Medieval Warfare on the Grid: The Case of Manzikert

RESEARCH QUESTIONS OR PROBLEMS

The need for mediaeval states to collect and distribute resources to maintain armies affected all aspects of political organisation and at critical times, when armies failed, the results could prove disastrous to society. Despite this, military studies seldom progress past the study of existing texts to bear out the pragmatic consequences of military behaviour, even though military activity in terms of resource allocation and consumption was decisive in shaping pre-modern societies. This project gathers historians, archaeologists and computer scientists in a project aimed at modelling logistical arrangements relating to the battle of Manzikert (AD 1071)[1], a key event in Byzantine history. The defeat of the Emperor Romanos IV Diogenes by the Seljuk Turks, and the civil war that followed, resulted in the collapse of Byzantine power in central Anatolia. These events were so traumatic, and the association with Manzikert so profound, that the defeat became known as 'the dreadful day'. Given the significance attributed to these events and, ultimately, the collapse of Byzantine power regionally, the lack of consensus between historians on the numbers of men involved at, or even the route taken by the Byzantine Army to, Manzikert is profound. Repeated debate on the arrangements leading to this critical encounter suggest the need for alternative methodologies that can break cycles of academic claim and counter-claim, have a wider applicability to military research and appreciate the role of military studies within broader cultural studies.

This project will provide a fundamental re-analysis of the Manzikert campaign and illustrate the use of Grid-aware distributed simulation techniques to model movement and sustainability of historic armies. The study will involve multiple simulations of varied army units moving within a digital environmental database collated at Birmingham. Alongside primary and secondary source material, the data will be used to interpret events related to the battle and assess contemporary interpretation of historic sources. Such simulation methodologies have a wide applicability and allow the re-use of models and processes in comparable regional or period studies.

Project goals are:

- To establish a novel, rigorous computational frameworks for analysis of historical, military logistical data (pertaining to movement, communications settlement; production, allocation, consumption of resources) for the early medieval periods in Europe and the Near East, using environmental data held at Birmingham, and as a collaborative research programme between Birmingham's Institute of Archaeology and Antiquity and Department of Computer Science.
- To create a reusable GRID-enabled simulation and data analysis infrastructure, that supports the framework outlined above.
- To utilise a GRID modelling framework to improve our understanding of the central role of warfare and conflict in the medieval periods. To use the results of multiple simulations of the Manzikert campaign to critique previous research.
- To demonstrate, using Manzikert, the opportunities provided the historical community by large-scale distributed simulation technologies and present fundamentally new insights into established historical questions.

RESEARCH CONTEXT

Armies possessed a role within mediaeval states that extended beyond their military function. The need to maintain permanent military structures ensured that military groups were formative in structuring society, affecting most aspects of political organisation, resource allocation and consumption. Although decisive in shaping pre-modern societies and despite academic interest in military history of all periods, research sel-

[1] An account of the battle is provided at (http://www.iaa.bham.ac.uk/research/fieldwork_research_themes/projects/logistics1/manzikert.htm).

dom progresses past the study of existing texts to explore the implications of military behaviour[2]. A methodology for analysing pre-modern military logistics is required which places campaigns within their wider cultural context. To achieve this, factors in the organisation of medieval societies (communications, resource production and consumption) must be integrated within an historic framework incorporating settlement data and land-use. Although these themes have been the object of study, they are frequently characterised by unproven assertions and rarely tested against a range of evidence. This project will bring together historians, experts on archaeological settlement and environmental specialists, to provide a strong set of models representing the behaviour of armies that can be implemented as part of a large distributed simulation exercise.

Whilst the historic outcome of the battle of Manzikert appears clear, its wider significance is contentious. There is uncertainty concerning the nature and disposition of Byzantine forces prior to battle and even aspects of the route taken to Manzikert. Clearly, our interpretation of this important event is limited if we cannot establish, with some certainty, the parameters of the military forces involved, the nature of the action and, ultimately, the wider historic context of the defeat. However, repetitive argument over sparse references within mediaeval texts gets us no closer to understanding these issues, and even results produced by competent and wide-ranging scholars remain subjective. The goal of the project will be to model the movement of a range of troop dispositions suggested for Manzikert against the terrain and environment, and to compare data with the historic account of the battle. The route from Constantinople to Manzikert is not actually explicit in the sources, although communication and resource data suggest that there were, perhaps, only two options. This is critical as logistical requirements for these routes are central to current debate on how Manzikert was fought and the numbers of troops involved. This will be subject to multiple simulation events to identify best fit. In cultural terms there will be the requirement to consider the physical context of the campaign, historical structures evolved to meet logistical demands and logistical responses to warfare or the nature of Byzantine support for the military more generally. This project builds on work by the Birmingham/Princeton Medieval Logistics Group, and addresses these issues directly through a novel GRID-based, distributed simulation. The results will have significant implications for study of pre-industrial societies in methodological and theoretical terms and will benefit academics with an interest in comparative military history, the cultural role of military organisation and the relationship of historical and modelled data.

RESEARCH METHOD

The project benefits from more than 3 years planning by the Medieval Logistics Group[3], and is supported by output from two of the group's workshops, involving c.40 specialists from Britain, USA, France, Italy, Austria, France and Turkey and including Byzantinists, historians, archaeologists, palaeoenvironmentalists, computer scientists, geographers and military logisticians. The historical and technical requirements for the study were published in a dedicated volume, "*General issues in the study of medieval logistics*" (J. Haldon, 2005). In line with this work the project will place Manzikert within a methodological framework constrained by the broader ecological and physical environment derived from digital datasets held at Birmingham as well as historic and cultural parameters defined by the project team and academic advisory committee.[4]

The Research Consortium

The PIs provide important complementary experience through their involvement with the Medieval Logistics Research Group, archaeological computing, modelling and distributed simulation, GRID and cluster computing. The project has a substantial advisory group (listed in the technical appendix attachment) to give advice on interpretation of complex historical data and technical implementation of the simulations.

Given the difficulties of interpreting the historical context of Manzikert, and in the absence of new historical sources, only a rigorous modelling exercise, guided by an experienced multidisciplinary team, is likely to break the cycle of claim and counterclaim. The team provides the necessary expertise to create a distributed,

[2] Literature dedicated to military history is immense and varied. A selection of references is provided at http://www.iaa.bham.ac.uk/research/fieldwork_research_themes/projects/logistics1/manzikert.htm

[3] (http://www.iaa.bham.ac.uk/research/fieldwork_research_themes/projects/logistics1/logistics.htm)

[4] The project was initially proposed as an EPSRC e-science demonstrator (EP/E00895X/1), although such information cannot be submitted on the JES form)

Agent-based simulation framework that can model military behaviour and campaigning, using contemporary historical evidence: providing a methodology for analysing military logistics and their wider social significance for other regions and periods.

Modelling and forecasting using descriptive agent-based simulation

Agent-based simulations are increasingly used to model social systems. Running agent-based models as simulations can generate hypothetical explanations of events that challenge existing, or support new, hypotheses. Although hypotheses can be generated without simulation, e.g. using static tools such as data mining, the results from simulation can lead to unexpected hypotheses that can be tested. Models generated from undirected data mining and without domain expert knowledge are "bottom-up" exercises and can make predictions that are irrelevant or contain no new information. By contrast, descriptive agent-based models make full use of expert knowledge. The consequences of a model's rules are not known in advance and the model, as a simulation, can generate unexpected outcomes. These properties may be used to form hypotheses that lead to further, focused data collection or directed analysis.

This project will develop models of different actors related to the Manzikert campaign, derived from secondary and primary sources. These will be used in agent-based simulations to analyse events and generate "what-if" scenarios based on models of military behaviour. Simulations will run at different levels of abstraction, (soldiers and commanders, army units, geographical regions). These models will provide understanding, have explanatory value for the end user and assist in the analysis of medieval warfare.

A number of methodologies offer substantial opportunities for descriptive modelling within this environment. Foremost is "Optimal Foraging Theory". Originating in classical mathematical biology[5], this emphasises the advantages of behavioural strategies that maximise net energy intake per unit time spent foraging. Although armies fit the general parameters of optimal foraging theory well, such models have rarely been applied because they rarely support cultural constraints. However, modified foraging theory accepts important cognitive and cultural controls, including lack of information on which to base decisions. As premodern campaigns were often characterised by ignorance of local conditions, this suggests that ancient campaigns should approximate modified foraging behaviour and that this can be modelled.

Foraging models demand an approximation of the environment as well as a technical base to permit analysis and modelling. Previously, few technologies could adequately approximate 4 dimensional models (X, Y, Z values plus time/movement), and iterative path finding algorithms are central to this application. Shortest path analyses, using the A* algorithm, should be helpful with routes to battle determined by looking at each action performed within the terrain and the new states generated by previous actions. Together with Game Theory, decision theory, probability and associated statistical methods these will provide the mathematical basis for decision-making. These procedures require the input of substantial historic and environmental databases at Birmingham, data on the physical context, historic administrative structures supporting logistical decisions and the social responses to warfare. These sources provide essential data pertaining to communications; production/allocation/consumption; and settlement patterns in the early Byzantine periods. The expertise provided by the PIs and advisory group supports the generation of behavioural rules and historic constraints for the model.

Simulation Interoperability Frameworks and Grid Technologies

Development of complex simulation applications is typically an interdisciplinary enterprise requiring collaborative effort from researchers with different expertise. Occasionally, appropriate model are readily available but it is likely that new models must be developed. Creating a new model for each new problem is wasteful; an alternative envisages the researcher drawing on existing work, combining and adapting components developed by others. For example, models of terrain, vegetation or even people can be input to create a new model. In doing so, researchers reduce development time and draw on the expertise of scientists who created the adapted components.

[5] MacArthur, R.H. and Pianka, E.R. 1966, 'An optimal use of a patch environment', *American Naturalist* 100, 603-9

The last decade witnessed an increasing interest in distributed simulation, not simply to speed up simulations but also to link disparate simulation components and data sources at multiple locations to create a common virtual environment. This has culminated in the development of High Level Architecture (HLA), a framework for simulator reuse and interoperability recently adopted as an IEEE standard. HLA is being widely adopted within the simulation community; HLA-compliance will be an increasingly important feature of simulators.

Using HLA, a simulation links a number of geographically distributed simulation components (Federates), into a single larger simulation (Federation). A Federation consists of one or more Federates, a Federation Object Model (FOM), and the Runtime Infrastructure (RTI). Each Federate can model a single entity (e.g. an agent), a number of entities or have a different purpose (e.g. a data logger or viewer used to 'steer' a simulation. It may act as a surrogate for a human participant, reflecting the state of the larger simulation to some user interface and conveying decisions from the participant to the rest of the simulation). The FOM defines types and relationships between data exchanged by Federates. The RTI middleware provides common services to Federates. Communication between Federates or Federations is via the RTI. The emergence of Grid technologies provides new opportunities for distributed simulation, enabling collaboration and use of distributed computing resources, whilst facilitating access to geographically distributed data sets. Recently, there has been an increasing interest in utilising Grid technologies to execute HLA simulations over the Internet. An important initiative here is the HLA-Grid system, prototyped at NTU, Singapore and developed further in Birmingham. In HLA-Grid, Federates are instantiated as Grid services to facilitate communication between Federates and the RTI.

Programme and Methodology

This project will develop a generic, reusable Grid-enabled infrastructure that will integrate descriptive agent-based simulations, environmental models, data sources and visualisation facilities to enable the analysis of medieval warfare events, using Manzikert as a case study.

As a simulation toolkit, we anticipate using RePast,[6] a Java-based toolkit for development of lightweight agents and agent models. RePast was developed at Chicago's Social Science Research Computing division and is derived from the Swarm toolkit. It has become a popular and influential toolkit, assessed as the most effective development platform available for large-scale simulations of social phenomena[7]. As part of the DS-Grid e-Science project[8], Birmingham developed HLA_RePast, a system for executing agent-based simulations with HLA. HLA_RePast permits integration, through an HLA federation, of multiple instances of RePast. Within the same project, HLA_RePast has been integrated with HLA_Grid for the execution of Grid simulations. Visualization requirements are provided through the substantial facilities in the HP VISTA Laboratories.

Birmingham's Anatolian datasets will be, transformed, Grid-enabled and interfaced to HLA. These will be used to create a basic terrain model (constituting a federate). Environmental attributes can be integrated into the federate and, in addition, the *Tabula Imperii Byzantini* maps provide valuable route and settlement data. An initial army model (a second federate) will be created using a limited number of men moving over a fixed distance and taking a fixed number of days. Using nutritional theory, energy input and expenditure over time will then be calculated. This simple model will be made more complex by incorporating concepts including Optimal Foraging Theory, game, probability and decision theory, network analysis, planning algorithms and more complex cognitive models. The next step demands elaboration of the model integrating cavalry and pack mules (a separate federate), using the Birmingham database for calculating provisioning and transport requirements/opportunities. The integrated system will be used to model the Manzikert events and a series of "what-if" scenarios in line with research questions relating to combatants and route factors.

Integration of the different components of the framework will start early in the project to enable the production of a prototype and an evaluation phase during the middle of the second year. Feedback from this will be

[6]. http://www.econ.iastate.edu/tesfatsi/RepastTutorial.Collier.pdf

[7] Robert Tobias and Carole Hofmann. Evaluation of free Java libraries for social-scientific agent-based simulation. *Journal of Artificial Societies and Social Simulation*, 7(1), January 2004.

[8] DS-Grid is funded by the e-Science programme as a project with Nanyang Technological University in Singapore. http://www.cs.bham.ac.uk/research/projects/dsgrid

used to finalise the work and to produce the final infrastructure. The project will conclude with a comprehensive evaluation.

PROJECT MANAGEMENT

The project consists of eight Work packages outlined, with the timetable and milestones, in the technical appendix. The PIs will manage the project. Primary direction will be through a Management Group (Principal Investigators, Research Fellow and the Postgraduate Researcher) via regular meetings. An Advisory Board includes experts from related academic fields plus representatives of the e-Science community and will meet every six months, via the Access Grid, to guide and ensure that project objectives goals are met within the timetable (see technical appendix). The use of the Access Grid also permits frequent informal meetings and a greater level of support than is usual for such projects. A local technical committee will manage IT support and GRID resources through the University Information Services (See above section 1A).

Funds are requested to employ a postdoctoral Research Fellow for three years to work on technical aspects of simulation and Grid applications. As experience of these technologies is missing within the Humanities, the Fellow will be managed through the School of Computer Science but supervised by both PIs.

Funds are requested for a PhD student to work on the descriptive agent-based models, the historical and environmental sources available at Birmingham and to integrate these within the GRID application. The student will be supervised by the PIs and managed through the Institute. Resources required to fulfil the project are substantial but largely provided by the University. Two workstations are required for the use of project staff. The programme represents real value in terms of the substantial academic output and the transfer of expertise to Humanities.

DISSEMINATION AND EXPLOITATION

Dissemination is vital to raise awareness of the GRID and simulation methodologies and obtain academic feedback. Results will be disseminated through seminars and academic papers, supported by project travel funds. Dissemination material will include the project report and software demonstrator, donation of data and software models to community depositories as well as published scientific papers. A web site will advertise the project's achievements. Advisory Board members will champion the project within their communities. The project's links with the Medieval Logistics Group is of real importance and a final Access Grid workshop will be organised through this group. This will ensure international dissemination to relevant academics including historians, geographers, computer scientists, archaeologists and logisticians and enhance the sustainability of the work through integration with initiatives associated with the group.