Moving beyond our academic circles, the members of the QUANTICOL project are keen to present the work of the project publicly. Our first example of this came on April 4, 2013 when Jane Hillston (UEDIN) gave a presentation which included information about the QUANTICOL project at the Edinburgh International Science Festival in the event *E2: The Edinburgh Enlightenment Exchange: Futureshock*. The audience was made up of members of the general public and there were approximately 100 people present.

3.2 Participation in FoCAS community events

The *Fundamentals of Collective Adaptive Systems* (FOCAS) coordination action is an umbrella project which creates and organises workshops, meetings and training for the FOCAS Proactive Initiative. The QUANTICOL project participates enthusiastically in these events in order to further disseminate its research contributions to the collective adaptive systems community.

- In June 2013, Stephen Gilmore (UEDIN) and Luca Bortolussi (CNR) attended the FoCAS coordination action in Barcelona. (See Figure 4.) All FoCAS projects were represented at the meeting. There were 35 delegates, all academic. Stephen Gilmore presented a short introduction to the QUANTICOL project which was featured on the FoCAS website at <http://focas.eu/focas-inter-project-meeting-2013/>. Stephen Gilmore and Luca Bortolussi participated in workshop activities with the other project members. Stephen Gilmore recorded a short video interview which is available on the FoCAS website at <http://focas.eu/stephen-gilmore/>.
- On 2nd September 2013, Mirco Tribastone (SOTON) gave a presentation about the QUANTICOL project at the *1st FoCAS workshop on the Fundamentals of Collective Adaptive Systems*, co-located with ECAL 2013, Taormina, Sicily, Italy. There were approximately 30 participants, some of whom were not related to FoCAS.

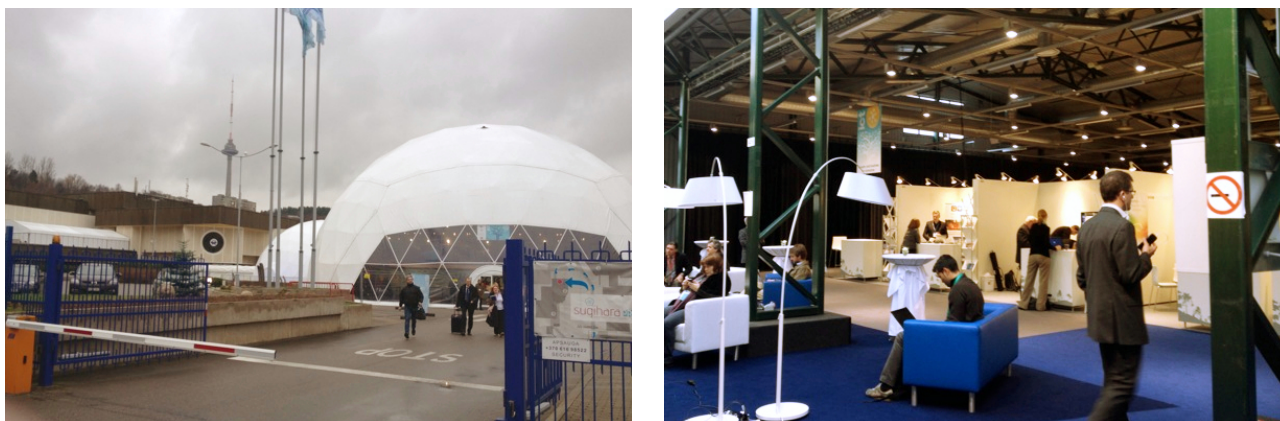


Figure 5: The QUANTICOL project participated in panel discussions at the ICT2013 meeting in Vilnius, Lithuania in November 2013

- On 7th November 2013, Vashti Galpin (UEDIN) took part in a panel on FoCAS on multidisciplinary approaches for smart, green and integrated transport at ICT 2013 in Vilnius, Lithuania (see Figure 5). The panel was chaired by Alois Ferscha (JKU, Linz; FoCAS CA), and the panelists were Vashti Galpin (UEDIN; QUANTICOL), Linh Truong (TU Wien; SmartSociety), Nikola Serbedzija (Fraunhofer Fokus Berlin; ASCENS), Kim Larsen (Aalborg University; CASSTING), Naranker Dulay (Imperial College London; ALLOW Ensembles) and Franco Zambonelli, (UNIMORE; FoCAS CA). The panel was organised by Jennifer Willies (Edinburgh Napier University), the FoCAS CA project manager.

The panel members spoke first about aspects of multidisciplinary research in the context of transport. The subsequent discussion considered cooperative versus competitive modelling approaches, after which it focussed on car use and how people could be convinced that they should use their car less or not at all. Another issue was the loss of privacy if a city car scheme is used. The discussion illustrated that this type of research requires input from the social sciences.

Vashti Galpin spoke about the availability of data and how this differed between different disciplines and raised the challenge of inferring user behaviour from usage behaviour, particularly for those users whose requirements cannot be satisfied, for example, in the case of an empty bike station or a full bus.

3.3 Contribution to FoCAS outputs

The QUANTICOL project is committed to supporting the FoCAS coordination action through contributing content, images and graphics to FoCAS outputs, helping to bring the work of the project to the attention of the FoCAS community. One example of this was an article published in the FoCAS newsletter in January 2014 (see Figure 6).

3.4 Engagement with other projects in FoCAS

Separately from the FoCAS coordination action, members of the QUANTICOL project have built connections to other projects directly.

- On May 15, 2013, Mieke Massink posted a brief description of QUANTICOL to the blog of the related EU-IP ASCENS project: <http://www.ascens-ist.eu/>. The QUANTICOL and ASCENS projects came together for a joint meeting hosted at EPFL in Lausanne, Switzerland, in July 2013.

- On 1st October 2013, Stephen Gilmore (UEDIN) and Mirco Tribastone (SOTON) attended the second project meeting of the CASSTING project, another FoCAS project, in Aalborg, Denmark. Stephen Gilmore gave a short presentation about the QUANTICOL project. There were 38 delegates at the meeting, including representatives from the industrial partners.
- On 14th February 2014, Jane Hillston, Allan Clark, Daniël Reijsbergen, and Stephen Gilmore (UEDIN) met members of the Smart Society FoCAS project including Michael Rovatsos to learn about each others' projects and learn about potential areas of collaboration.

3.5 Engagement with other projects and communities beyond FoCAS

Further connections to other projects and communities have spread the QUANTICOL message beyond the collective adaptive systems community.

- On July 17, 2013, Luca Bortolussi (CNR) gave an invited talk at the annual meeting of the APS INFORMS society in San José, Costa Rica, on fluid model checking (<http://aps2013.eie.ucr.ac.cr/>). There were approximately 25 people in the audience, coming from the Applied Probability Society (APS) academic community, where there is not much awareness of model checking techniques.
- On 18th November 2013, Maurice ter Beek gave an invited presentation at the Copenhagen Meeting on Variability Analysis at the IT University of Copenhagen, Denmark. This was the kick-off meeting of the Danish project VARIETE (Variability in Portfolios of Dependable Systems). The audience consisted of 15 computer scientists (one from industry, a few visitors from abroad and the participants of the project, predominantly from the IT University of Copenhagen) with affinity to formal variability analysis. The talk included general information about the QUANTICOL project, as well as a report of two recently submitted initial investigations performed by Maurice ter Beek, Stefania Gnesi and others from CNR into (quantitative) variability analyses of a product family of bike-sharing systems.

3.6 Future outlook for dissemination activities

Together with other project leaders working in the collective adaptive systems field, Jane Hillston (UEDIN) will coordinate a week-long Schloß Dagstuhl seminar on *Qualitative and Quantitative Modelling and Analysis of Collective Adaptive Systems* from 15th to 19th December 2014. This prestigious invitation-only event will bring together leading researchers in the CAS and autonomic systems communities for an intensive residential research seminar which will enrich and inform future research on CAS.

4 Engagement with smart city system owner and user communities

We believe that the most effective way to engage with smart city owner and operator communities is not through traditional peer-reviewed publications but rather through engagement and interaction directly and through the provision of software and services to be made available to the owner and operator community. In this section, we describe our work in this vein.

4.1 Development of software and demonstrators

The QUANTICOL project is working with bike-sharing data from Transport for London and FIAB-Pisa and with automatic vehicle location data provided by smart transport owners and stakeholders such as Lothian Buses and the City of Edinburgh Council. This data is a vital component of our modelling, allowing us to validate our data against genuine measurements and to ensure that the

quanticol

a quantitative approach to management and design of collective adaptive behaviours

Case Study: Model-checking Edinburgh buses

One of the case studies in the QUANTICOL project is concerned with modelling and analysing the public transport system in the city of Edinburgh, with a specific focus on the bus network. Buses in Edinburgh are thoroughly instrumented with GPS positioning instrumentation, and report their latitude and longitude every thirty seconds back to a central server which uses a predictive model to estimate arrival times at bus stops. These predictions are relayed back to passengers of the bus service using on-street signage, made accessible via a web site, and delivered by smartphone apps.

The Traffic Commissioner for Scotland sets standards for bus operators mandating the percentage of buses which should be on-time for services (that is, they depart from their stop no more than one minute early and no more than five minutes late for specific timing points along the route). The gravity and seriousness of these definitions was made clear when the Traffic Commissioner for Scotland held a public enquiry into the operation of Edinburgh's Lothian Buses in response to a complaint about buses running too early. The public enquiry and the subsequent decision of the Traffic Commissioner were reported in national newspapers.

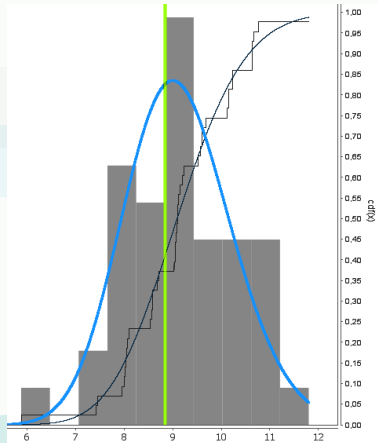
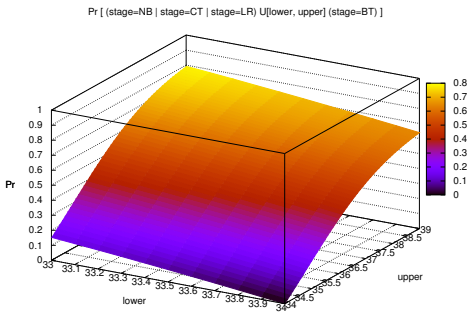
Using measurement data from the city's automatic vehicle location service, the QUANTICOL project has been able to build accurate stochastic models of Edinburgh's bus services. Using this it is possible to determine whether potential changes to their service would expose a bus company to liability in the future.

The first step was to find an appropriate stochastic model which would capture the variability in the bus service due to delays which occur for operational reasons such as traffic conditions, passenger boarding and alighting, and road congestion. Empirical distributions of journey times were used as an input for the HyperStar tool for fitting phase-type distributions to data sets, producing a phasetype stochastic process as the result.

Phase-type distributions have the desirable property that they can approximate any distribution with non-negative support arbitrarily closely and can also be represented as continuous time Markov chains. This allowed the QUANTICOL researchers to reformulate the problem as a modelchecking problem and verify probabilistic logic formulae against this model.

This efficient modelling method meant that the researchers on the project can compute the probability of completing a journey within a specified window of tolerance on arrival times. Varying the upper and lower bounds on the time of arrival allows the modellers to see whether the bus service could operate under stricter terms of operation or whether there is no potential for this because they are already near to failing to meet their targets for on-time arrivals.

A future modelling problem is the representation of hybrid buses which, in addition to meeting their time bound on arrival, would like to arrive within the energy bound imposed by the capacity of their battery. Representing these two dimensions in the model will be a new challenge for the QUANTICOL project to tackle. **Stephen Gilmore**

blog.inf.ed.ac.uk/quanticol

Figure 6: The QUANTICOL project was featured in issue 2 of the FoCAS community newsletter with an article on modelling Edinburgh buses using the QUANTICOL methods and tools.

results computed by our models have genuine predictive power. Among other uses, an important function of the data is to allow us to parameterise our models with rates, probabilities, and capacity information. This allows us to incorporate the essential details which ensure the accuracy of our models.

The first step in our journey in moving towards accurate and powerful models is to fully explore the data and to understand its strengths and limitations. To this end, the QUANTICOL project formulated a plan to create a novel visualisation of the real-time vehicle tracking data which was provided by Lothian Buses. The intention was to make a visualisation which was accessible to three constituencies of users:

- the academic members of the project who are experts in modelling, but are not experts in transport provision and regulation;
- regulatory bodies who are responsible for setting standards and targets for transport provision, punctuality, and service; and
- transport operators who are experts in transport service implementation and regulation, but who are not experts in data analysis and modelling.

Jane Hillston (UEDIN) specified a web-based visualisation service for Lothian Buses data which was implemented by her MSc student Shao Yuan and later extended by Daniël Reijbergen. (See Figure 7.) The visualisation application is based on a browser-server architecture, and is able to visualise genuine bus traces around Edinburgh using Google maps. The application can visualise multiple bus routes on the map simultaneously, with each individual bus and time period being selectable by the user. Historical bus movements are stored in a local database, and are retrieved and visualised on the Google map according to the user's interests and requirements. This facility to replay the events of a day was appreciated both by representatives of the bus company and the city council. On occasions where an event such as a traffic accident or a burst water main has significantly disrupted traffic flow it is necessary to later review the bus company's response to this problem and discuss whether a different response would have been better. The ability to review events and study patterns of bus movement is helpful in understanding the impact of the alteration to journeys and journey times.

Extending from this, the visualisation software is now able to display *post-hoc* analysis of events, representing information which is computed from multiple trajectories and records of bus movement. A focus of this activity is the Princes Street area of Edinburgh, the main artery for vehicles travelling between the north and the south of the city, and between the east and the west. This street experiences high volumes of traffic and significant congestion, making it of significant interest to the city council and to the bus company. The QUANTICOL project defined an irregular patch structure over the street, subdividing it into areas which contained at most one stop point for buses (either a bus stop or a traffic light). Using the location data provided, the project constructed a *heat map* of the area from the provided GPS data, showing where buses were most likely to be stopped (See Figure 7, middle.)

4.2 Working meetings with owner and user communities

Because of the different nature of our interaction with owner, operator and stakeholder communities in smart transport, we planned to structure these meetings as “working meetings” founded on dialogue and discussion, rather than presentations concerned with information dissemination. These meetings have been vital in eliciting and shaping the priority areas of the project for the case studies and modelling work undertaken.

- On 2nd October 2013, Jane Hillston and Daniël Reijbergen (UEDIN) met with the City of Edinburgh council to elicit requirements and identify transport-related problems and questions which were of genuine interest to the city. This meeting identified several problems which were identified as possible future priorities for the modelling in the project.

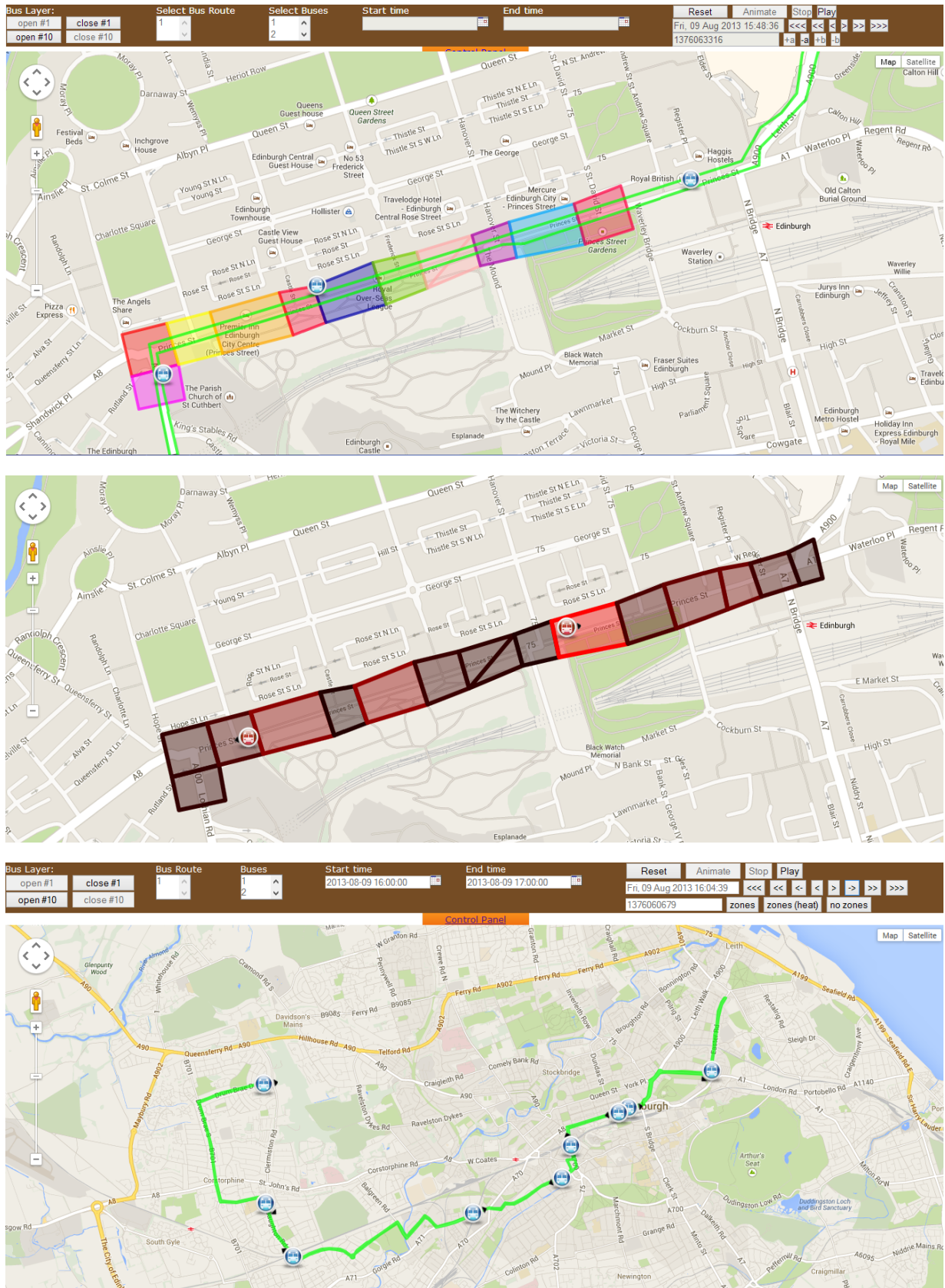


Figure 7: Visualisations of Lothian buses data created by the project. Top: an isolation patch view identifying bus stops and traffic signals on Edinburgh's Princes Street. Middle: a heat map view highlighting residence periods. Bottom: a route view showing bus route number 1.

- The new controllers in traffic lights, which would allow a bus approaching a junction to send a “late” signal (delaying a light change in order to give the bus a chance of recovering the timetable) are an object of study and interest.
- Princes Street and the congestion of buses there is a major concern.
- Princes Street is also subject to particular congestion problems at specific times of year, such as during the Festival.
- The City Council has an ambition to move to a 20mph speed limit throughout the city centre.

The meeting also briefly discussed the availability of data. The MyBusTracker API provided by the city council offers good data on the static information about bus routes, stops, chainage points etc, and estimates of arrival times and journey times. However, actual data from the buses is reported to Lothian Buses for operational purposes through the software system provided by INEO in France. The bus positioning data is reported every 30 seconds but not routinely stored, nor does it seem straightforward for Lothian Buses to switch recording on either selectively, or for the whole system. This was identified as an issue which should be investigated further and discussed with Lothian Buses.

- On October 21st 2013 Jane Hillston (UEDIN) met with Cecilia Oram from Sustrans, a UK charity whose objective is to encourage sustainable transport, with a primary focus on walking and cycling, but some interest also in buses. The meeting discussed the QUANTICOL modelling case studies related to smart urban transportation. From this meeting we learnt that the London bike-sharing scheme solves the bike redistribution problem by using Large Goods Vehicles to redistribute bikes. We also learned that Glasgow will be starting a bike-sharing scheme in 2014 and that it could be beneficial to link to the Glasgow Future Cities project as they are considering active travel, social transport, and energy efficiency which correspond very well with the QUANTICOL case studies.
- On 21st November 2013, UEDIN held a working meeting with Lothian Buses. The main topics addressed during the meeting were:
 - presenting the progress made regarding the bus data visualisation tool developed at UEDIN,
 - discussing preliminary results obtained through scientific modelling and data analysis,
 - asking for clarification of certain behaviour observed in the data, and
 - discussing what types of additional data could be provided.
- On 22nd November 2013 Mieke Massink (CNR) attended a meeting of FIAB-Pisa (Federazione Italiana Amici della Bicicletta — Italian Federation of Bicycle Friends) where Marco Bertini, responsible for the “Bikes Office” of PISAMO running the shared bikes system in Pisa, gave a presentation on the bike-sharing system in Pisa. The meeting was attended by approximately 30 people, many of them interested in the new bike-sharing system *Ciclopi* in Pisa that started its activities in May 2013. The idea for attending this meeting from the perspective of the QUANTICOL project was to get in touch with the user-community of bike-sharing systems and hear about their experiences. At a later stage the idea is to organise a meeting in which some results obtained within the QUANTICOL project concerning bike-sharing can be presented at a FIAB meeting. The bike-sharing system in Pisa currently consists of 14 bicycle parking places involving 200 bicycles. As of November 2013, there were 500 bike trips per day of on average 13 minutes each. Two small trucks are used to redistribute the bikes when needed and to repair broken bikes. The system runs 24 hours per day and 7 days a week. The largest user community in Pisa (60%) consists of university students. During the presentation it was also briefly mentioned that there is an on-going research collaboration with CNR.

4.3 Participation in trade shows and industry-focussed meetings

On 5th November 2013, Stephen Gilmore and Daniël Reijsbergen from UEDIN presented the QUANTICOL project at Demofest 2013, an industry/academia meet-up in Glasgow. There were approximately 200 delegates at the event, which was held in the Mitchell Library in Glasgow. QUANTICOL was assigned a stand at the event, suitable for hosting a laptop computer and a poster in a structured format presenting the main themes of the project in the form of bullet-point lists. (See Figure 8.)



Figure 8: Dissemination of the QUANTICOL project at the DemoFest meeting in Glasgow, Scotland in November 2013

5 Conclusions

The QUANTICOL project has formulated a dissemination plan for the project. It has identified a high-level strategy for engagement with interested parties outside the project. It has enumerated and will pursue a range of dissemination activities through the project, choosing particular types of dissemination as appropriate for particular audiences. Progress has been made in each kind of dissemination activity during the first year of the project. Plans have been put in place for future dissemination activities to ensure that the QUANTICOL project will play a central role in shaping thinking and research on using quantitative modelling and analysis to understand and enrich collective adaptive systems.

6 Acknowledgements

The authors thank Nicolas Gast for his careful proof-reading of this deliverable and many helpful comments which improved the presentation.

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