Multidisciplinary Integrative Georelational Database for Spatio-Temporal Analysis of Expansion Dynamics of Early Humans

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Abstract

There is increasing evidence that the biological evolution of humans started in Africa, from where they dispersed in at least two waves to other continents. However, only our own species *Homo sapiens* managed to colonise the entire globe thereby successively replacing other contemporaneous hominin species. Within a few tens of thousands of years, modern humans successfully inhabited the globe, settling in Australia, the Americas and even the polar regions. The project "The Role of Culture in Early Expansions of Humans" (ROCEEH) is funded by the Heidelberg Academy of Sciences and is projected to run for 20 years. The new research center's aim is to reconstruct the spatial and temporal patterns of the expansions of hominins between three million and 20,000 years ago in Africa and Eurasia. The main goal of the project is to explain the biotic and abiotic reasons for different hominin expansions. Implicit in the current working hypothesis is the assumption that the influence of changing environmental conditions decreased as the importance of cultural and technological innovations grew. To achieve these general objectives a relational spatial archaeological and physiographical information system was developed and implemented. In this paper we focus on the technical issues of this database, its functionalities and preliminary implementation in order to assess early human expansions.

***Key words**: web based data base, early hominins,Africa*

1 Introduction

The course of human evolution reflects the natural history of how our species diverged from the line of the great apes and developed a wide range of unique morphological features and behavioural adaptations. This evolution is demonstrated by abundant fossil material, and starting about 2.5 Ma by the presence of localities in East and South Africa containing stone tools and other anthropogenically modified materials. Biological and cultural evolution of humans is typically accompanied by changes in the distribution areas of the species involved. These changes in distribution area are called "expansions" which may reflect a real expansion ("positive expansion") or shrinkage of the distribution area ("negative expansion"). Around 2.0 Ma hominins expanded out of Africa and settled vast areas of non-tropical regions (Marean 2005). This and subsequent colonisations were only possible in connection with cultural innovations (Mellars 2006a, 2006b). The history of our species is characterised by a gradual departure from biologically driven behavioural systems to culturally governed behaviour that is unique to humans. While Darwinian principles apply for both cultural and biological evolution, it is only our species that has freed itself from its environmental niche and has colonized vast regions of the sub-tropics, temperate, sub-arctic and arctic regions. This series of dispersals was only possible in connection with a wide range of cultural innovations including the controlled use of fire, the manufacture of clothing, the development of complex technologies and sophisticated behavioural forms based on symbolic communication. Thus only through the accelerating cultural evolution of humans we can

model how humans expanded across the inhabitable world.

In the early decades of palaeoanthropological research, the best evidence for early fossil humans came from Europe. As fieldwork in other areas intensified, researchers recovered empirical evidence for early hominins in new regions including Java, China, South and East Africa. By the end of the 20th century a wealth of fossil material pointed to Africa as the key continent for documenting the evolution from greater apes to australopithecines and early *Homo* as well as for the origins of modern humans. At present nearly all researchers view Africa as the only centre of early hominin evolution (Klein 1999, Schrenk et al. 2004, Conard 2006a).

Considerable debate currently focuses on the question of where, when and why modern humans evolved and how *Homo sapiens* colonized the Old and New Worlds. Until the middle of the 1980s the consensus view argued that modern humans evolved across all regions of the Old World, as argued by the adherents of the multiregional hypothesis for the evolution of modern humans. The work of Bräuer (1992), Stringer (2002) and other innovative palaeoanthropologists, has since the 1980s led to a major paradigm shift in which the Out of Africa 2 hypothesis argues for an exclusive African origin of modern humans (White et al. 2003). Despite two decades of major resistance to this hypothesis (Wolpoff 1996; Wolpoff et al. 1994), a wealth of new fossil finds from Africa and a much improved chronological framework for the Middle and Late Quaternary have led the great majority of researchers to support the model for the African origins of modern humans.

Moreover the Out of Africa model has recently been supported by large genetic data sets based on samples from living humans and by a small, but important, number of ancient DNA sequences from fossil finds of the Late Pleistocene (Foster 2004). Although nearly all contemporary researchers support the Out of Africa 1 and 2 hypotheses, numerous fundamental questions concerning the evolution of hominins and the spread of their range across the inhabitable world remain to be answered.

Therefore the Heidelberg Academy of Sciences and Humanities financed a 20 year long running new Research Centre that started in 2008 and is aimed at answering some aspects of the interplay of cultural evolution, biology and changing environmental conditions that allowed humans to evolve out of a behavioural niche of a great ape and move into a culturally defined behavioural niche characterized by a wide range of technological innovations. Especially the cultural aspects are emphasized in this research centre entitled “The role of culture in early expansion of humans” It seeks to reconstruct the spatial and temporal patterns of the expansion of hominins between three million and 20,000 years ago in Africa and Eurasia (e.g. Serangeli & Bolus 2008). Other facets of the project explore the routes of expansion, the biological mechanisms and the cultural potential with which our ancestors sustained themselves in new environments. The main goal is to explain the reasons for different hominin expansions: Implicit in the current working hypothesis is the assumption that the influence of changing environmental conditions decreased as the importance of cultural and technological innovations grew.

Fig. 1 shows that the research centre encompasses four phases with different foci. The first six years will concentrate on the creation of the database and the collection of African data about the modes of hominin living and evolution. In the second six years the focus of data collection will shift to Eurasia, while the third six years are mainly thought to look for routes, causes, and consequences of hominin expansions. A concluding phase of two years will sum up the results at the end of the project.

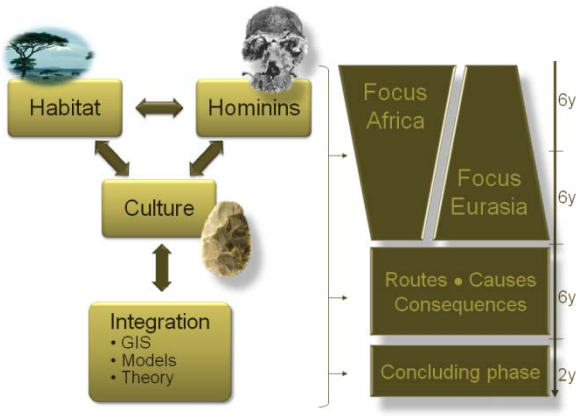

Figure 1. The structure and time frame of the ROCEEH Research Centre.

Backbone of the Research Centre is a central, web-based database providing the foundation for the scientific investigation into the earlier expansions of humankind. The database integrates vegetational history, paleontology, climatic record and geophysical information in standardized and homogenized formats. Based on this data prehistoric habitats as well as early human expansion dynamics will be modelled encompassing archaeological and paleo-anthropological perspectives. In addition to a detailed review of the existing literature, the project members conduct new field work to collect additional sets of data (Tanzania/ South Africa). Pollen analysis, the investigation of faunal and hominin remains, and the examination of Stone Age artefacts recovered from excavations and contained in museum collections will systematically expand the pool of data (e.g. Haidle in press a, b; Hardy et al. 2008; Hertler 2008; Hertler & Vollmer 2008). The interdisciplinary data is stored, managed and analyzed with the help of a Geographical Information System (GIS) to understand the spatial and temporal changes and their interdependency. Geographical modelling helps to understand expansion pathways and to reconstruct paleo-topography and geography (Märker et al. 2009; Pelacani et al. 2008). In the following sections we focus especially on the technical details of the database system.

2 Database system structure

There are already some archaeological databases on the market focussing on specific aspects of human evolution and expansions (e.g. Foertsch, 2006, Weniger et al. 2005, Semal et al. 2004). However, so far none of these are able to visualize and analyze the geographic data with respect to human expansion processes in a proper way. Thus, we started to develop a tool for our specific research questions.

One of our first tasks before building up the central database for the new ROCEEH Research Centre was the definition of the aims and functionalities of the entire database system. We identified the following objectives the database should fulfil. The database is intended to: i) be easily accessible, ii) integrate and homogenize the data, iii) import data, iv) store and assess data by data queries, v) perform simple spatial analysis, vi) visualize the data, and vii) exchange the data.

These general requirements imply specific functionalities. The database must be easily accessible via the internet; it must have an interface that is easily operable and manageable concerning both users and data. Moreover it should support open source software and common standards and formats.

In our case we conceived the entire system as a web based interface solution with WebGIS functionalities. Fig. 2 shows the general conceptional structure.

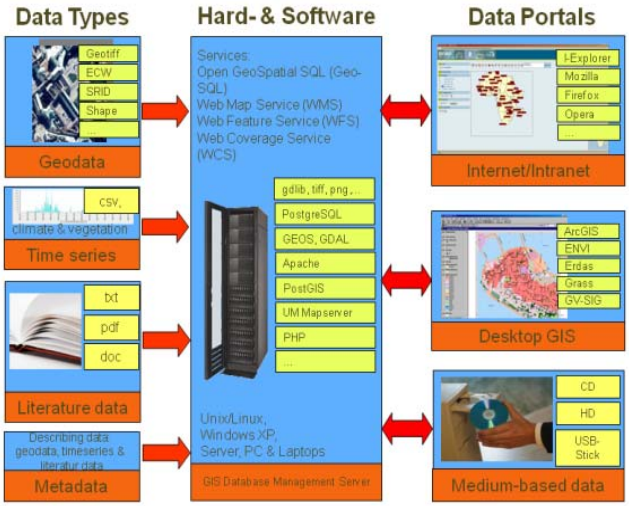

Figure 2. The conceptual structure of the ROCEEH database system.

The system is able to handle the most frequent geodata formats such as ESRI shape files, images in various formats like TIFF, GIF, JPG, PNG. Moreover data time series for climatic or hydrological information are provided as CSV, TXT or ASCII formats. The Research Centre will collect and screen the relevant bibliography to get specific archaeological information on hominin finds, artefacts and social or cultural aspects. Thus, document formats like PDF, DOC and TXT are supported. The data is described via metadata. Therefore, we adopted the Dublin core standard (http://dublincore.org). The different data types are physically stored on the central server, running with the operating system FreeBSD. On this

machine the software was installed to drive the web based database system. This includes the following services: Open GeoSpatial SQL (Geo-SQL), Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS) and an Apache Webserver, as well as TYPO3 software package and a PHP scripting module.

The main parts of the system are the data portals that allow accessing the system in different ways. The easiest and most comfortable way is, to use a web browser. Via the browser it is possible to communicate with the system in terms of: i) user and data management, ii) data import and export and iii) data visualization. Through the browser the user operates with the WebGIS-Interface based on the PostGIS (http://postgis.refractions.net) database enhance-ment and a UMN map server (http:// mapserver.org). The software used to realize the interface is based on PHP scripts developed by Codematix, Germany (http://www.codematix.de).

The other way to assess the data is to export the data on to the local desktop to analyse them with desktop applications including GIS-software (SAGA, ARCGIS, GRASS) and office software such as MS Office or Open Office. After elaboration of the data the resulting information can be re-imported into the system. Moreover the data can also be exchanged on media like USB sticks, CD, DVD,etc.

3 The ROAD prototype

After the implementation of the hard- and software, the main database model was developed. Therefore, the ROCEEH members discussed objects, content and relations of the different aspects covered by the Research Centre in an interdisciplinary and holistic way. Thus, the different aspects tackled by the Research Centre are translated into objects, object keys, relations between objects and describing attributes. This process of defining the preliminary, conceptual geo-relational database model was finished in late 2008 but will continue in the future, if new aspects are discovered, which are not yet part of the database model. Subsequently the conceptual geo-relational model was implemented using PostgrSQL (http://www.postgresql.org/). To handle geo-objects the PostGIS enhancement was installed. Geo-objects can be visualized through the UMN Map server application, running on the server and accessible for the user via the Internet. The database system prototype was called ROAD, standing for: **R**OCEEH **O**ut of **A**frica **D**atabase. Figure 3 illustrates the implementation procedure for ROAD.

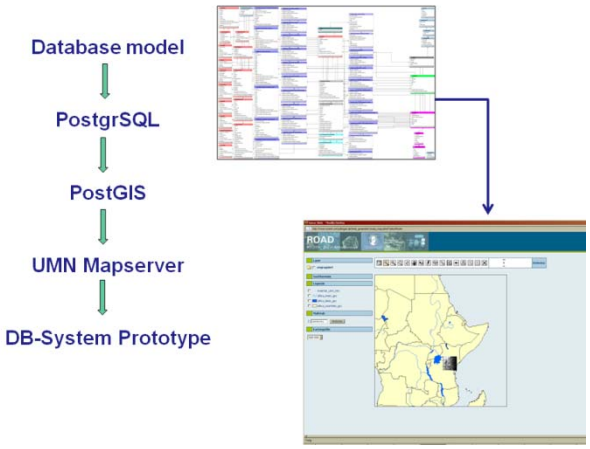

Figure 3. Implementation concept for the ROAD database-system prototype.

The ROAD-GIS interface is driven by the Map server functionalities. Thus, it allows the user to visualize the data in a manner similar to a simple Desktop GIS application. The interface and specific masks, such as import or export functions, are programmed in PHP. These tools and procedures allow proper and easy use of the prototypes' interface. ROAD is accessible on demand to the public at the following address: http://www.roceeh.net/road.

The ROAD interface consists of two major components: i) the administrative part with user and process management and ii) the data manipulation, database query and visualization component.

Fig. 4a shows the data menu. Here geo-data can be imported, edited as well as visualized as layers. These layers can be combined into maps, so that a map editing tool is available with basic GIS functionalities. Moreover, data queries can be performed on the ROAD database due to its relational structure. The menu also allows the setting of property rights to the data and makes data available to specific users or groups. Fig. 4b demonstrates the user administration menu.

Figure 4 a/b. ROAD interface with data and administration menu.

Moreover, specific processes and rights can be attributed to the users. For example certain data operations are only allowed for project personnel whereas functionalities to generate maps are attributed to all users. Furthermore, the menu provides the possibility of getting the information in the user specific language. So far we implemented six languages: English, German, Italian, Russian, Ukrainian, Arabic and Spanish.

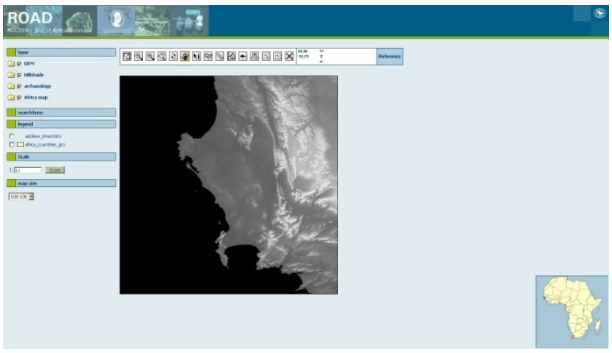

Figure 5. Map application for South African study area.

The ROAD prototype also offers the possibilities to generate maps and specific layouts that can be printed as pdf. Fig. 5 shows an example of ROAD's map tool illustrating a visualization of the South African study area. The first project specific applications of ROAD are presented in this Volume by Märker & Heydari-Guran (2009). In the case study spatially distributed data of Palaeolithic sites on the Iranian Plateau are analyzed. Moreover the relations between site locations and the topographic situation are assessed.

4 Conclusions

This paper presents the general aims and structure of the ROCEEH project. In the next 20 years the ROCEEH Research Centre will reconstruct the spatial and temporal patterns of the expansions of hominins between three million and 20,000 years ago in Africa and Eurasia. The main goal of the project is to explain the biotic and abiotic reasons for different hominin expansions. Moreover, we will assess how changing environmental conditions allowed humans to evolve out of a primitive behavioural niche and move into a culturally and technological developed behavioural niche. Especially the cultural aspects are emphasized in the ROCEEH Research Centre.

The backbone of this project is a central, geo-relational database that is intended to support the above mentioned research questions. ROAD is intended to guarantee an easy access via different types of internet browsers. ROAD assures, due to its structure as a geo-relational data base, a proper and uncomplicated way to manage and administer users and data. It allows the exchange of data and simple analysis including data queries and visualization of data via the Map server interface. ROAD was developed mainly utilizing open source software and following common data standards. We hope, that in the future this database will become a central tool for all scientists that work on the issue of early human expansions.

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