The Way is the Goal – Modelling of Historical Roads

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Abstract. Roads are an important aspect of historical geographies. However, there are cases in which a road is mentioned in written texts, but there is no further evidence of this road. For these cases, where the exact course of the roads in question is unknown, GIS can provide the tools to model the unknown roads. Wayfinding algorithms, like least cost paths, can calculate routes over a landscape, based on assigned cost values. This is a simple, yet efficient way to calculate historical roads.

Of course, physical factors like the relief and rivers are important for the routing of historical roads. But which factors are important for the routing of historical roads, besides the relief and rivers? Furthermore, it is important to think about the epistemological consequences. What can we learn about the past using GIS?

Theoretical considerations which are discussed are based on constructivist approaches, like systems theory, cybernetics and observer theory. Especially the epistemological questions of GIS in historical research are highlighted. This approach will provide a framework to integrate the considerations and theories from the contributing disciplines like historiography, transport and social geography, cultural history and archaeology.

Furthermore, two case studies are presented. The first one is a medieval Byzantine road in the Former Yugoslavian Republic of Macedonia, which is mentioned in documents from the 13th and 14th Century AD. The second case study deals with travel route of a Buddhist monk from the 10th and 11th Century AD in the Western Himalayans.

Keywords: historical GIS, modelling, historical roads

1. Introduction

Road networks are an important component of historical geographies. To understand traffic relations and cultural movements, it is important to

know how roads could have connected different places. In some cases the courses of historical roads are known, either because maps or archaeological remains exist. However, there are cases in which a road is mentioned in written sources, but there is no further evidence, like archaeological remains, of the road. Furthermore, in many cases only fragmentary remains of the road do exist. For these cases, where the exact course of the roads in question is unknown, GIS can provide the tools to model the unknown roads. Wayfinding algorithms, like least cost paths, can calculate routes over a landscape, based on assigned cost values. This is a simple, yet efficient way to calculate historical roads. As most GIS analyses, least cost path calculations need the fitting input data to produce valid results. Which data is used, depends on the factors, which contribute to the development of historical roads. Therefore, one of the key questions is which factors should be used?

The modelling algorithms of a GIS produce sharp results. However, the nature of the research questions allows only fuzzy interpretations, since historical facts always include various uncertainties. Furthermore, most analyses are conducted using recent geodata, since historical data is hardly available or of inferior quality. This also adds to the uncertainty of the final model. Thus, to understand the model, these uncertainties have to be considered in the visualization of the models.

As the research is not yet completed, the results presented in this paper are only preliminary.

2. Theoretical Considerations

Roads are integral parts of traffic systems, which are subsystems of social systems. These traffic systems develop out of general social necessities for transport and movement. The roads are physical manifestations of these processes on the landscape. The actual routing of the routes is influenced by physical factors as well as social factors.

The physical factors, like the relief and watercourses, are relatively easy to determine. The social factors, however, are much more difficult. Not only are they harder to determine, but they are not that easily formalized and modelled with GIS as are the physical factors.

2.1. GIS, Realism and Constructivism: Epistemological considerations

This research is being undertaken to gain knowledge about historical roads. Therefore, it is essentially to consider which kind of knowledge we can gain,

what the knowledge is about and how this knowledge can be obtained. These epistemological questions are very important, especially considering the proposed tool.

GIS relies on data, which represents the real world. This data is then analysed, using mathematical algorithms. The first premise of this approach is the assumption that there is an *apriori* reality. This reality can be represented in an objective way by model-building. Model building is the process of encoding a part of reality into a mathematical (computer based) form. The analyses then follow causal chains of geographical phenomena, which are known by empirical research (Schuurman 2002). This way of thinking has an inherent realist (and even positivist) approach to it. (Bodenhamer, Corrigan, Harris 2010, p. ix)

When dealing with humanities, and historical sciences in particular, this approach, based on well-defined and mutually exclusive categories as well as a realist epistemology, is not suited. Ambiguities, subjective perceptions and fuzzy categories are important in the humanities.

Therefore, the GIS-based approach has to be modified to satisfy the needs of a constructivist epistemology of humanities. As the positivistic structure of most commercial GIS cannot be altered easily without its total reconceptualization, at least the process of a GIS analysis can be observed and deconstructed.

When conducting a GIS analyses, many contingent choices are made, most of them are based on often unknown assumptions, technical and institutional restrictions, scientific socialisation, just to name a few.

Because of the contingency of this choices, the results of the analyses are contingent as well. Therefore, the whole process has to be reflected and deconstructed, the choices of the analysts themselves have to be observed, to verify if a result is viable or not. For this deconstruction, observer theory or also known as 2nd order cybernetics (Heylighen 2001) constitutes the underlying theory.

2.2. Historical Uncertainty and Data Uncertainty

Since the research focus is objects in the past, of which remains are few, there is cannot be no absolute proof of the course of the roads: “A historical fact is not met with approval by ‘proving’ it to be true or false, but primarily by finding academically funded arguments for it” (Jordan 2009, p.183, translated by the author).

As Bodenhamer, Corrigan and Harris (2010) point out, the past cannot be recaptured, only represented. Therefore, whatever the results of the analyses, they are only possibilities or representations, not the "true historical reality".

A big issue in historical GIS is the availability of historical geodata. Most of the available geodata is contemporary or recent data. In many cases data about historical conditions simply does not exist. Major changes in the landscape, like river regulations, often date back only to the last two centuries. Therefore, although no detailed maps exist from the middle ages, maps from the 18th or 19th century can give an approximation.

Nonetheless, there simply is no large scale geodata from the Middle Ages or earlier periods. Recent geodata and historical maps can serve as approximations. To a certain level of detail, this approximation is sufficient, but this has to be considered when interpreting the results of a historical GIS analysis.

3. Methods

All the aforementioned considerations show that historical road modelling is a challenging endeavour. The first step is to analyse various written sources, like travel reports, and documents. The geographic information gained from these sources acts as a starting point for further analyses.

As Lock (2010, p. 95) states, viewshed analyses and least cost path calculation present promising methods to model "inhabited landscapes", moving along the representational axis from observation to inhabitation.

Viewshed analyses can determine which point on the landscape can be seen from a specific point. These analyses are used to examine the visibility of the road or certain landmarks alongside the road and should provide additional information about the landscape or rather the perception thereof.

Least cost paths, a type of wayfinding analyses, are the tools which are seen as most rewarding for finding the actual routes on the landscape. The aim of these analyses is to find the way between points A and B over a surface, accumulating the least cost along the way. This surface can be a real surface, like topography, or abstract surfaces like the land price. These surfaces, also called friction surface or cost of passage maps, can be calculated in many ways. The aim of this research is to find a way to integrate the social, sacred and physical landscapes into this friction surface.

Of course, the theoretical model as well as the specific model will be evaluated by applying it to known routes. The results of the evaluation process will be used to enhance the original model.

Cartographic visualization is the method of choice to visualize the results of least cost path analyses. The result of a least cost path calculation is a discrete line. As aforementioned, the results cannot be sharp, due to epistemological reasons. Therefore, a discrete line is a misleading interpretation, since it hides the uncertainty and mimics certainty.

Fuzzy shapes, with their lack of precise boarders, can be used to visualize uncertain geographies (Piatti *et al.* 2009). With this method, the uncertainty is plainly visible. This will work with maps in which pilgrimage routes are the main content (thematic maps), but can be difficult to implement in topographic or multi thematic maps, where pilgrimage routes are a map content among many other contents. In this cases, visualizing routes as fuzzy areas will overload the map and make it hard to read.

Therefore, a compromise between readability and correct visualization of the uncertainty has to be found.

4. Case Studies

The current research focuses on two subjects. One is a Byzantine medieval road in southeastern Europe, the other are historical travel routes of Buddhist monks in the Western Himalayas. The first is considered a secular road. It was used for travel, trade and troop movement. If this road had a sacral function, it was secondary. The travel routes of the monks on the other hand are parts of a sacred landscape. Therefore, the two roads had different functions. They were in a completely different cultural surrounding as well.

4.1. Byzantine Road

The modeling of the Byzantine medieval road is a pilot study to show the viability of least cost paths to model historical roads. Due to the lack of funding, the project was not continued.

1.1.1. Research Background

The background of the research on the Byzantine road is the project "Tabula Imperii Byzantini" (TIB)[1] at the Institute for Byzantine Studies at the

[1] http://www.oeaw.ac.at/byzanz/tibpr.htm, accessed 18.04.2011

Austrian Academy of Sciences. The research topic of the TIB, which was founded in 1966, is the historical geography of the Byzantine Empire. The project's aims are to create a historical atlas and historical gazetteers of the Byzantine Empire, which existed from the division of the Roman Empire in 394 AD until the fall of Constantinople in 1453 AD. The main sources of the research within this project are written texts, archaeological finds, toponyms and physical landscape properties (Popović 2010a).

Accompanying the TIB is the project "Economy and Regional Trade Routes in Northern Macedonia (12th – 16th Century)"[2]. Detailed research on regional lines of communication and trade routes is the focus of this project (Popović 2010a). Within its scope, the road in the Strumica valley between Štip and Petrič is given special attention. It is mentioned in a few texts from the late Byzantine era in the 13th and 14th century AD (Popović 2010b) and is described as *basilikos dromos*, which translates as "*emperor's road*". It is not clear whether this hints at its importance or if the name implies the emperor's responsibility to maintain this road. The road is located in the eastern part of the present-day Former Yugoslavian Republic of Macedonia (FYROM) and Western Bulgaria. It is part of a connection between two important Roman roads, the *Via Egnatia* and the *Via militaris* (also known as *Via diagonalis* or *Via Traiana*).

[2] http://www.oeaw.ac.at/byzanz/routes, accessed 10.05.2011

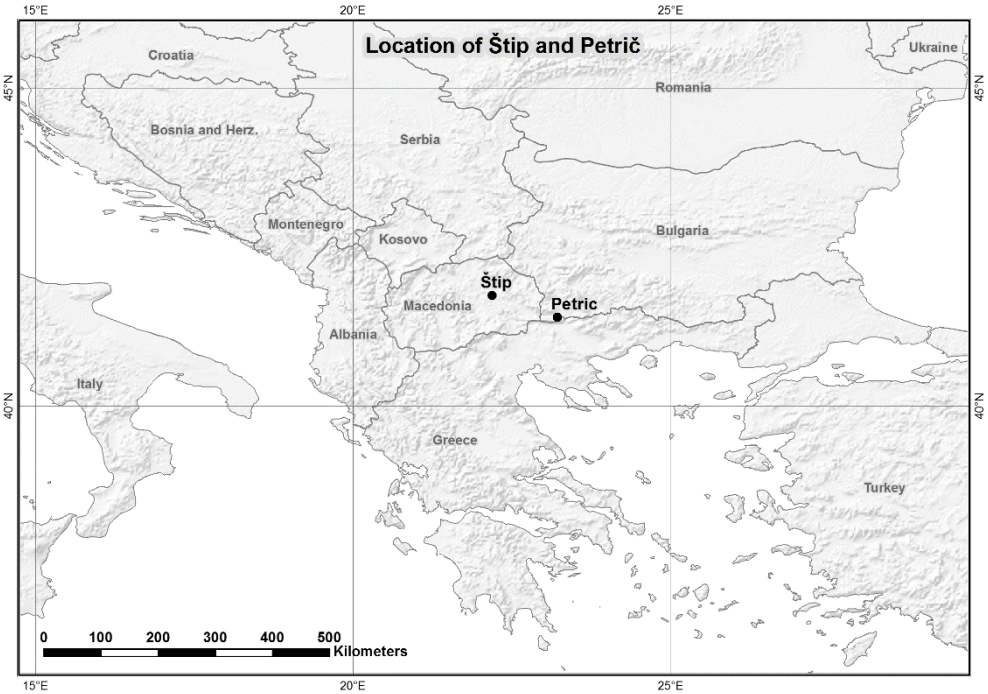

Figure 1: Location of Štip and Petrič

Since this road is mentioned in more than one medieval document, it can be assumed that it was not only relevant locally, but on a larger scale as well. Therefore, it is desirable to include this road in the map of the TIB. But since there are no archaeological remains of this road, the exact course remains unclear. Therefore, least cost path calculations are a possibility to create a model of the *basilikos dromos*.

1.1.2. Considerations

The road at hand is primarily a secular road, without an important sacred function, although some monasteries lie near its course. Therefore, the routing of the road is primarily determined by the physical landscape. For least cost calculations of roads, the most important factor is effective slope. Medieval roads tend to stay at the same height level and taking a longer course. Therefore, the height above sea level, or the difference in height above sea level, plays an important role as a well.

Out of written medieval sources some waypoints are known. The most important is the Ford of Stavrak. Here, the road crosses the river. It is located where the river Turija joins the Strumica, about 11km east of the town of Strumica (Popović 2010b). Furthermore it is known that the *basilikos*

dromos did not go directly to Petrič, but bypassed it on the other side of the river instead. The road also bypassed Kalugjerica and ran between the village of Vladevci and the Strumica.

1.1.3. Implementation

Due to budgetary restrictions of the project, calculations have to be based on freely available data. SRTM data (90m resolution) and ASTERDEM data (30m resolution) are used as digital elevation models. Data from the Vector Map Level 0 (Vmap0) is used for the rivers. The locations of settlements and landmarks are recorded using a GPS receiver. These points are then used to define the waypoints for the calculations. Adjustments to the data were necessary to fit the datasets to each other and to get consistent data.

For this calculation, the theoretical considerations mentioned in the previous chapters are not implemented. The calculation is based solely on the cost factors relief, effective slope and rivers and used the basic least cost path algorithm of *ESRI ArcGIS 10 Desktop* (path distance and cost distance). The cost for traversing a slope was calculated by using a formula for the energy expenditure of walking at a specific slope (van Leusen 2002). If the path would change the height above the sea level more than 100m, the cost for the whole path would also increase. Rivers were given very high cost of passage values, since they are hard to cross.

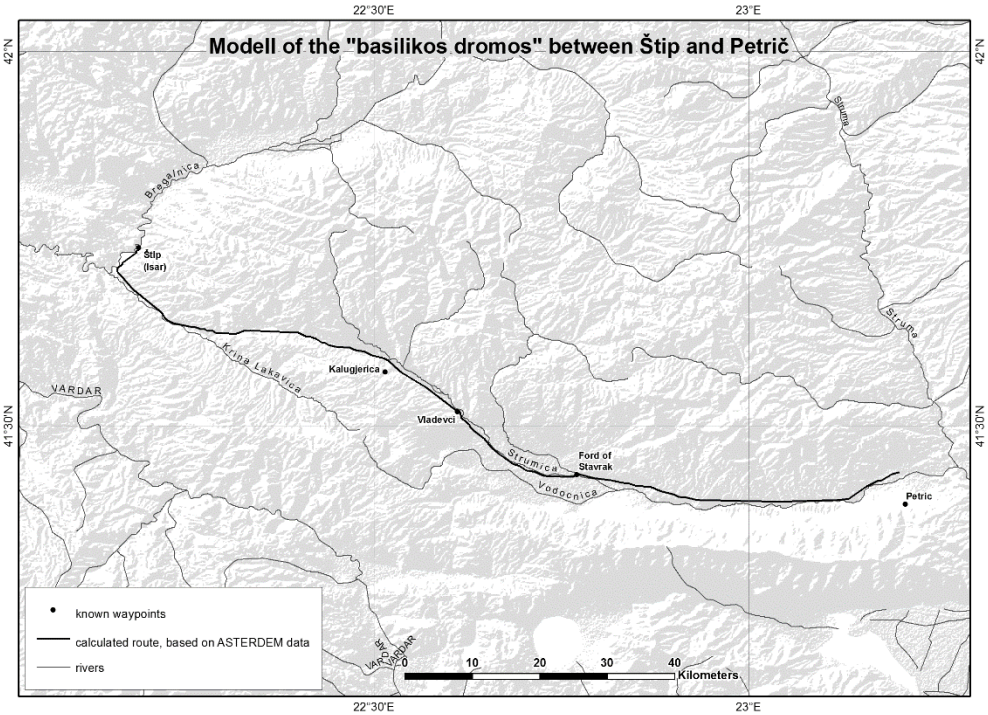

Figure 2: Final calculation of the *basilikos dromos*

1.1.4. Results

The results are shown in figure 1. The calculated course of the road matches the estimated course. The differences between the calculations based on the SRTM data and the ASTERDEM data is very small. Although the calculation is based on very simple theoretical considerations, the results are viable. Of course, further evaluation, like conducting the calculations on roads, where the course is known, is necessary.

4.2. Travel routes of Buddhist monks

The travel routes of Buddhist monks also follow trade routes, but contrary to the roman roads, the sacred landscape is likely to have an influence. The physical landscape is captured and transformed into a computer model easily, but the sacred landscape is much more elusive. Also, it is a challenge to estimate the influence of the sacred landscape on the development of the routes.

1.1.5. Research Background

Within the project CHWH (*Cultural History of the Western Himalayans from the 8th Century*)[3] and its subproject CHIS (*Cultural History Information System*)[4], historical Buddhist pilgrimage routes in the Western Himalayans are an important issue. There are very few cartographic representations of these routes, even descriptions and travel reports in written form are rare. Therefore, integration into the CHIS online mapping application is not possible or at least very challenging. Therefore, modeling the routes is a possibility to include pilgrimage routes into the application and the maps. The research also takes place within the interdisciplinary doctoral collage '*Cultural Transfers and Cross-Contacts in the Himalayan Borderlands*'[5] at the University of Vienna.

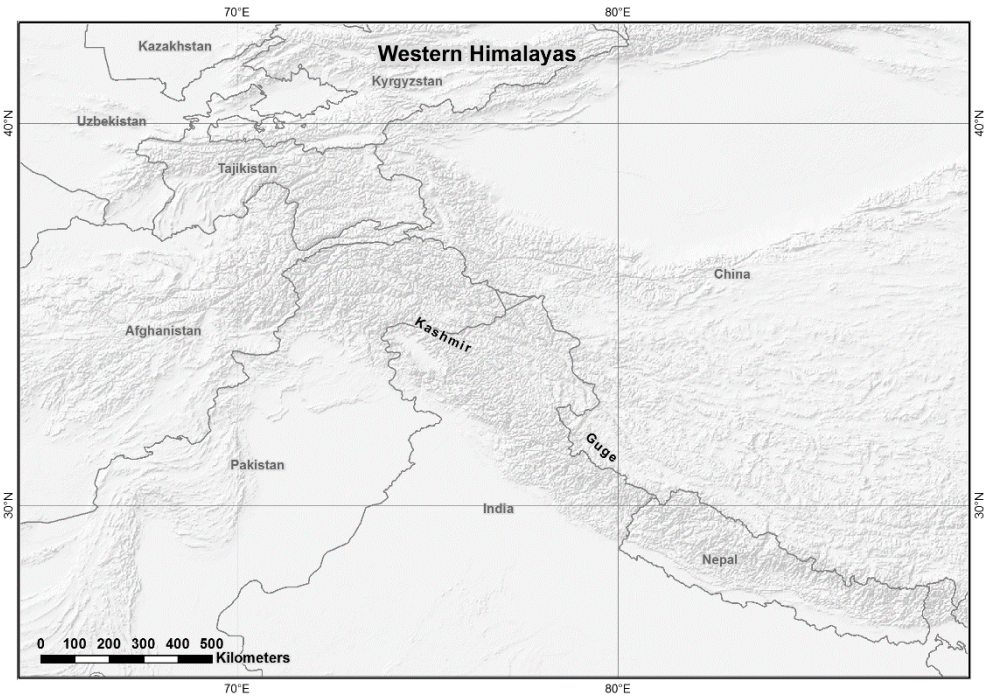

Figure 3: Western Himalayas

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[3] http://www.univie.ac.at/chwh/, accessed 28 March 2013

[4] http://www.univie.ac.at/chis/, accessed 28 March 2013

[5] http://www.univie.ac.at/ik_cirdis/, accessed 28 March 2013

1.1.6. Rinchen Zangpo

Rinchen Zangpo (also Rin-chen bzang-po) was a Tibetan Buddhist monk in the late 10th and early 11th century. He was a famous translator of Sanskrit Buddhist texts into Tibetan and played an important role for the Second Propagation of Buddhism in Tibet. He was born in the Kingdom of Guge (western Tibet) in 958 CE and died in 1055CE (Roerich 1988, p.68f). To study languages and Buddhism, he travelled several times to Kashmir. He is said to have founded over a hundred temples and monasteries, among them many in Himachal Pradesh and western Tibet, some of them still existing today.

Furthermore, he invited craftsmen from Kashmir to Tibet, therefor he is not only an important figure for religion, but for art history as well. (Luczanits 204)

Although some waypoints of his travels are mentioned in texts, the exact travel route remains unknown. However, for Tibetologists and Art Historians, it would be desirable to have a more precise knowledge of his travels, as this would help to better understand the religious geography and sacred landscape of the area.

The travel routes of Rinchen Zangpo are not pilgrimage routes in a narrow sense, but as the travels were motivated religiously, the sacred landscape would have a significant influence on them. The monasteries founded by Rinchen Zangpo are important pilgrimage sites even today.

Figure 3 shows the preliminary calculations of the travel route of Rinchen Zangpo, using only the relief as cost factor. Tholing is the ancient capital of Guge. Srinagar was the center of the historical Kashmir region. (Klimburg-Salter 2007)

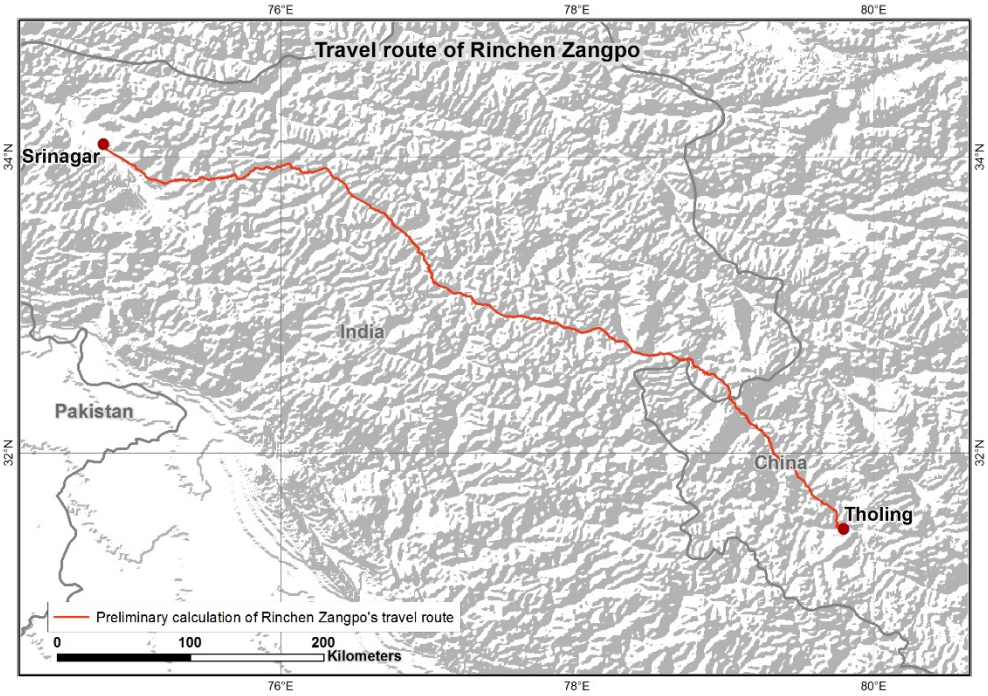

Figure 4: Preliminary calculations

1.1.7. Sacred Landscape

Sacred landscape is a complex phenomenon. It is created by the perception of the physical landscape and by religious ideas and cosmology. It influences the movement of pilgrims, but is influenced itself by the pilgrims' movement in return (Malville and Saraswati 2009, p.1). Malville's and Saraswati's (2009) view of pilgrimage as self-organizing system fits the aforementioned theoretical considerations.

Of course, the natural landscape is the basis for the sacred landscape. The sacred landscape develops by interpreting the physical landscape to fit religious believes. It is therefore socially constructed. To model this landscape (or at least some key aspects thereof) in GIS, it is necessary to deconstruct it.

This part of research is still underway, first results will be presented at the ICC 2013.

5. Conclusion and Perspective

Traffic conditions and cultural movements are important, yet elusive components of historical geography. Although GIS can provide algorithms to calculate unknown traffic routes, the question is which factor should be used for such calculations. However, theoretical models about road development are very vague and have yet to be refined to be used as a basis for modeling. Systems theory will provide the foundation for the integration of the various aspects into a theoretical model, which will be implemented in GIS.

The approach presented is in its early stages, but the results so far are promising. It is important to consider the epistemology of historical research and GISscience to satisfy the philosophical requirements of historical science. The course of historical routes cannot be proven with certainty, but they can be argued, and computer calculations are viable methods.

The greatest challenge of this research is the modeling of the cultural landscape, especially the sacred landscape, in GIS. Due to its complexity and subjectivity, it requires a systemic analysis. Once the elements of these complex systems and subsystems are identified, it is necessary to code them into GIS-usable datasets, consisting of points, lines, polygons and raster datasets.

Furthermore, an adequate visualization method has to be found to visualize the uncertainty contained in the models. Fuzzy shapes are a promising method, but they can be problematic in a detailed topographic map. There will be a trade-off between readability of the map and showing the uncertainty.

This research will hopefully lead to a framework for modeling historical roads, be they sacred or mundane. This will also lead to better understanding of historical geographies.

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