

3D-VQGIS: 3D Visualization and Qualitative Analysis of Geospatial Data

Guoxiang Ding and Mei-Po Kwan
Department of Geography, the Ohio State University
(ding.45@osu.edu; kwan.8@osu.edu)

1. Introduction

After Sep. 11th, the Muslim people in USA were facing a critical situation of anti-Muslim hate crimes, which caused great impacts to Muslim people's daily lives. The Muslim people's social status and their lives therefore became the focused concern in the hostile urban environment. What is the Muslim people's reaction and feel to this change? And how do they adapt themselves to the critical urban context?

This paper discusses a qualitative analysis of activity-travel data and in-depth interview with the aid of GIS representation to study the daily activities patterns of a Muslim woman in Columbus (Ohio, U.S.A) after Sep. 11th. Necessary GIS extensions have been developed to support the analysis. Section 2 summaries the strengths and weaknesses of knowledge representation formalism of current GIS platforms. The space-time path and representation in 3D also is introduced, as well as the discussion of spatial knowledge representation. Section 3 briefly describes the conceptualization and object models in 3D Visual Qualitative Geographical Information System (3D-VQGIS), including the explanation of the application purpose and system capabilities. Section 4 discusses the organization of system modules, and shows the design and implement of the 3D-VQGIS using the real travel data and empirical materials of a Muslim woman. A landscape of 'fear' also is generated to show the system's outcome, which clearly indicates the activity patterns and feelings of the Muslim woman's travel. And section 5 is the conclusion part with the discussion of limitation of this system and possible future developments.

2. Background

2.1 Quantitative and Qualitative Approaches in GIS

The formalism to represent knowledge determines the choice of methods in research. Generally speaking there are two approaches in representing spatial knowledge in geography: qualitative approach and quantitative approach. These two approaches are quite different to each other per se. However, both are very important and widely used in geography researches.

Quantitative approach is the classical approach using exact numbers and numerical models (Renz, 2002) in conventional Geographical Information Systems (GIS) that was largely designed for the analysis of quantitative data and for building spatial analytical models (Burrough and Frank, 1996). Dereferencing within these GIS is based on specific coordinate systems and precise locational information of geographical entities and their boundaries. Spatial knowledge of human subjects is often represented in a similar manner. Features in GIS are usually treated as exact objects (areas, lines, points) or discretised fields (pixels, voxels) (Burrough and Frank, 1994).

This as yet, however, is a restriction and bottleneck of information retrieval and process in practice, since information does not always exist in determinate and numerical forms. It is not always necessary to have knowledge with precise positions to perform spatial reasoning or to communicate spatial knowledge, and space and processes are not always continuous and numerical (Burrough and Frank, 1996). Examples such as addresses, postal codes, interviews, documents, and participant observation data, and so on. Some of the information can be converted and integrated into GIS using specific techniques, such as geocoding; but a lot more information is not compatible with GIS, such as descriptive information about the orientation and massive locations, which is also spatially implicit and is important for spatial knowledge understanding, explaining and reasoning.

Quite differently, qualitative approach represents knowledge using a set of finite vocabularies, which is close to the way of human cognition and knowledge communication (Renz, 2002). It is strong in elucidating the human environment and human experience within a variety of conceptual frameworks, such as the feelings, emotions, perceptions, cognition, and so on, which was regarded as unknowable (Winchester, 2000). Therefore qualitative approach is often used to verify, analyze, interpret and understand human's behaviors and activities. From the research paradigm perspective, qualitative research can be positivist, interpretive or critical, and qualitative research methods include action research, case study research, ethnography and grounded theory (Myers and Avison, 2002). It is necessary to collect empirical materials, such as documents, reports, memos, e-mails, newspapers, pictures, videos, audios, interview transcripts and so on to support qualitative study. Qualitative approach generally is used to understand the context in which events and outcomes occur by open-end data collection, such as in-depth interview embedded in structured research (Frechtling and others, 1997).

Both approaches have their own strengths and weaknesses. The integration of both approaches building on their complementary strengths has been widely supported (Frechtling and others, 1997; Winchester, 2000). Simply speaking, quantitative approach is weak in processing descriptive information, because quantitative methods and representation are difficult to handle spatial information due to the uncertainty and complexity in space. Qualitative seems to be better suited whenever human cognition and interaction are involved, because it is difficulty for humans to use and understand the exact knowledge numerically. Humans are more familiar with thinking and communicating in language and logic qualitatively. As for the consideration of GIS application in social and behavioral research, GIS should shift from traditionally technological to managerial and organizational issues (Myers and Avison, 2002), and qualitative approaches should be incorporated into existing GIS in conjunction with other methods to better support spatial uncertainties and complexities that humans have. In summary, qualitative approach suits for formative evaluations, whereas quantitative measures for summative evaluations using values (Frechtling and others, 1997).

2.2 Space-Time Trajectory and 3D Representation

Space and time are two most fundamental notions. They provide a basis for all modes of thought and belief and a context for understanding, and both are entanglement and inseparable (Peuquet). Peuquet also states that '*the space and time are references to a conceptual framework of knowledge of the world*', and '*things occur or exists in relation to space and time*'. The concept of space is very complex, but in geographical space, it refers to the spatial positions or locations.

An event is the moment an occurrence takes place that cause one state to change to another; events also are part of a process of change caused by action and reaction as well as synthesis of both (Wachowicz, 1999). A triple $\langle X, Y, Z, T, U \rangle$ can be used to denote the fundamental primitive element of geographical information, in which U is the event at the location $\langle X, Y, Z, T \rangle$ in space-time (Goodchild and others, 1999). Space, time and event are internally related, represented in a triad: what, where and when (Peuquet, 2002; Worboys, 2003b) (Fig. 1). Ontologically an event can be regarded as a process that can be decomposed into several elements, such as time (when), location (where), causality (how), intension (why), person involved (who/what) and the goal (result) (Worboys, 2003b, a). Sequences of events identify the temporal patterns of the man-environment interaction (Peuquet and Duan, 1995). Obviously study of humans' travel activities and behavior can also be taken as sequences of events in space and time.



Fig. 1 Triad Representation of Space-Time Objects (Source: Peuquet, 2002a)

Space-Time (ST) measure is spatiotemporal model for activity research with three-dimensional space collapsed into two-dimensional. It is derived from Hägerstrand's time-geographic concepts that individual movements over time can be represented by an indivisible trajectory. For an individual, his/her life ST trajectory starts from the point of birth and ends at the point of death when we use two-dimensional plain to show geographical positions and use perpendicular dimension to show represent the time (Hägerstrand, 1970). Part of the life ST trajectory (a day, a week) shows the activities of individual during this time interval. This approach has wide application in geography, including the study of travel behavior and individual activities (Newsome and others, 1998). It is recognized as the most valuable model that make the time variable explicit by studying the path in space and time, and their interactions between space and time in individual level (Peuquet). In ST model, person involved is implicitly identified, because a ST trajectory is specific to a specific person. Besides, ST trajectory manifests certain processes over time by the connection, ordering and synchronization of events, which makes ST trajectory a good model to capture spatial and temporal sequence and the coexistence of events (Wachowicz, 1999).

ST model provides an event-oriented framework for analyzing individual's activity based on spatial and temporal change with space and time constraints (Hägerstrand, 1970; Lenntorp, 1976; Weber, 2001), and the 3D visualization of ST trajectory in GIS provides an interactive environment for human activity exploration, which links GIS with theoretical and dynamic explanatory models (Clark, 1991). Through 3D, it's helpful to analyze and view the geographical patterns and trends (Musin). Several kinds of 3D models, such as voxel, Boundary Representation model (B/R), Constructive Solid Geometry (CSG) have been developed. However, none of these real 3D solid models have been practically implemented in GIS. Usually

GIS uses 2.5D model based on 2D representation of spatial objects and a third dimensional data of attribute for x, y position. 2.5D cannot handle multiple Z-values in 3D space (Musin, ; Li, 1994). Another problem is that though 3D environment is now widely supported in most commercial GIS, such as ArcScene, the time dimension still is not supported in 3D environment to provide the dynamic models.

2.3 Spatial Knowledge Representation

Enormous amounts of spatial information are constantly being perceived and processed in intuitive and informal ways in human cognition (Burrough and Frank, 1994). The interaction between human and environment creates experience which subsequently acts back on the environment by human reaction. The spatial knowledge therefore is contextual to the environment, and the foundation, abstraction and representation of human perception form the basis of spatial knowledge process in GIS and determine the validity of the system. It is hard to quantize the acquired experience and perception, and quantitative mathematical methods were rejected as impractical (Burrough and Frank, 1994); however, they can be represented through spatial reference in natural language (Mark and Frank, 1994), such as voices and texts in a descriptive way to capture such as scene description, route description and so on (Ron, 1997). Advanced systems such as knowledge-based expert systems are attempts to store and represent knowledge. Burrough (1995) noticed a large gap between the richness of ways in which people can perceive and model spatial and temporal phenomena and the conceptual foundations of most commercial GIS.

Interview is commonly used to capture human's perception and perspective in knowledge acquisition. In-depth interview seeks open responses and encourage the interviewee's opinion about their own experience and reaction in their own words, which helps to yield rich data and new insights. The outcome of interview is usually empirical materials in the form of pictures, video or audio tapes, interview notes or transcripts, and hereby provides ways of discerning, examining and interpreting meaningful patterns of themes (Frechtling and others, 1997).

Human activities is the process of experience or knowledge acquisition grounded with space and time properties, and the representation, exchange and processing of spatial and temporal information jointly in empirical materials are required in GIS and other components. The integration of empirical materials of experience into ST model in GIS hence incorporates a rich data representation both quantitatively and qualitatively, which not only characterize the human's activity in space over time, but also pictures the specific knowledge acquired during the movement. With the rich representation ability of empirical materials in GIS, exploration of ST trajectory becomes a process of understanding human's activity-pattern. 3D-VQGIS is the system that utilizes the ST model to incorporate qualitative analysis into GIS, and it studies the impact of post-9/11 anti-Muslim hate crimes with the in-depth materials of Muslim woman in Columbus, Ohio.

3. Conceptualization and Object Model

3.1 CADQA and GIS

The terrorist attack on 9/11 shocked the homeland security problem, and the aftermath also influenced the life of Muslim people, particularly for Muslim woman because of their easily identified costume and dressing. Muslim people's social life and access to the city were greatly constrained because of the hostile attacks and security consideration. Investigation on the impact of Muslim people's life has been carried out in Columbus, Ohio by interviewing a few Muslim people's experiences and their reactions after 9/11, by recording their space-time trajectory, and by their daily life activities observation. Qualitative analysis of the interview materials with the aid of Computer-Aided Qualitative Data Analysis software (CAQDA) is easily applied in the Muslim people study. Besides, GIS is applied to investigate Muslim people's Space-Time trajectory to find out the pattern of their activities and their reaction to the urban environment. In last decades, endeavors of computer application to handle unstructured, qualitative data produced CAQDA systems, such as NUD*IST, NVivo, AQUAD, Metamorph, askSam, Martin, QUALPRO, Metadesign, SemNet, and so on. These systems are developed for functions as word searching, data coding, data storage and retrieval, memoing, graphic mapping, hierarchical tree building, concept building, and reflexive report writing (Peace, 2000). Different CAQDA systems have different functionality, but the most basic functions are word searching and concept building. CAQDA systems are fast in processing ability of large blocks of data, and the versatility in approaches to work with data more interactively (Kearns, 2000), compared with the traditional qualitative analysis using cards and paper. The usage of CAQDA has revolutionized the way of traditional analytical work in qualitative research, as well as close integration of data entry and analytical processes (Peace, 2000); however, as many more geographers started to use CAQDA systems for qualitative analysis in geography after they have done enough work in statistics and GIS, CAQDA systems are still lack of abilities of map representation and visualization, which is an important way in geographical analysis. CAQDA systems are purely good in constructing concepts and theories in a qualitative way, while GIS utilizes quantitative data for spatial analysis and visualization. The special needs and requirements in geography demand the integration of qualitative analysis and quantitative study to make use of the complementary strengths of both methods, which results in the needs of integrating CAQDA with GIS to provide GIS with qualitative analysis abilities.

GIS can simulate the environment of qualitative research in geography, and the graphical representation of environment helps the understanding of qualitative researches, particular the human behavior. In our research, we try to develop qualitative modules by extending ArcScene GIS using inbuilt native VBA and ArcObjects customization to support 3D qualitative data analysis in individual perception and feeling representation in urban environment.

3.2 Objects, Features and Component Object Model (COM)

For GIS, an object-oriented approach is more flexible compared to the object approach (e.g., ArcView GIS 3.2) because it adds a framework for anyone to extend the data model, and end users or third party developers are not restricted to developing with a proprietary language (e.g., Avenue or AML). With the object component approach, users have more options and can extend the data model with exactly the same technology as the GIS software vendor. In object-oriented

design, an object represents an entity such as a house, lake, or person. A method has a name, a set of input parameters, and a return type.

Component Object Model (COM) is a protocol that connects one software component, or module, with another. With this protocol, it is possible to build reusable software components that can be dynamically interchanged in a distributed system. ArcGIS is built in conformance with COM architecture. COM classes use interface to organize methods and properties, and classes can share the same interface but have different implementation (polymorphism), which expresses the complex behavior of objects.

ArcGIS adopts GeoDatabase data model in the commercial relational database. GeoDatabase lets the user characterize features of their own type by defining user's own object type, by defining topological, spatial and general relationships, and by capturing how objects interact with other objects (Zeiler, 1999). ArcGIS also provides a hierarchy of COM classes (ArcObjects) ready. Since COM allows components to be reused at a binary level, the users can easily extend objects classes in conjunction with other COM classes at the lowest level without accessing to source code, header files, or object libraries using whatever COM-supported programming languages. A custom object is a combination of a database table and code compiled to a DLL. A custom feature is implemented internally in ArcGIS as a feature class table, as a behavior class stored in a DLL, and as a globally unique identifier in the Windows Registry that binds the feature class and its behavior class.

3D-VQGIS utilizes the GeoDatabase data models to customize and store the features and objects in Access Database. Objects in the application include:

- a. Individual's activities and trips: this is represented as a network in space-time composed of segments and junctions. Each segment shows the location, start time, end time, routes, mode of travel, activities performed, and so on.
- b. Geography objects in the urban environment.
 - i. Buildings with attributes like function/use (e.g. commercial, educational, etc.), height, number of story, addresses, and so on.
 - ii. Land parcels with attributes like land use. Only a set of relevant commercial parcels of interests, such as shops, shopping malls, schools, are included.
 - iii. Street network and rivers
- c. Qualitative empirical materials, including textual sources, visual and oral sources, comments and notes, and other supplemented materials. These are collected during interview and participant observation.

All these objects are stored in GeoDatabase with customized behaviors and attributes.

We seek to build an application that facilitates the entry, storage, query, and qualitative analysis of a variety of data collected through qualitative methods within a 3D GIS environment.

Qualitative research involves the collection and use of a variety of empirical materials-case study, personal experience, life story, interview, observational, historical, interactional, and visual texts-that describe routine and problematic moments and meanings in individuals' lives (Denzin and Lincoln)

These materials include a variety of format: text (e.g. a person's comments on particular geographical features, interview transcriptions, etc.), voice and video clips, photos or other still

images, maps, hand-written sketches or diagrams, etc. But in this study, we are particularly interested in describing people's feelings about the urban environment, especially in terms of the changes in feelings of fear and safety when conducting activities outside of the home (e.g. traveling, shopping, dropping off kids to schools, etc.). We hope to be able to describe and represent the urban environment that reflects an individual's subjective feelings, emotions, and perception.

There are two different types of data need to be represented in the application:

- (a) Two components of feelings of fear and safety:
 - i. Degree of fear (1-7)-attached to an individual space-time path to describe changes in personal feelings when traveling and over time.
 - ii. Degree of safety (1-7)-attached to geographical objects (buildings, street segments, land parcels, particular shops, public area like parks, etc) and is unique to each person. So when rendered, ArcScene display a subjective representation of a person's urban environment.
- (b) Other materials collected through in-depth interview: text, photos, voice clips, etc. Each piece of these materials needs to be attached to particular space-time points to reflect where and when they are relevant. For example, a comment like "I don't feel comfortable shopping in this Supermarket in the morning." should be attached to the building and time coded.
- (c) We also hope to be represented a person's familiarity with various areas of the study area.

3.2 Capabilities of 3D-VQGIS

3D-VQGIS utilizes documents and codes to manage qualitative data in Database. Documents are plain or rich text records that can be formatted for inspection, and code is a container for categories and coding. Code can represent any categories-concepts, people, abstract ideas, places and any other things that matter the research.

The capabilities of 3D-VQGIS are:

- a) Data entry-input and store various types of qualitative data.
- b) Qualitative Coding and Space-Time Coding — attaching various nodes or empirical materials to space-time segments.
- c) Search and modeling-3D representation of a person's subjective environment; interactive spatial query (searching), other analytical capabilities and so on.

4. Design and Implementation of 3D-VQGIS

The design and implementation of 3D-VQGIS is application-driven. A Muslim woman's data has been used to demonstrate the design and implementation of the application. 3D-VQGIS has four main modules (*Fig. 2*): (a) Trajectory Generator. This module is used for reading space-time information of activity-travel data and for generating 3D trajectory features in GeoDatabase; (b) Coding Browser and Coding Editor, which are used for qualitative coding and analysis, and code/document management; (c) Source Browser is a module designed to store, browse and manage empirical materials in GeoDatabase; and (d) Space-Time Coding. Space-Time coding module interactively links the empirical materials and codes to activity-travel data, and performs 3D and qualitative geovisualization in ArcScene. These modules are integrated into ArcScene by

extending ArcObjects COM components. Generally there are several options for customizing ArcGIS desktop: use build in customization environment (VBA); use standalone programming environment (e.g. VB, VC++, Delphi) to create standalone applications or extend custom components; and extend the data model by crating custom features using aggregation-supported COM language, or using ArcCatalog, Visio UML, and CASE tools. In 3D-VQGIS, DLLs are created and plugged into the ArcScene as a new control or component, and VBA scripts are also written for customization. The customization scripts and reference of customized DLLs are stored in ArcScene SDX file.

The GeoDatabase used by 3D-VQGIS can be created by the customized module with predefined feature dataset. Feature dataset is a logic container for similar feature classes, and also is required to maintain topological relationship of certain feature classes. Three feature dataset are defined for space-time trajectory, urban environment feature objects, and empirical materials respectively.

4.1 Generation of 3D Objects in GeoDatabase

The Space-Time trajectory provides a framework of activity pattern analysis. The space-time trajectory is built from the travel dairy data, which is collected from the travel diary as shown in *Table 1*. The space-time trajectory is a 3D network composed of segment feature class and junction feature class stored in the same feature dataset. Each segment has a Segment ID, start location, start time, end location, end time, activity type, and other various attributes. Using geo-coding technology, start location and end location can be changed into the map space to construct 3D network. Segment represents the activity process, while junction represents the starting or ending point of the event. *Fig.3a* shows the Muslim woman's daily activity-travel pattern and activity extent in 2D space; *Fig.3b* shows the generalized woman's space-time trajectory in 3D. *Fig.3a* clearly shows the activity patterns of the Muslim woman, however, it is inconvenient to perceive the time window of each activity even with time stamp labeled, and it is difficult to show temporal information of those repeated activities; From *Fig.3b* time information of activities are included and easily perceived in 3D space.

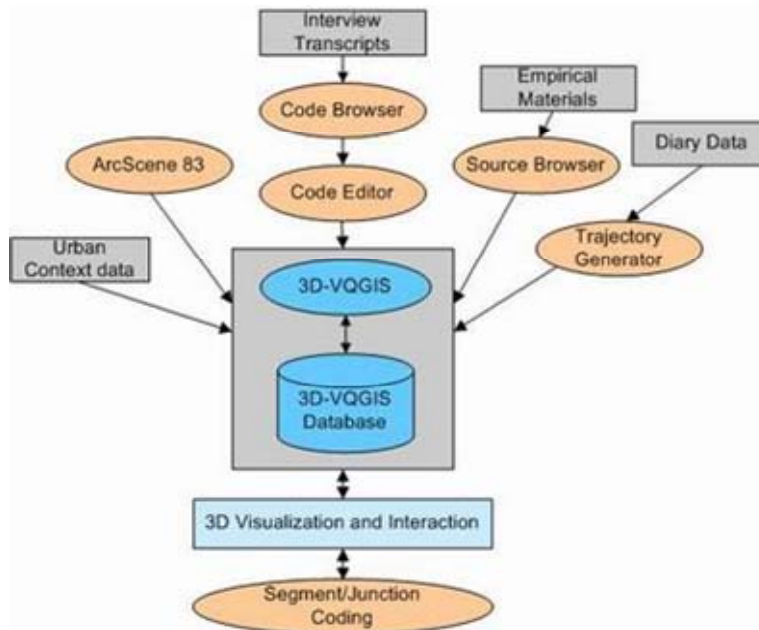


Fig 2: The Organization and Structure of 3D-VQGIS

4.2 Qualitative Coding and Coding Tools

The central task of qualitative analysis is to extract and abstract so that to locate significant themes in complex data, consider them together and abstract from them, providing rich descriptions and theories. Qualitative coding is one of the most popular qualitative analysis techniques to code and retrieve text. Coding Browser and Coding Editor are two modules developed for qualitative coding analysis of interview transcripts. Coding Browser is basically used for the management of both codes and documents (Textbase and Codebase managers) in the database, while Coding Editor is a text editing tool for visually coding of documents. Both coding modules facilitate the reduction of interview transcripts by selecting, simplifying, abstracting and transforming process. The analyst decides what to be singled out for further analysis by the principle of selectivity.

The reduction of transcripts produces codes of different kinds, which has several purposes in qualitative analysis. Codes basically are containers for keeping emerging ideas and their links with data, and they are also a good way of asking questions, exploring their relationship with other codes to the result of searches. Any number of codes can be created either in Coding Browser or Coding Editor during coding or without any coding.

Table 1: the Muslim Woman's Daily Activities

Start Place	Start Time	End Place	End Time	Description
home	0:00am	home	8:05am	Stay at home
Home	8:05 am	Windermere School	8:14 am	Send kids to school
Windermere School	8:20 am	Home	8:30 am	Return home
Home	9:00 am	Mosque	9:07 am	Go to church
Mosque	11:40 am	Plaza International	11:41	Having lunch
Plaza International	12:05 pm	Kohl's	12:06 pm	Shopping
Kohl's	12:30 pm	Kroger	12:45 pm	Grocery shopping
Kroger	1:55 pm	Home	2:07 pm	Return Home
Home	2:40 pm	Windermere School	2:50 pm	Pickup kids at school
Windermere School	3:10 pm	Home	3:22 pm	Go back home
Home	3:22 pm	Home	12:00 am	Stay at home

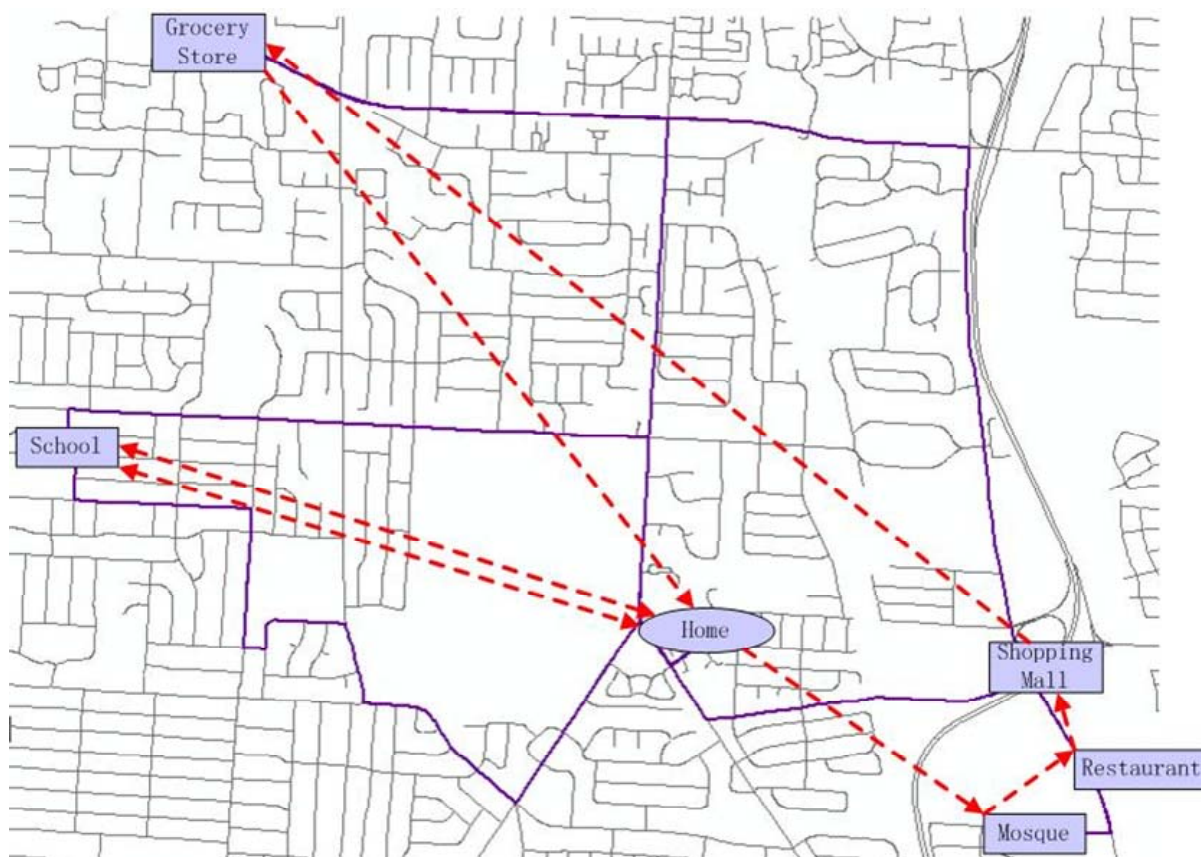


Fig.3a Daily Activity Travel Pattern after 9/11

The understanding of rich data always involves abstracting from it into categories. From the representation of spatial knowledge, four categories of codes are defined to simplify the coding process: *where* (spatial reference: environment, locations), *when* (temporal reference: schedules,

time constraints), *what/who* (subjects domains and concepts, such as feelings and fears) and *how* (hypothesis, decisions). All these categories are cognitively distinct, but they are intrinsically highly related (Peuquet, 2002). *Where* and *when* specify the space-time information that can be incorporated in Space-Time trajectory. Each activity taken is regarded as an event that can be decomposed into these four categories, and this is actually a deductive way in coding. However, more categories can be applied depending on application needs.

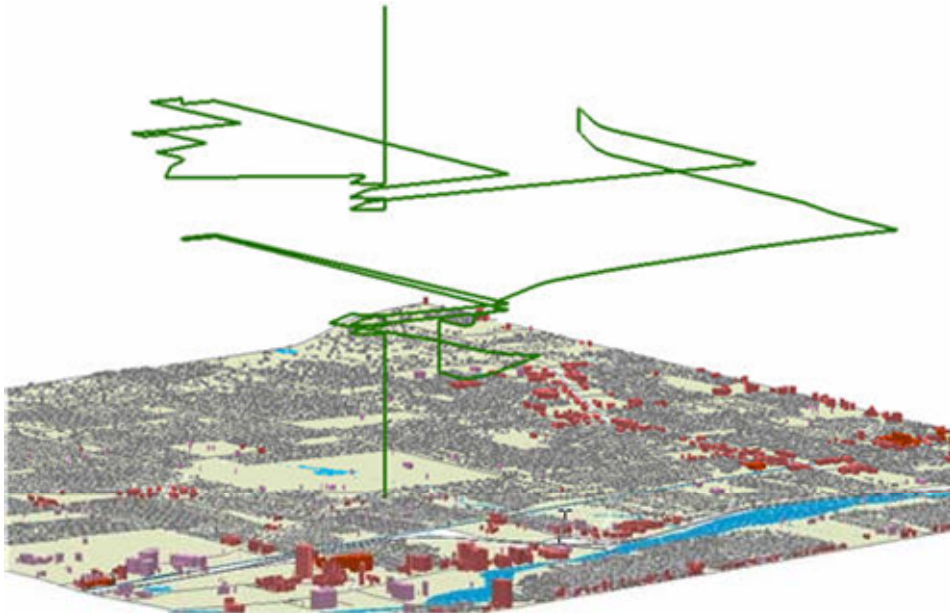


Fig.3b Space-Time Trajectory of the Muslim Woman

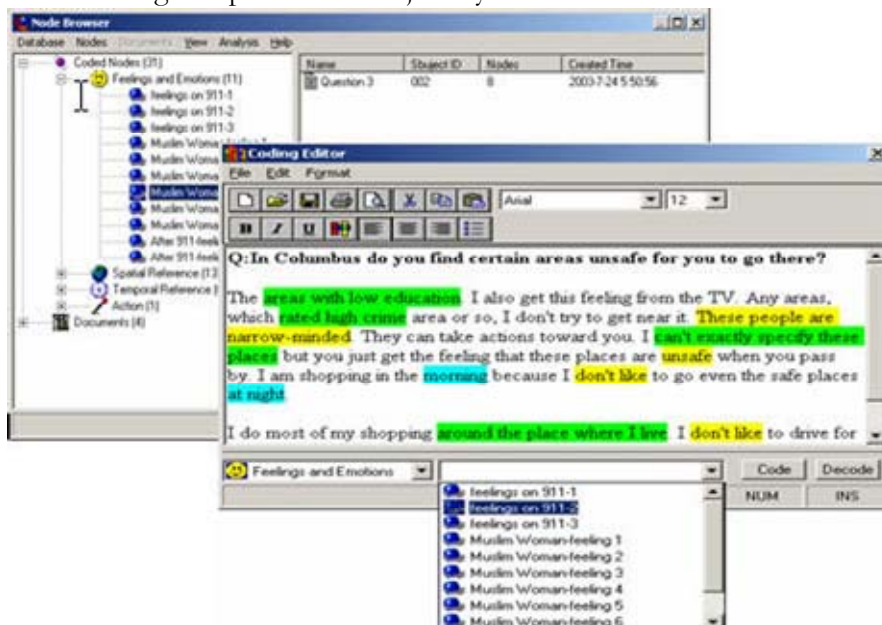


Fig. 4 Coding Analysis in Coding Browser and Coding Editor

During the interview of the Muslim woman's activities, a structured or semi-structured interview helps to identify the post-9/11 impact of their life. Each question is organized into a document in the database to easily identify codes of interested topics. Documents can be imported from a

word processor into Coding Editor in rich text (or ordinary plain text) files, and can still be edited here to change and add something in the lifetime of analysis. Coding Editor provides ways to format the document, and create codes interactively by selecting text in it. Coding Browser is similar to window explorer in that the user can choose different views of documents and codes, and also providing ways to alter, organize, preview, create or delete the codes and documents; besides, the properties of codes and documents also can be changed in Coding Browser, such as the name of the creator, the value of codes and so on. When browsing codes or documents in Coding Browser, detailed information will be listed to show which codes have been coded from the selected document, or in which documents have the selected code been coded. Such information helps the researcher to track back the coded data and retrieve not only the coded value but also the context. The handling of codes and documents in Browser and Editor helps to develop ideas and questions. (See *Fig. 4*)

4.3 Empirical Materials in Qualitative Analysis

Empirical materials are generated from interview and participant observation, including the pictures, audio and video clips, interview notes together with the coded codes become resources for qualitative analysis. 3D-VQGIS provides Source Browser to efficiently manage and explore the empirical materials collected during interview and participant observation. By Source Browser, it is convenient to add, delete, explore and update empirical materials in 3D-VQGIS database. In the right pane there is a list of materials that has been incorporated into the database. General empirical materials, such as text, voice, video or images can be directly previewed in the left pane by selecting the source, or can be explored in window programs by double-clicking the selected item. Other materials, such as PDF files or spreadsheets, cannot be previewed directly. However, they can be explored only if appropriate supportive window programs have been installed. Empirical materials stored in the database give supplementary explanation of activities.

4.4 Space-Time Coding and Visualization

The Space-Time trajectory describes the activity path in urban context, and putting the empirical materials back into urban context provides a hyperspace that helps to understand the activities in space and time. Linking empirical materials into Space-Time segments or junctions gives immediate access to recall vivid situation of interview, and embed codes in segments or junctions in trajectory tells the idea of what happened there.

Space-Time coding is the process of attaching codes or empirical materials to a particular space-time segment of a person's space-time trajectory. When navigating the Space-Time trajectory, the analyst can rethink and organize codes and empirical materials existing in database. For one process, codes have indicated the place, the time, the causality and the protagonist, which have corresponding Space-Time counterparts in quantitative space. Linking these codes into corresponding Space-Time segments causes the integration of quantitative and qualitative data. The linking of codes and empirical materials into segments/junctions is performed interactively in 3D environment by clicking the trajectory, as well as exploring linked empirical materials or codes, which helps to understand the human's activities, feelings, and perceptions better within explicit urban context. The linking can be done into specified segments or junctions, or into the vicinity of that area in a batch. The analyst also can step back to the original texts by codes,

consider what the coded texts mean and assess their implications for questions, and write notes for certain topics. This linking operation combines materials of interested topics together selectively to figure out the outcome or prove the assumption.

The central task of qualitative analysis is to successfully link the codes into trajectory so that mapping and visualization tools can be utilized in GIS. When studying the feelings of the Muslim woman, the codes of fear is coded in Coding Editor first and then selectively chosen to be linked into the trajectory by the implied information of space and time. Quantized the fears into different degrees, the values about fear in linked codes hence show the different degree of fear, and generalize the landscape of fear of the Muslim woman to the urban context by mapping techniques (Fig.5).

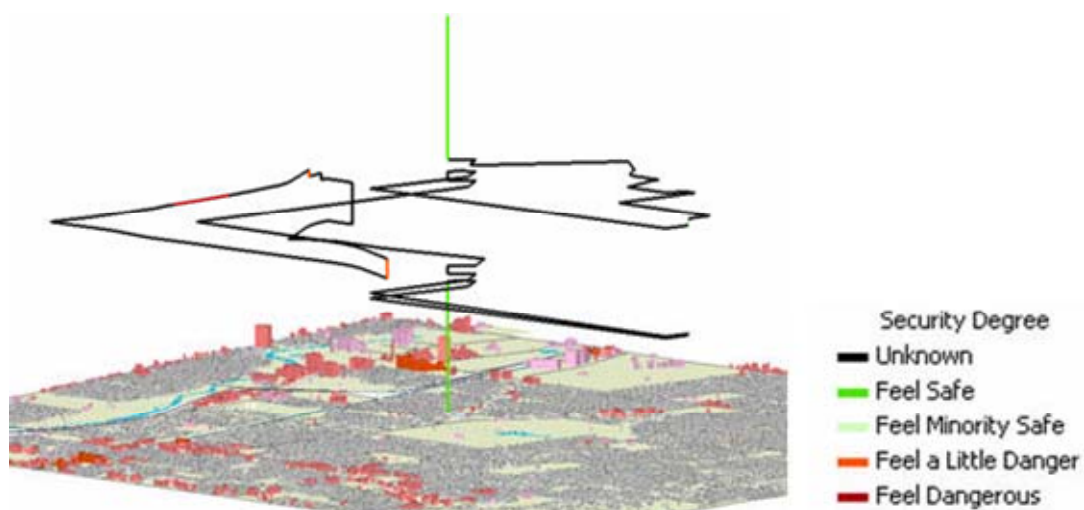


Fig. 5 Landscape of Fear of Muslim Woman After 9/11

5. Conclusion and Discussion

Similar to the contemporary computer aided qualitative data analysis software such as NVivo, Capabilities for representing and handling qualitative information within the 3D environment of a GIS has been discussed. The 3D-VQGIS is treated as a code-based theory builder with capabilities including coding qualitative data, identifying relationships between concepts and building qualitative models. The activities patterns has been studied using this system to study the impact of post-9/11 anti-Muslim hate crime, and a 3D scene of the 'landscape of fear' is generated after qualitative coding and analysis, which shows the serious situation of the activity spaces and feeling of Muslim woman. The incorporated qualitative coding method helps to process the interview high efficiently and interactively, and the space-time coding explains the qualitative data quantitatively, which facilitates the generalization of theories.

However, there are still some limitations of 3D-VQGIS. Firstly, this application is designed to study the problem of personal activities patterns using time geography in 3D space. For time geography approach, it is pretty expensive and difficult to collect the travel diary data, which subsequently limit the representation of qualitative analysis in activity pattern research. Secondly, qualitative techniques, such as qualitative coding, have been incorporated into the ArcScene. For geographers, the versatility of problem demands different research paradigms and analysis

techniques, and more options need to be provided for the researchers. Besides, providing methods to create any attribute fields for codes is necessary for advanced and complex analysis so that statistical methods can be applied. Another limitation of 3D-VQGIS is the limitation of space-time representation. In this research, it is good if one trajectory is used to understand the Muslim woman's behavior in space-time. When considering ethnics groups, dozens of trajectories will entangle each other and hard for Space-Time coding and recognition; An effective way of representation multiple trajectories in 3D space need to be considered. besides, in 3D it is vague to identify the spatial position of processes or events in Space-Time trajectory without aid of specially designed identify tools. The last limitation of incorporating qualitative analysis is the automatic spatial and temporal reasoning. To correctly and efficiently recognize the location and time window demands the artificial intelligence and knowledge base. This, however, is a challenging and prospective direction in qualitative analysis within GIS.

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