A Space-Time GIS for Studying Individual-based Human Activities and Interactions

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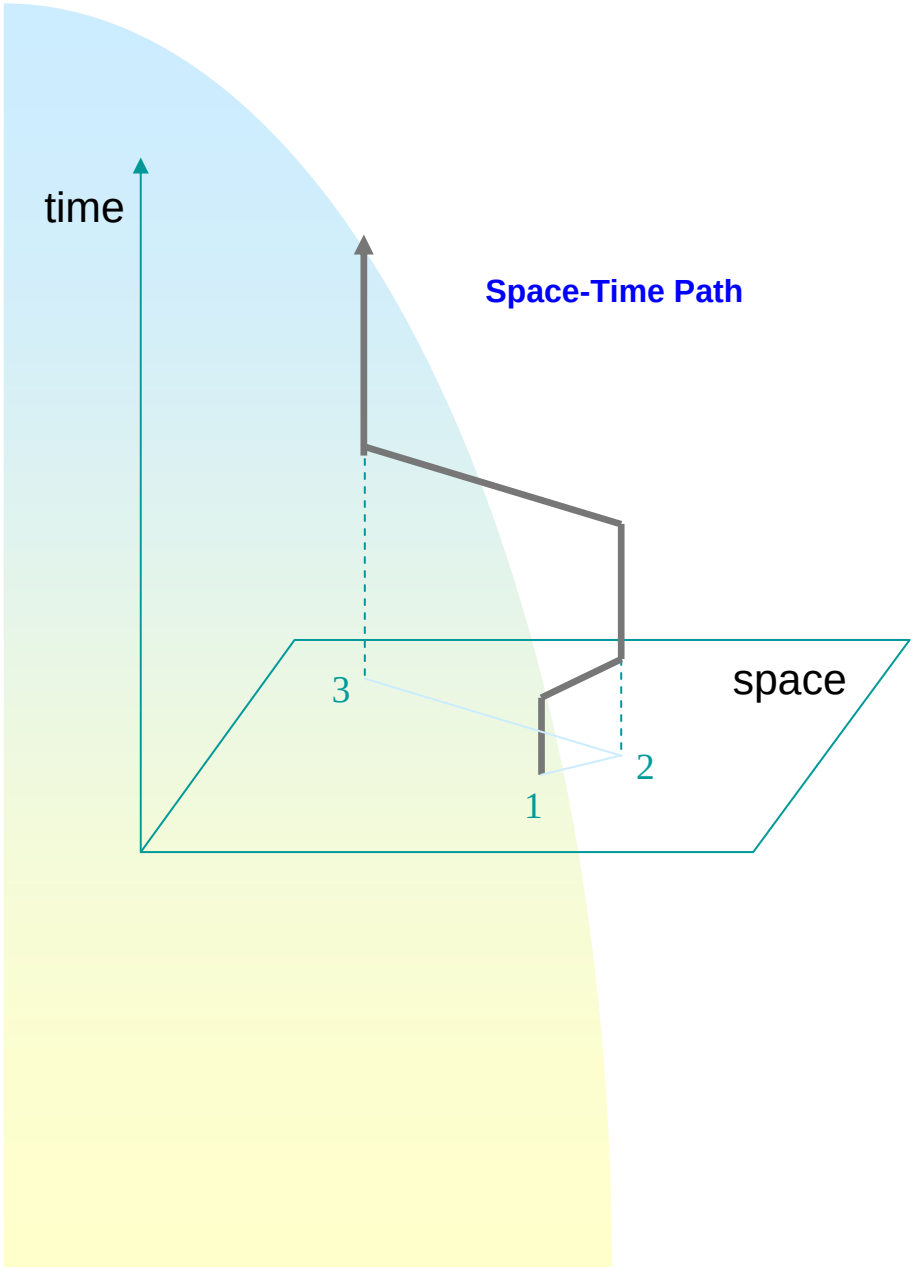
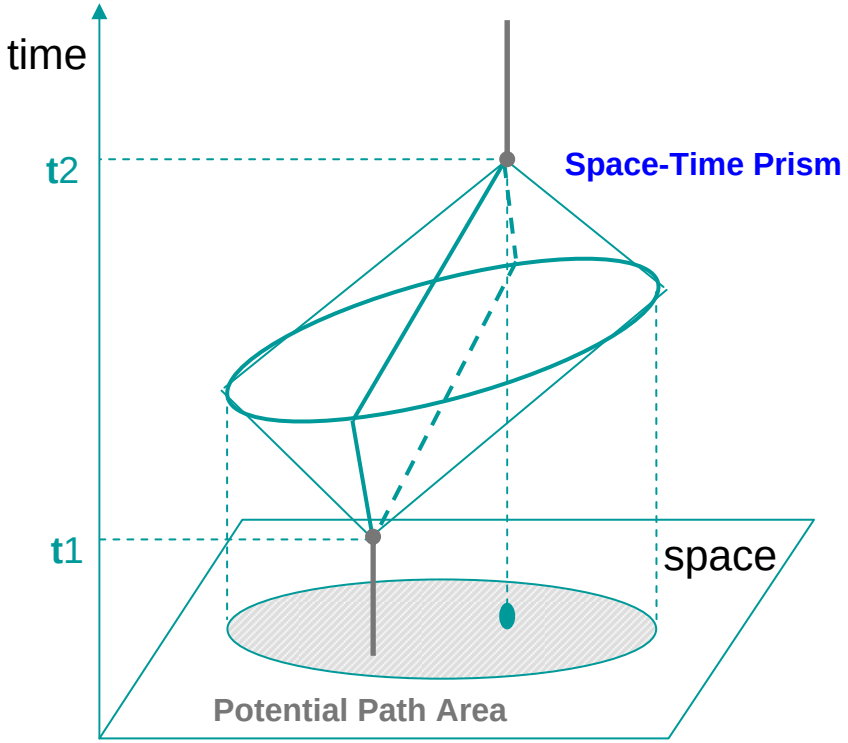
Why Individual-based Space-Time GIS for HSS?

- Human activities interact and intertwine to create a complex social system that fulfills our physiological, economic, social and other needs.
- All activities (including “do nothing”) are associated with specific location and time.

Hägerstrand's Time Geography:

- Hägerstrand's time geography examines human activities under various constraints in a space–time context.
- Space and time are connected through the concept of space–time path, which depicts the sequence of an individual's activities at various locations over a time period.
- The possible locations that a person can visit within a given time window form a continuous space known as a space–time prism.


time
Space-Time Path
space
3
2
1


time
t2
Space-Time Prism
t1
space
Potential Path Area

Individual Tracking Data in Today's World:

- Modern location-aware, along with information and communications, technologies have made it a relatively easy and affordable task of tracking individuals.
  - Global positioning system (GPS) provides a low-cost way of tracking moving objects.
  - Cellular phones have become an important source of collecting individual tracking data.
  - RFID, Internet surfing, telephone logs, credit card transactions, ...

"Imagine that your business had a complete log of your customers' wanderings – every trip to the grocery store, every work commute, every walk with the dog. What could you learn about them? ..... Just as important, ..., would customers be concerned about privacy .....? This isn't science fiction. A nascent industry extending from the laboratories of Google and Nokia to a host of data-fueled startups is wrestling with these very questions."

("The Next Net" by Stephen Baker, *BusinessWeek,* March 9, 2009, p. 42)

Google Latitude

http://www.google.com/latitude/intro.html

Google Latitude - Microsoft Internet Explorer

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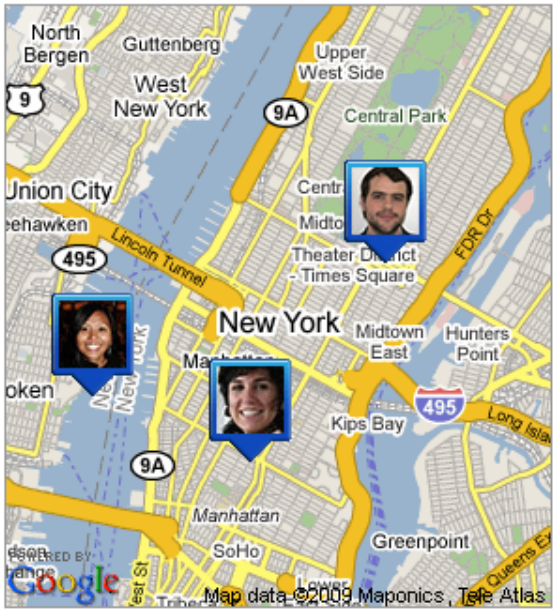
Google Latitude

Introducing Google Latitude



Fred wants to hang out with his friends, and checks to see where they are.

Learn more about Google Latitude

Watch a video

See where your friends are on a map

Enjoy Google Latitude on your phone, computer, or both.

Start using it on your phone

See your friends' locations and status messages and share yours with them.

Enter your number or visit google.com/latitude on your mobile web browser.

United States

Send a link to my phone

Will it work with my phone?

View it on your computer

See your friends' locations and status messages on a full screen even without a compatible phone or data plan.

Add Latitude to iGoogle »

Google

This service is free from Google; carrier charges may apply. The number entered on this page will only be used to send you a text message. It will not be linked to any Google services unless you've given us permission elsewhere.

Sense Networks

http://www.sensenetworks.com/

- According to Baker (*BusinessWeek*, March 9, 2009),
  - "... a startup called Sense Networks is pouring over the movements of nearly 4 million cell-phone users over the course of a year. They have been tracked by global positioning systems, by cell towers ..., or by local Wi-Fi networks ..."
  - "Phone companies and advertisers provide Sense raw data on people's movements and behavior."

Citysense - Powered by Sense Networks - Microsoft Internet Explorer

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Citysense™

Live San Francisco Nightlife Activity

Where is everybody?

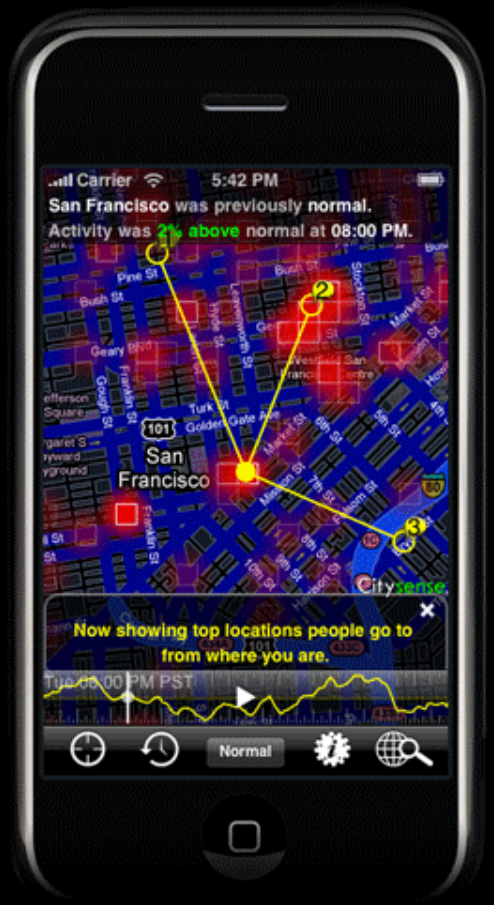
- How busy is the city? Know when to go out
- See the top nightlife hotspots in real-time
- Find out what's there in one click
- Find out where everyone's going next

>> More info

For real-time nightlife on your iPhone®, visit the App Store

Also available for the BlackBerry®

Go to www.citysense.com on your BlackBerry® to download.



SKYHOOK Wireless: How It Works > Overview - Microsoft Internet Explorer

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Address http://www.skyhookwireless.com/howitworks/ Go Links

Skyhook Wireless
http://www.skyhookwireless.com/

SKYHOOK WIRELESS

WHO WE ARE | HOW IT WORKS | SKYHOOK IN ACTION | LOCATION APPS

How it Works

- Overview
- Components
- Coverage
- Architecture
- Performance
- Comparison
- Privacy
- FAQ

XPS Overview

To see Skyhook's hybrid positoning system (XPS) in action, view a demo now:

XPS - Combining Location Sources

Skyhook's hybrid positioning system (XPS) is a software-only location solution that allows any mobile device with Wi-Fi, GPS or a cellular radio (GSM/CDMA) to determine its position with an accuracy of 10 to 20 meters. Unlike other hybrid location solutions, XPS uses land-based Wi-Fi access points, GPS satellites and cellular towers to determine location information. The XPS platform provides a fast, accurate and reliable location source to mobile applications and services by leveraging the strengths of each

SKYHOOK Wireless: How It Works > Overview - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address http://www.skyhookwireless.com/howitworks/ Go Links

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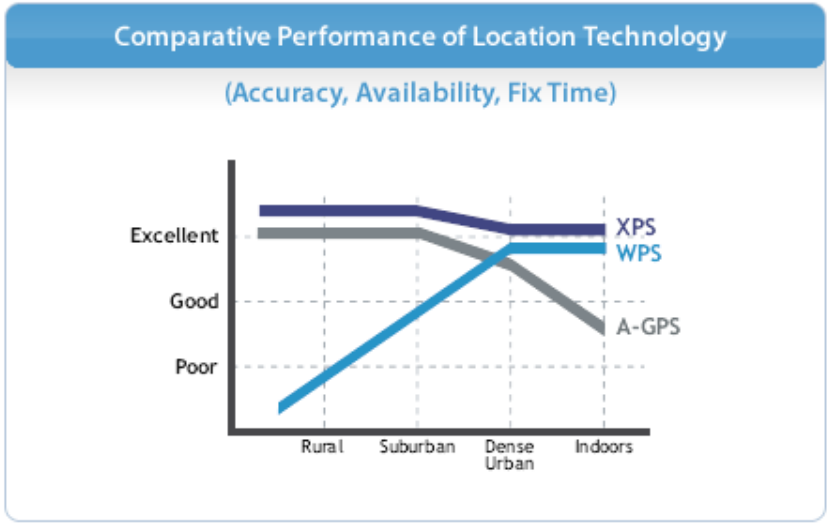
The following graph illustrates the performance of XPS relative to assisted GPS (A-GPS) and WPS (Wi-Fi location).



XPS is configured to integrate and synthesize the location output of Skyhook's Wi-Fi Positioning System (WPS), GPS and cellular towers (Cell ID). It then uses advanced hybrid positioning algorithms to combine each of these location sources to arrive at a single position with a high degree of confidence.

LBS Application

SKYHOOK Wireless: How It Works > Coverage - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address http://www.skyhookwireless.com/howitworks/coverage.php Go Links Convert Select

Check Coverage in Your Area

Type in your address and click Find It.

Address lookup

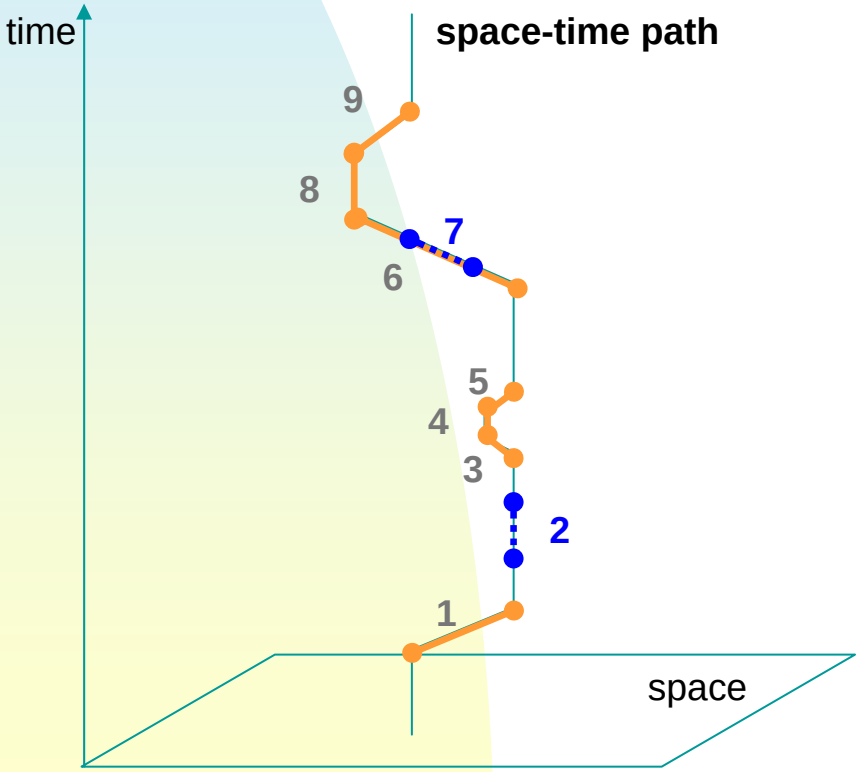
Taipei, Taiwan Find It

Success
Taipei City, Taiwan (25.091075, 121.5598345)

Error on page. Internet

A Space-Time GIS Implementation:

- Represent individual activities on a space-time path using *spatio-temporal linear referencing* and *dynamic segmentation*.

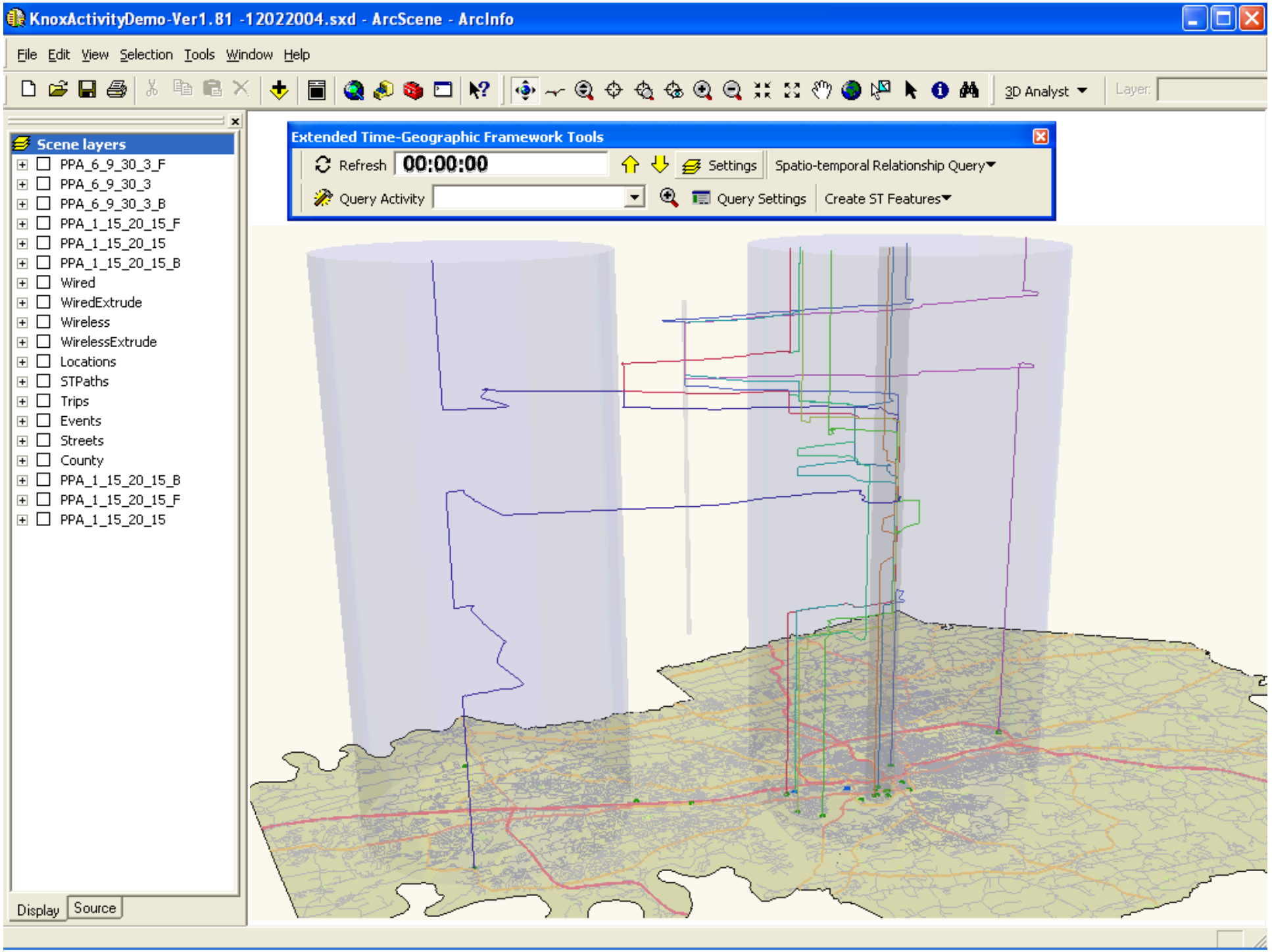


Physical activities:

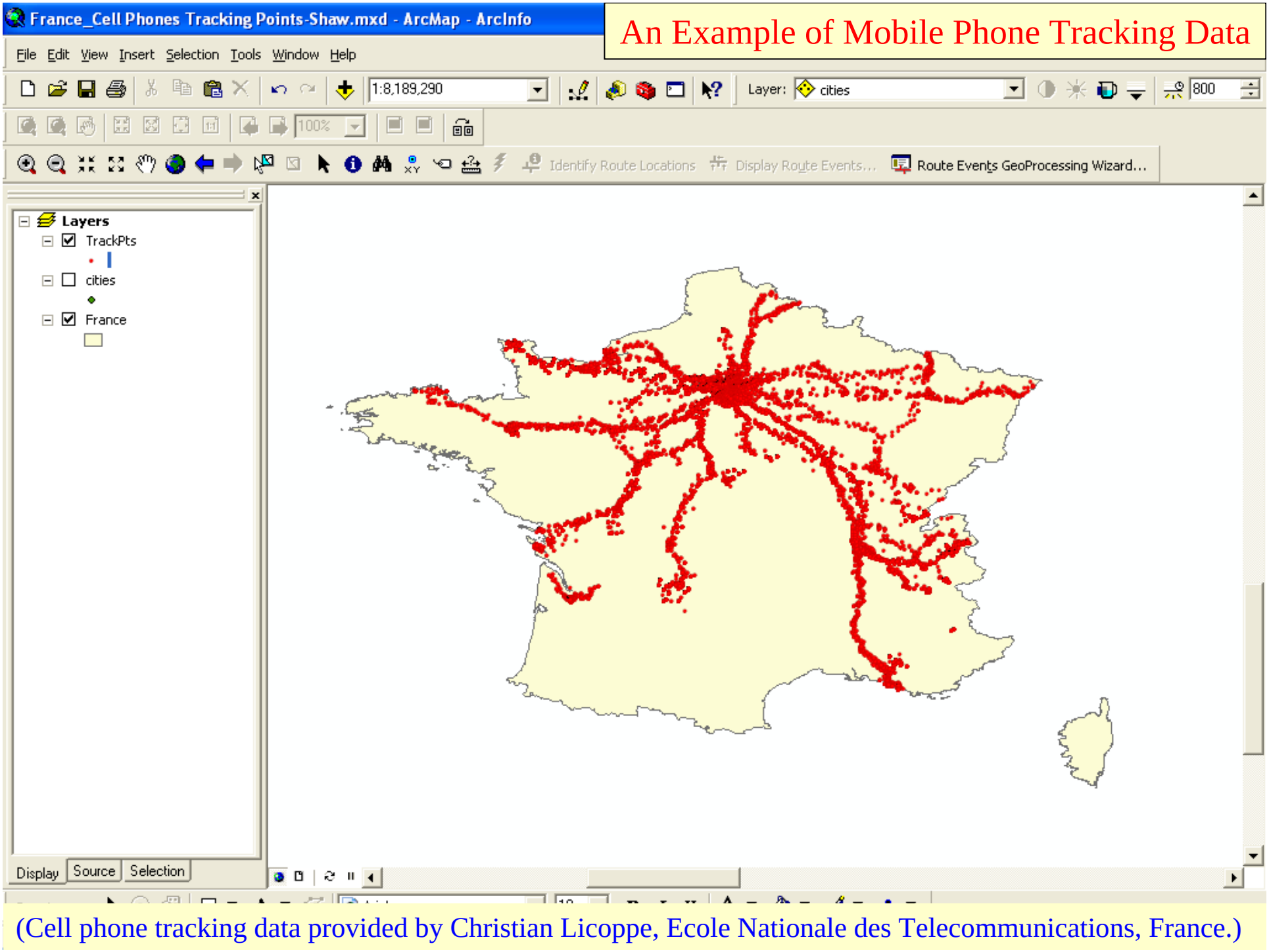
1. Drive to work
3. Walk to lunch
4. Have lunch
5. Walk back from lunch
6. Drive back home
8. Grocery shopping
9. Return home

Virtual activities:

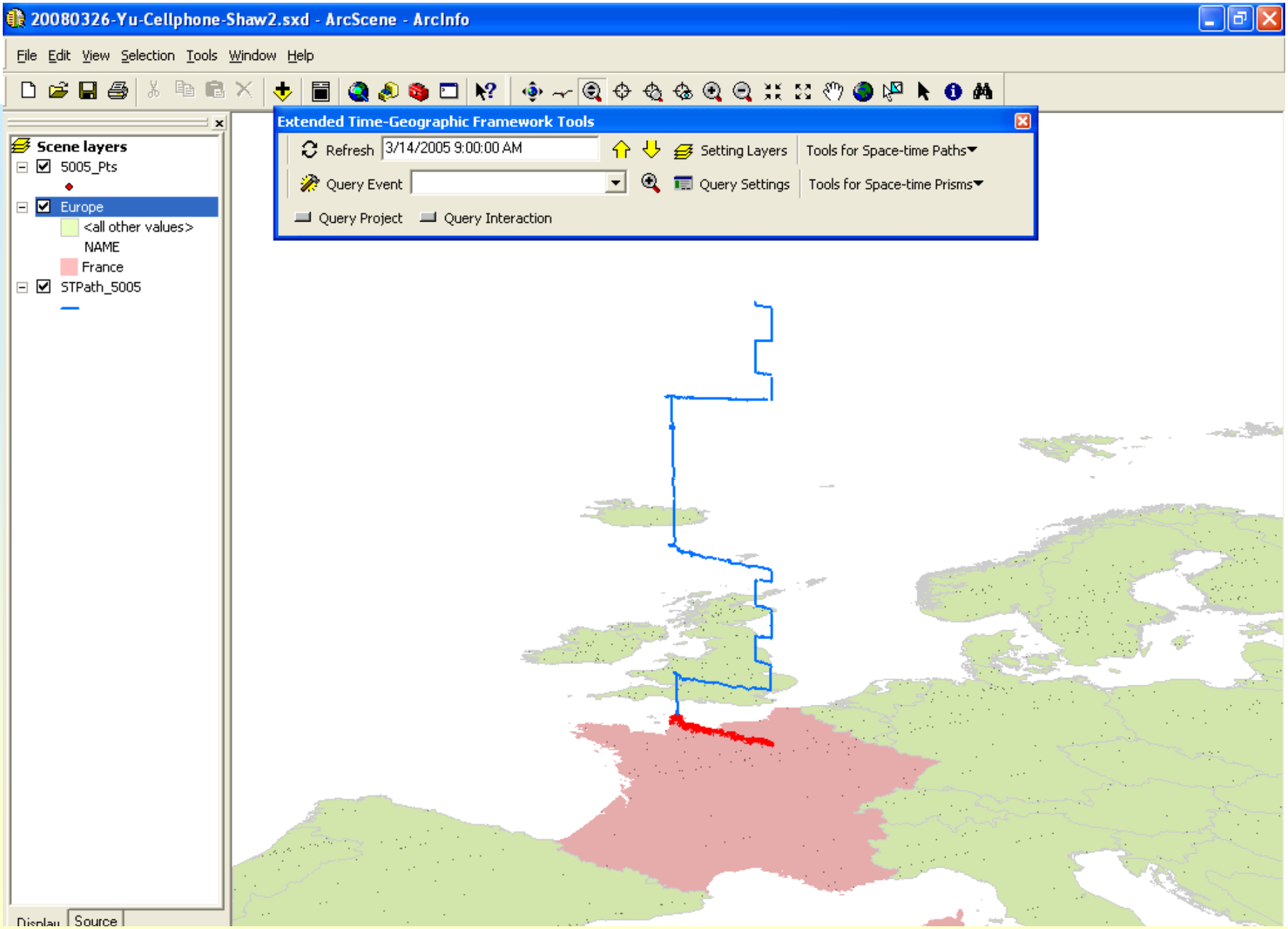
2. Instant messaging with colleagues
7. Receive a cell phone call from spouse to do grocery shopping


KnoxActivityDemo-Ver1.81 -12022004.sxd - ArcScene - ArcInfo
File Edit View Selection Tools Window Help
3D Analyst
Layer:
Scene layers
PPA_6_9_30_3_F
PPA_6_9_30_3
PPA_6_9_30_3_B
PPA_1_15_20_15_F
PPA_1_15_20_15
PPA_1_15_20_15_B
Wired
WiredExtrude
Wireless
WirelessExtrude
Locations
STPaths
Trips
Events
Streets
County
PPA_1_15_20_15_B
PPA_1_15_20_15_F
PPA_1_15_20_15
Display
Source
Extended Time-Geographic Framework Tools
Refresh
00:00:00
Settings
Spatio-temporal Relationship Query
Query Activity
Query Settings
Create ST Features

An Example of Mobile Phone Tracking Data



(Cell phone tracking data provided by Christian Licoppe, Ecole Nationale des Telecommunications, France.)



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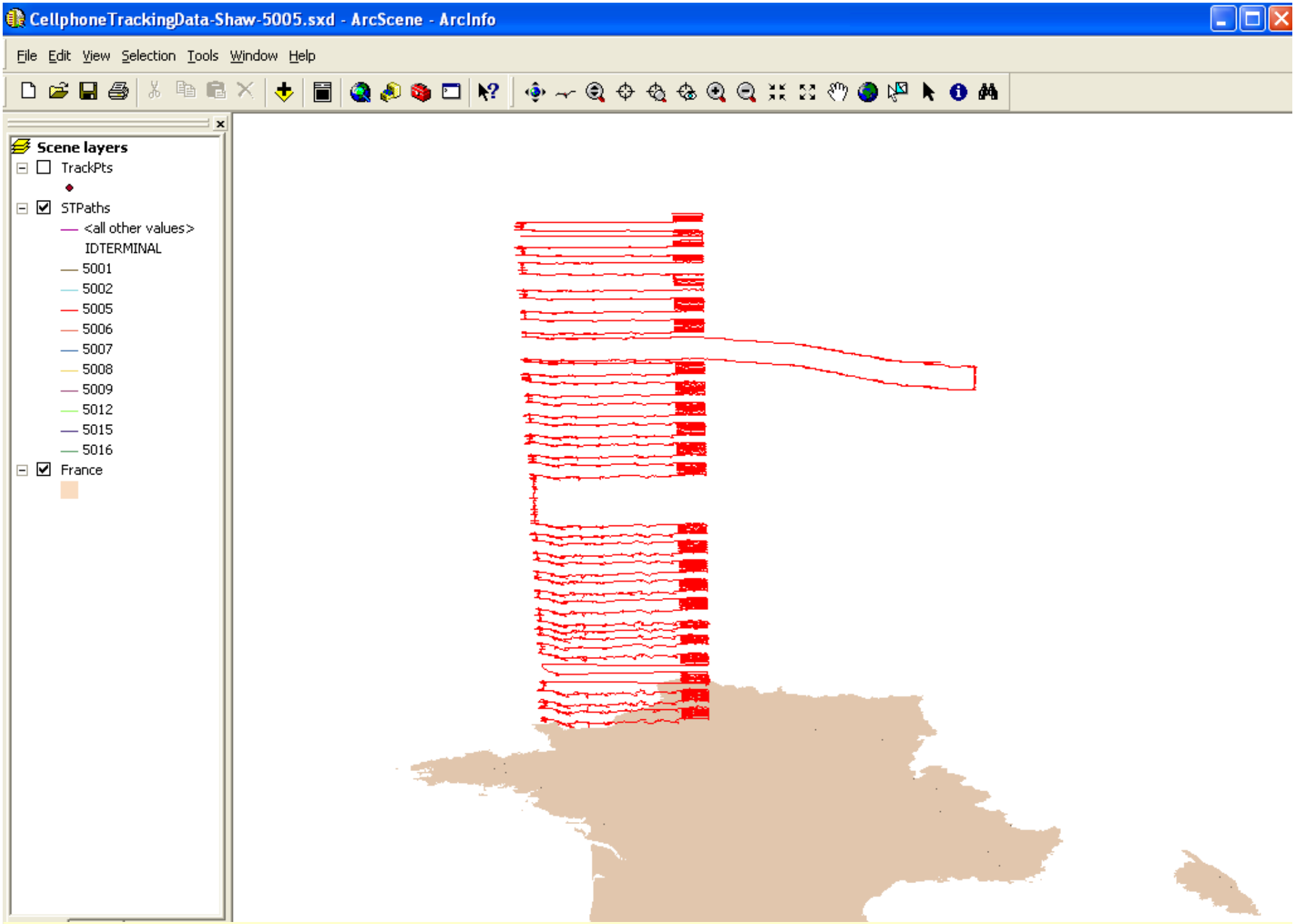

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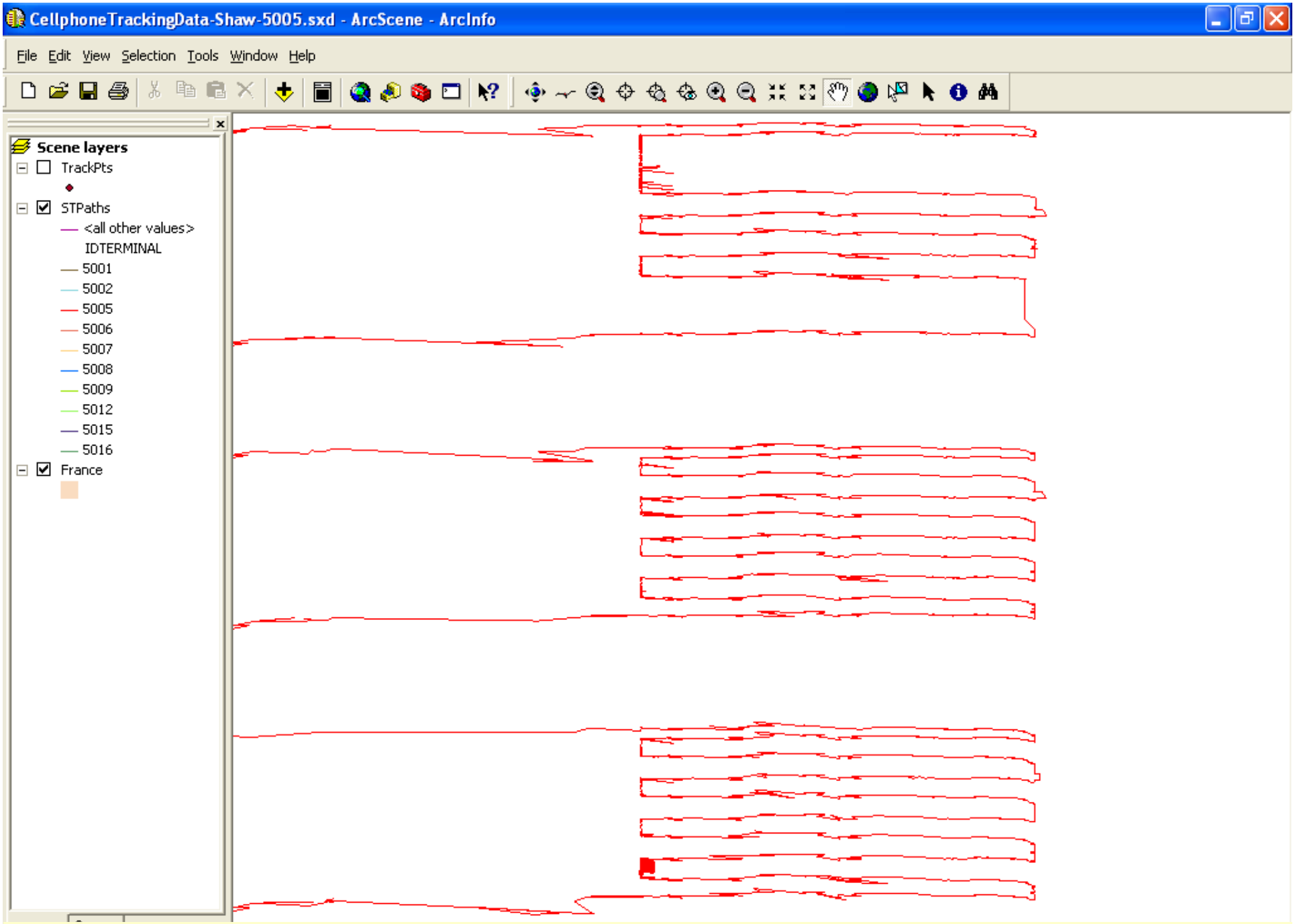

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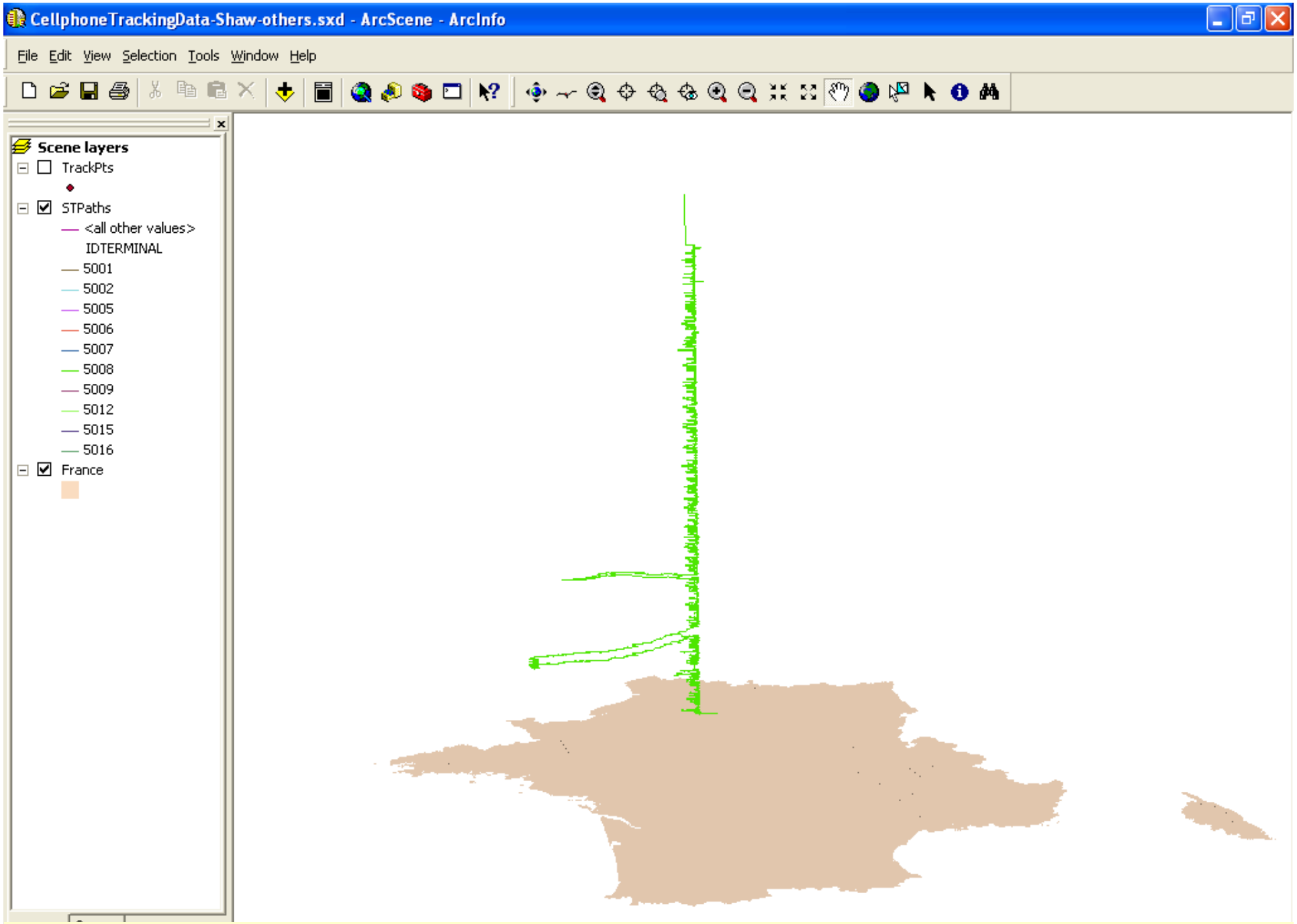

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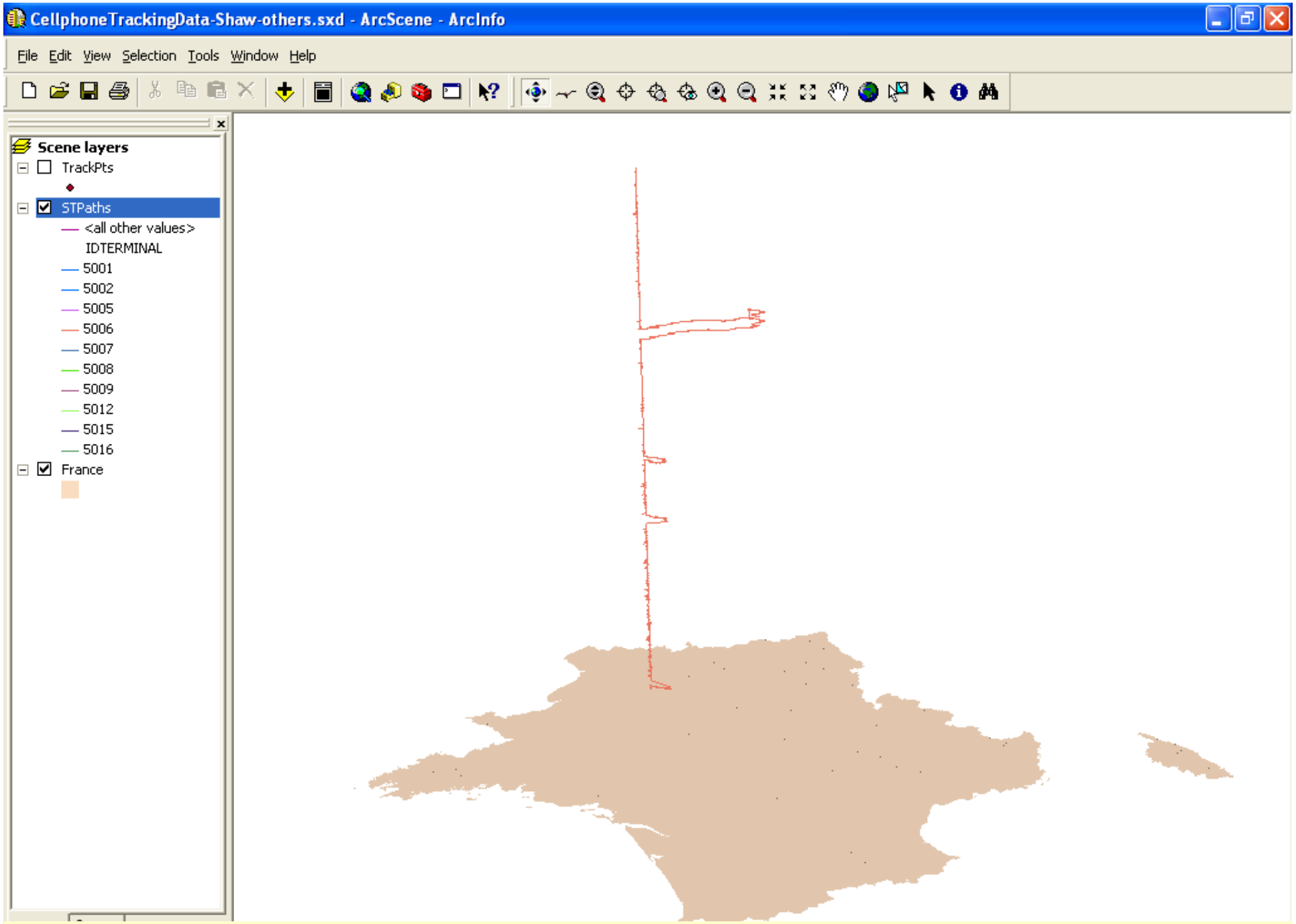

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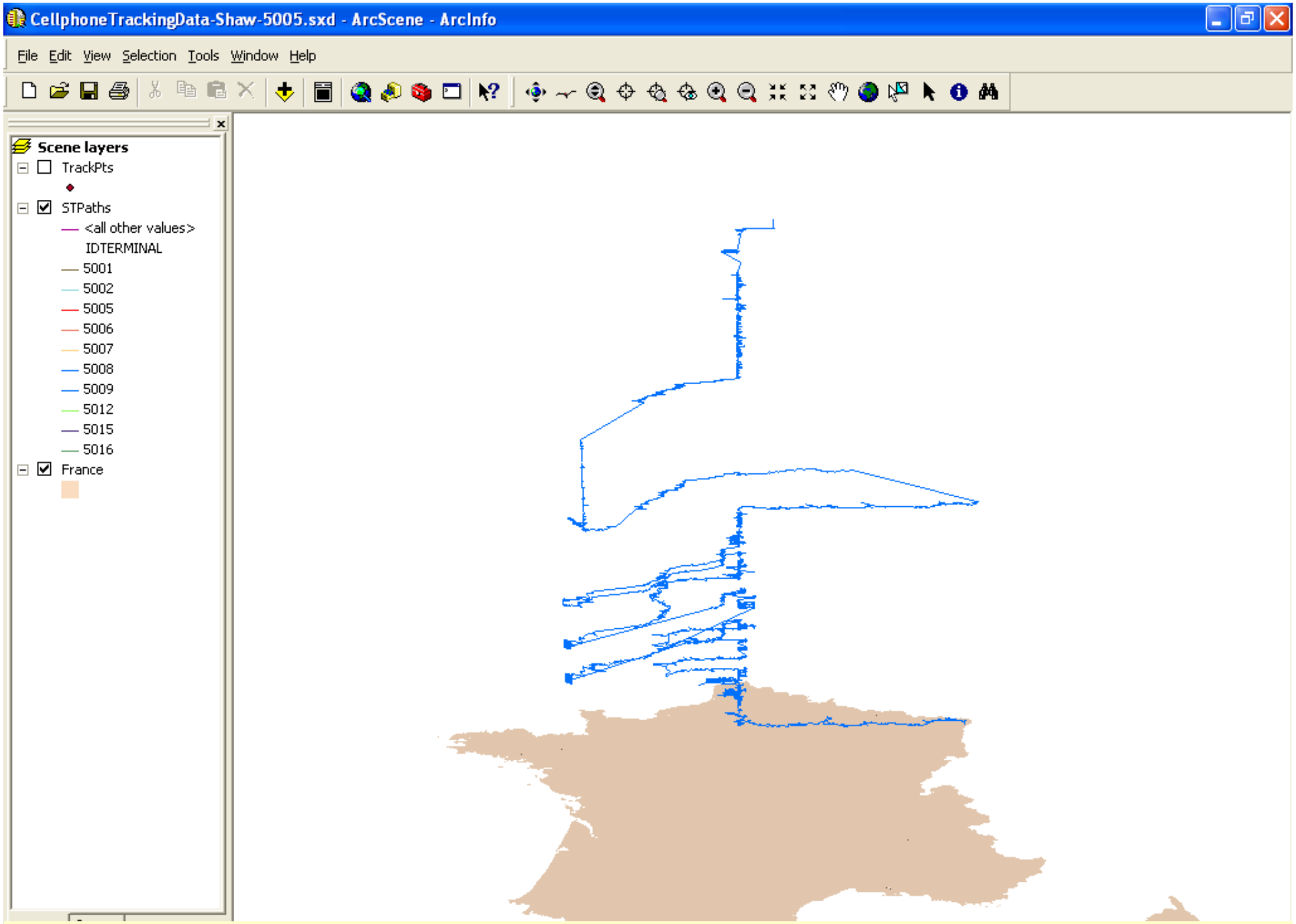
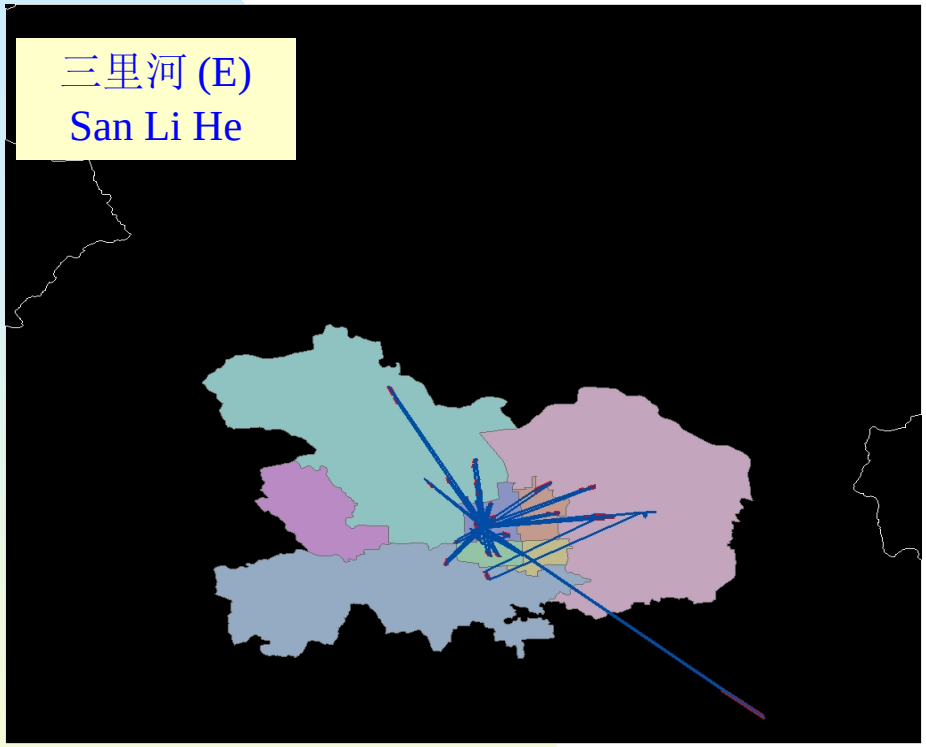


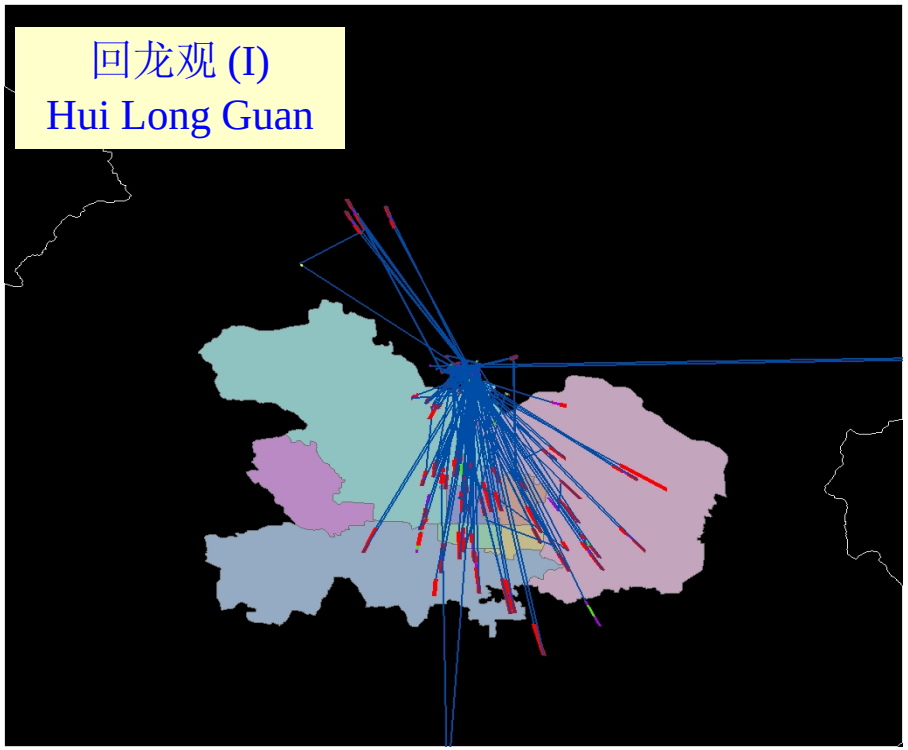
(Cell phone tracking data provided by Christian Licoppe, Ecole Nationale des Telecommunications, France.)

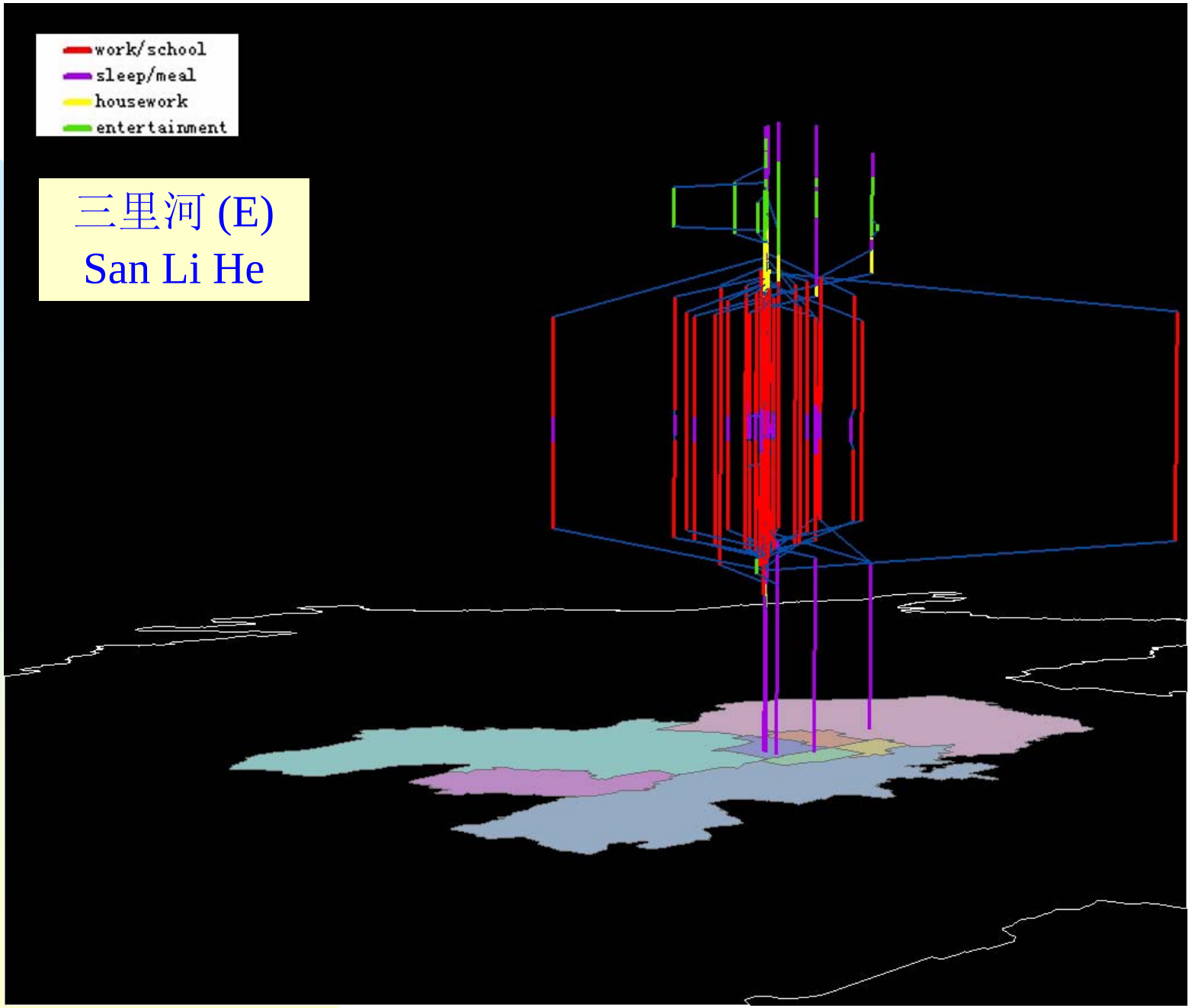
- Example of activity-travel survey data of ten selected neighborhoods in Beijing, China.
- This survey was conducted in October-November of 2007 by the Behavioral Geography Research Group of Beijing University.

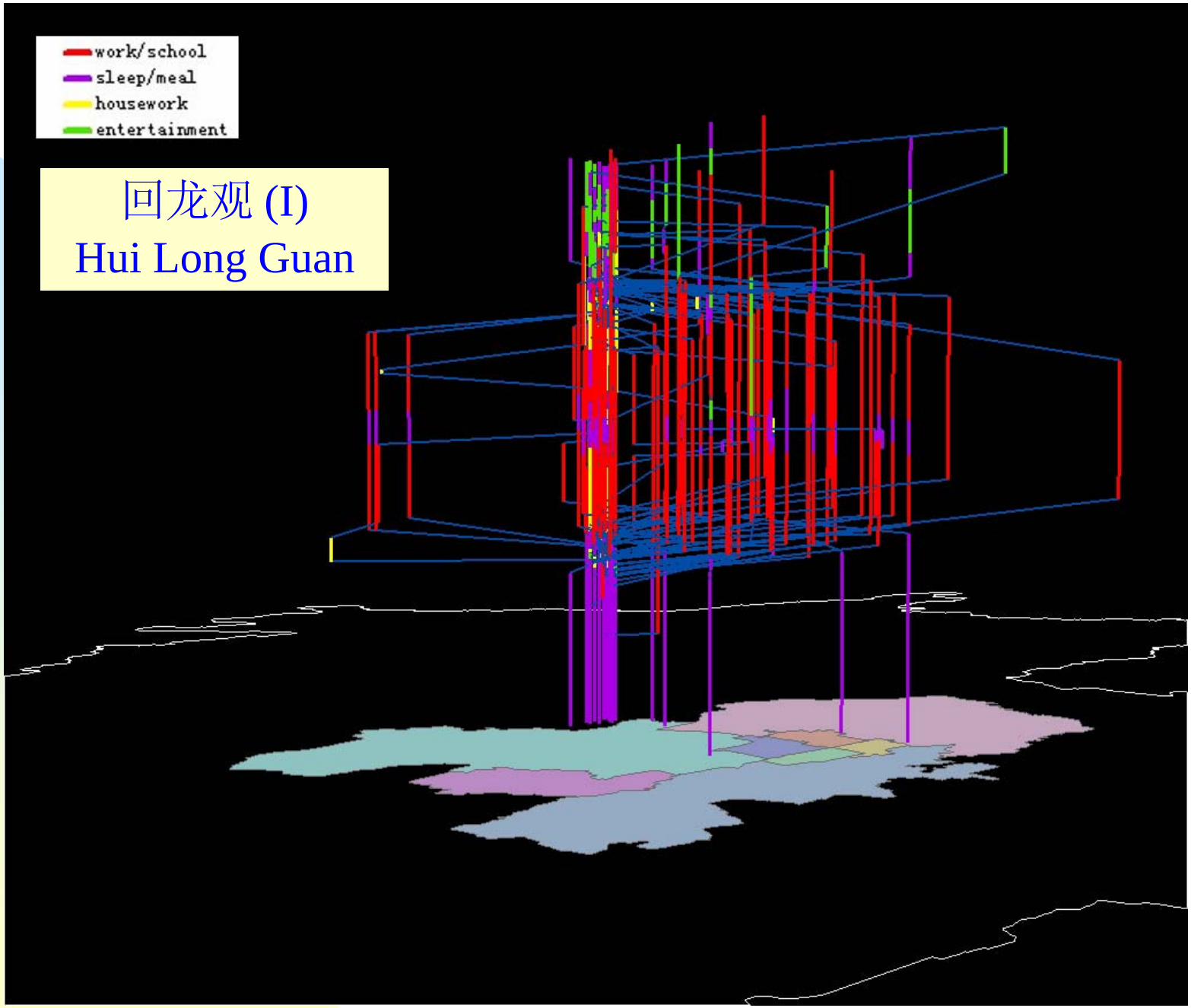
(Analysis was performed with assistance from Jie Chen.)

ID	Neighborhood Name	Characteristics	Valid Samples (Persons)
A	交道口 Jiao Dao Kou	Migrant workers, low income, and older population	115
B	前海北沿 Qian Hai Bei Yan	Migrant workers, low income, and older population	103
C	燕东园 Yan Dong Yuan	Mainly faculty and staff of Beijing University	100
D	望京花园 Wang Jing Hua Yuan	Mainly high school teachers and staff	133
E	三里河 San Li He	Mainly government employees	96
F	同仁园 Tong Ren Yuan	Mainly workers of a Chinese medicine company	132
G	当代城市家园 Dang Dai Cheng Shi Jia Yuan	White-collar managers of private firms, middle to high income population	91
H	和平里 He Ping Li	Staff of government-owned businesses, retired employees, older population	99
I	回龙观 Hui Long Guan	Middle to low income population	133
J	方舟苑 Fang Zhou Yuan	White-collar managers of private firms, middle to high income population	117
	合计		1,119


三里河 (E)
San Li He

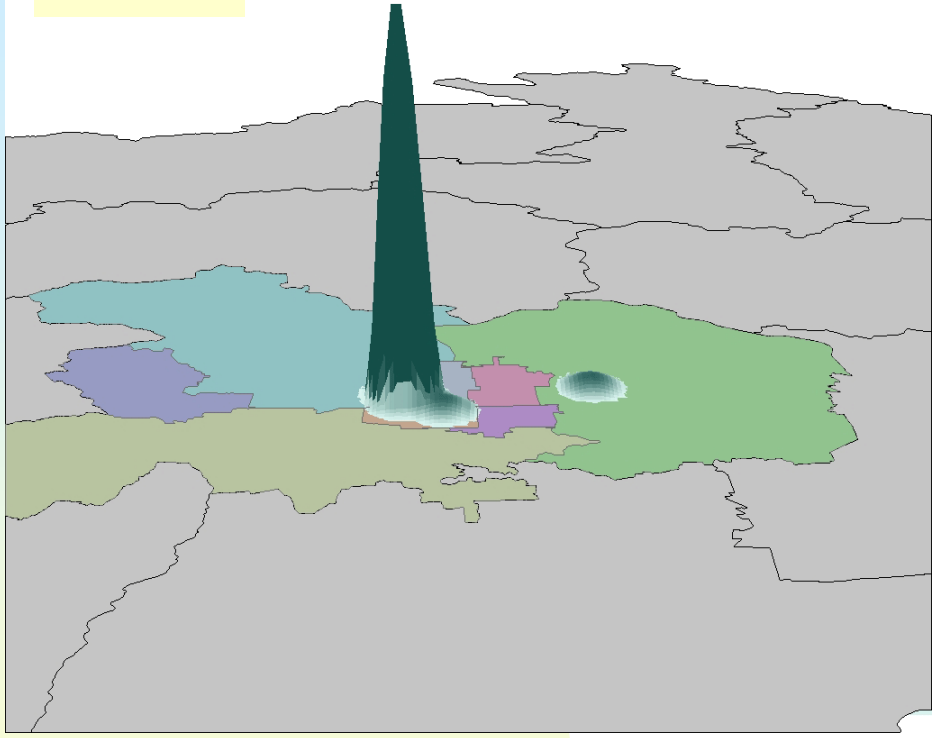

回龙观 (I)
Hui Long Guan


work/school
sleep/meal
housework
entertainment
三里河 (E)
San Li He


work/school
sleep/meal
housework
entertainment
回龙观 (I)
Hui Long Guan

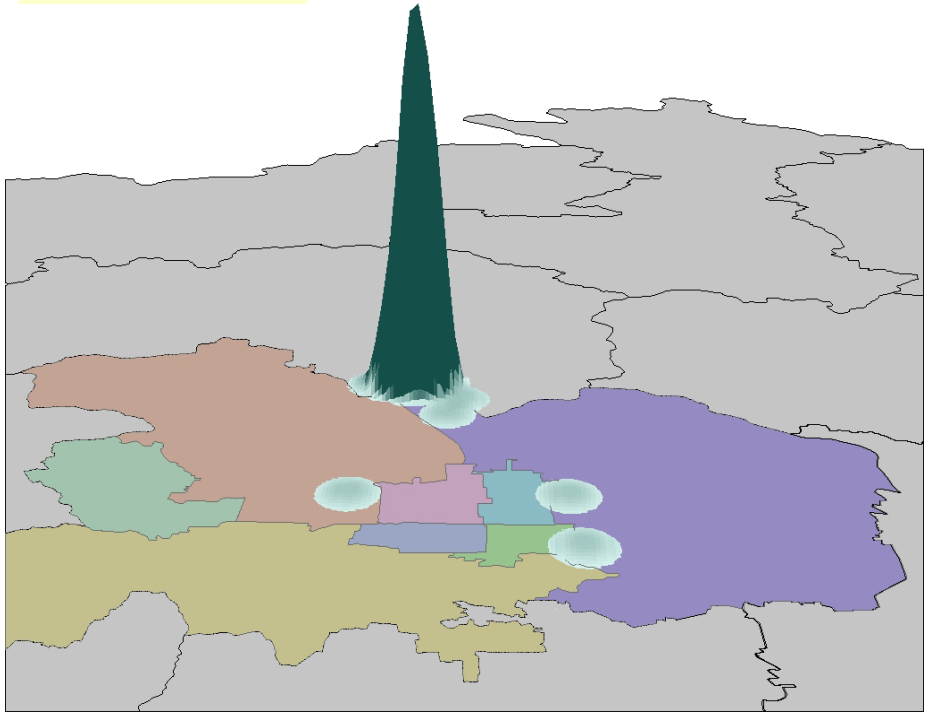
三里河 (E)
San Li He

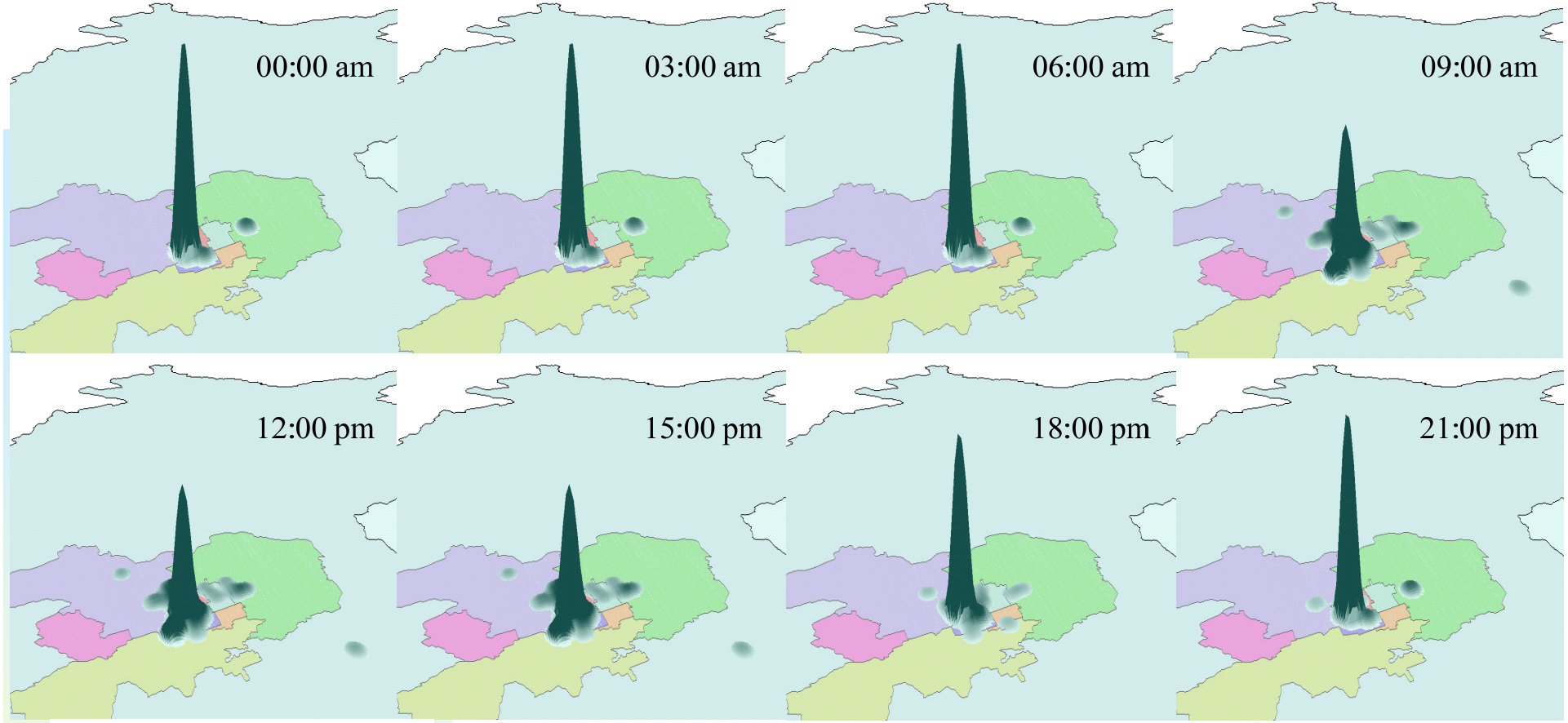
01:00 am

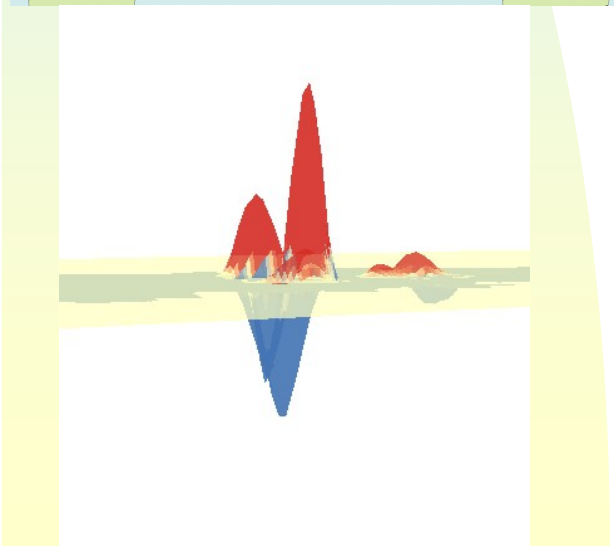


回龙观 (I)
Hui Long Guan

01:00 am

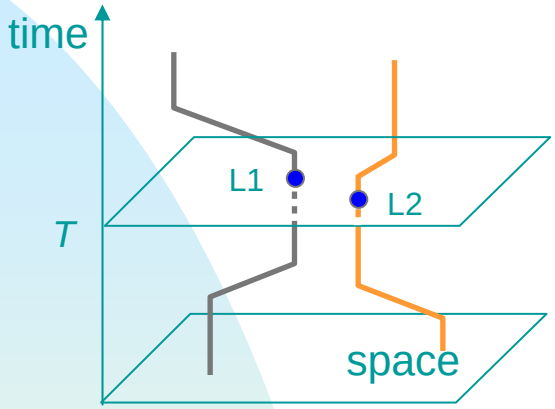




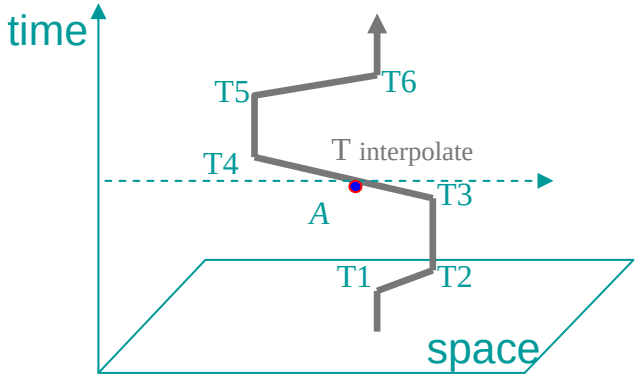


Difference in spatial distribution between 12 p.m. and 9 a.m.

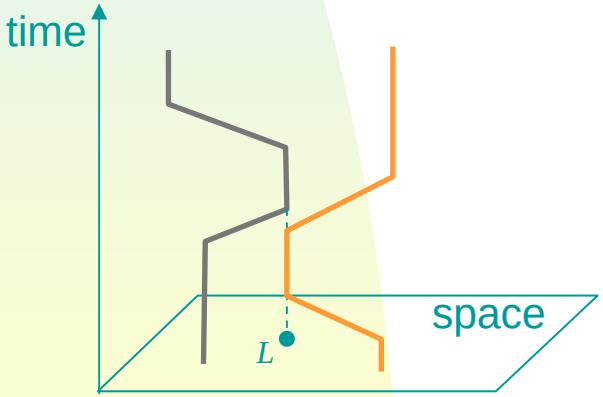
Exploratory spatio-temporal analysis functions:



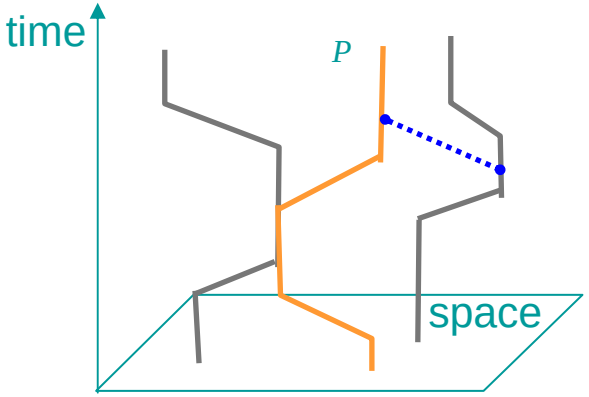
Find locations of ST paths at time *T*



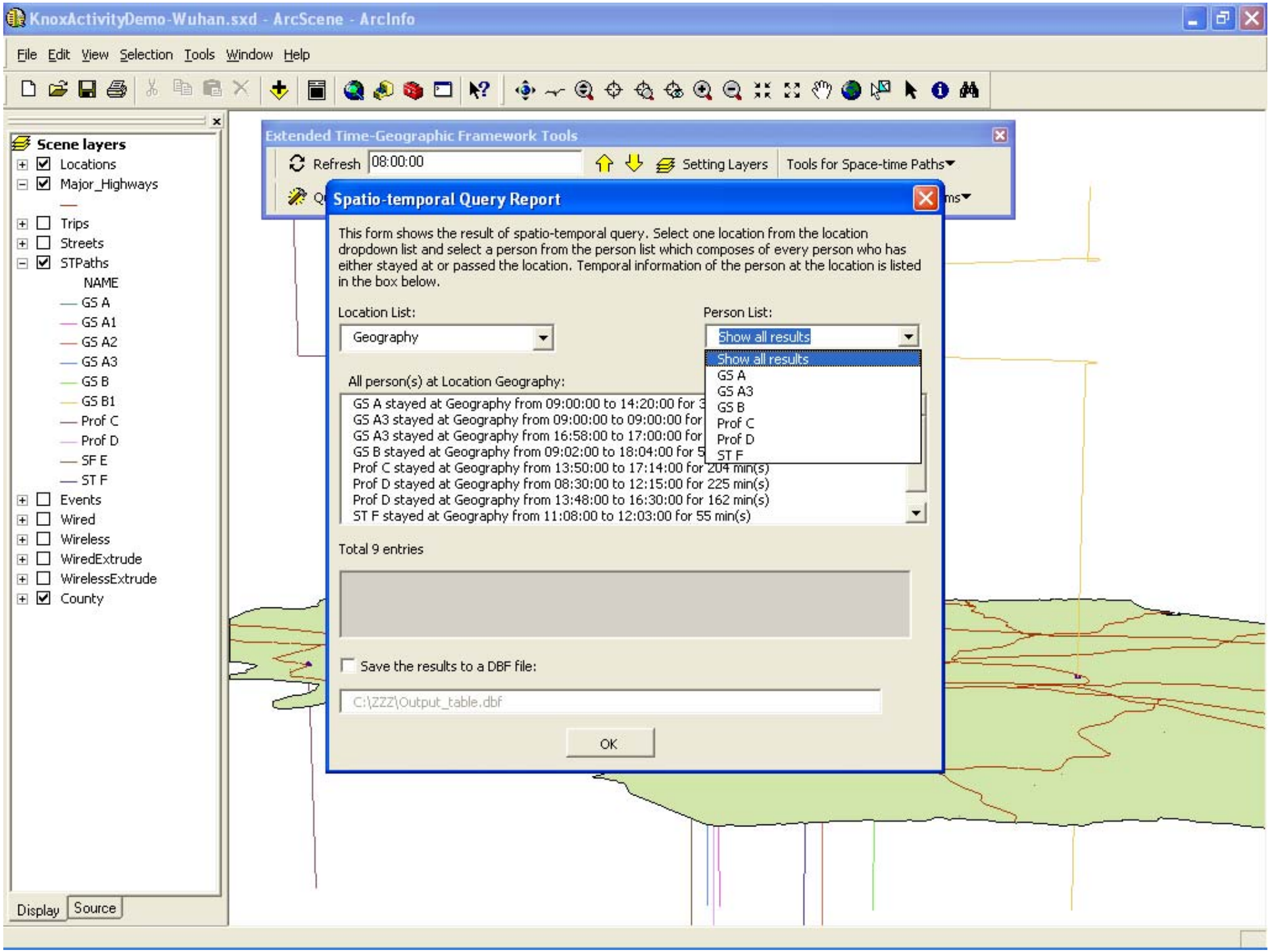
Locate time for point *A* on the ST path

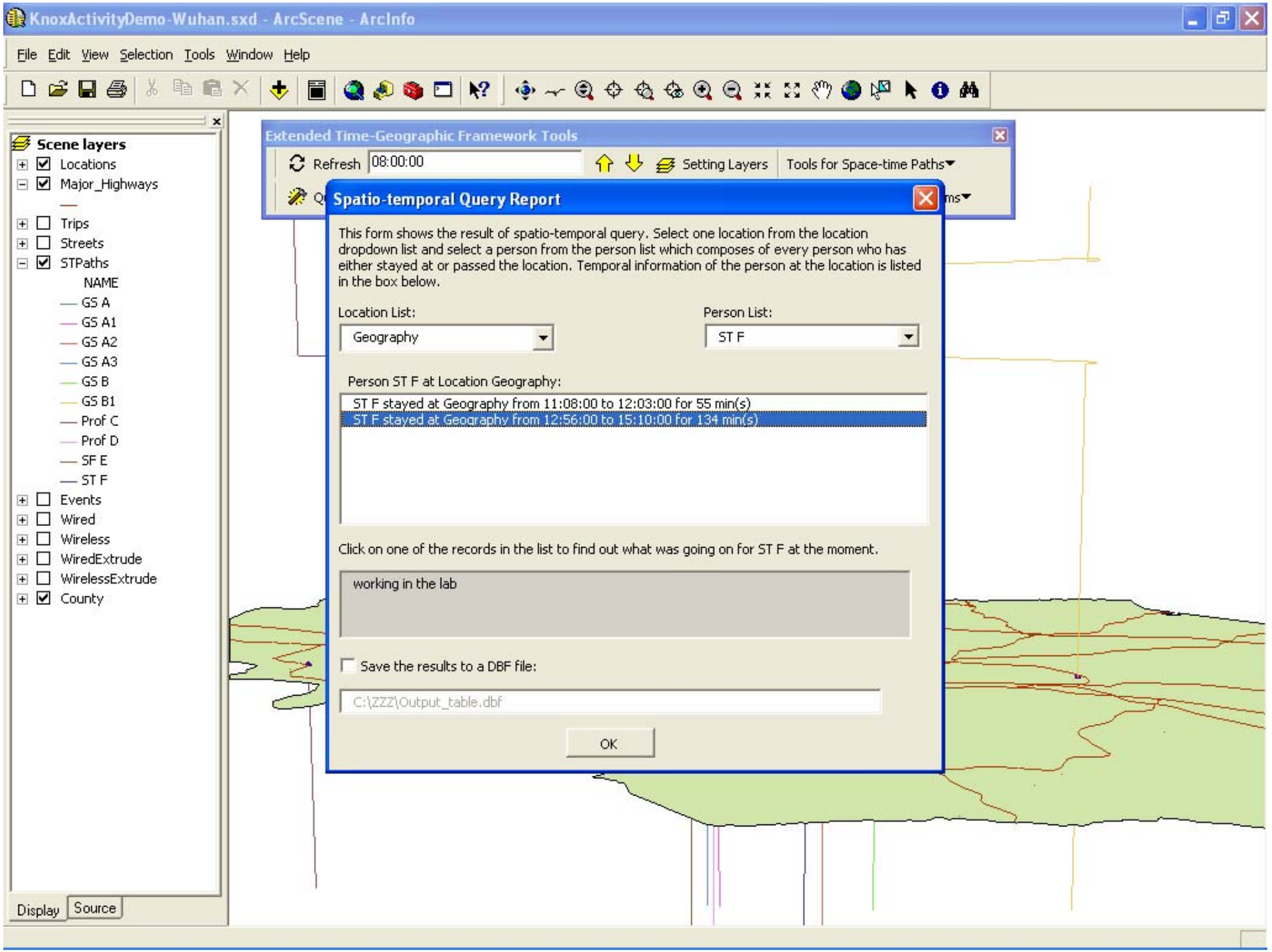


Find ST paths that visited location *L*



Find ST paths interacting with person *P*


KnoxActivityDemo-Wuhan.sxd - ArcScene - ArcInfo
File Edit View Selection Tools Window Help
Scene layers
Locations
Major_Highways
Trips
Streets
STPaths
NAME
GS A
GS A1
GS A2
GS A3
GS B
GS B1
Prof C
Prof D
SF E
ST F
Events
Wired
Wireless
WiredExtrude
WirelessExtrude
County
Display
Source
Extended Time-Geographic Framework Tools
Refresh
08:00:00
Setting Layers
Tools for Space-time Paths
Spatio-temporal Query Report
This form shows the result of spatio-temporal query. Select one location from the location dropdown list and select a person from the person list which composes of every person who has either stayed at or passed the location. Temporal information of the person at the location is listed in the box below.
Location List:
Geography
Person List:
Show all results
Show all results
GS A
GS A3
GS B
Prof C
Prof D
ST F
All person(s) at Location Geography:
GS A stayed at Geography from 09:00:00 to 14:20:00 for 3
GS A3 stayed at Geography from 09:00:00 to 09:00:00 for
GS A3 stayed at Geography from 16:58:00 to 17:00:00 for
GS B stayed at Geography from 09:02:00 to 18:04:00 for 5
Prof C stayed at Geography from 13:50:00 to 17:14:00 for 204 min(s)
Prof D stayed at Geography from 08:30:00 to 12:15:00 for 225 min(s)
Prof D stayed at Geography from 13:48:00 to 16:30:00 for 162 min(s)
ST F stayed at Geography from 11:08:00 to 12:03:00 for 55 min(s)
Total 9 entries
Save the results to a DBF file:
C:\ZZZ\Output_table.dbf
OK


KnoxActivityDemo-Wuhan.sxd - ArcScene - ArcInfo
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Scene layers
Locations
Major_Highways
Trips
Streets
STPaths
NAME
GS A
GS A1
GS A2
GS A3
GS B
GS B1
Prof C
Prof D
SF E
ST F
Events
Wired
Wireless
WiredExtrude
WirelessExtrude
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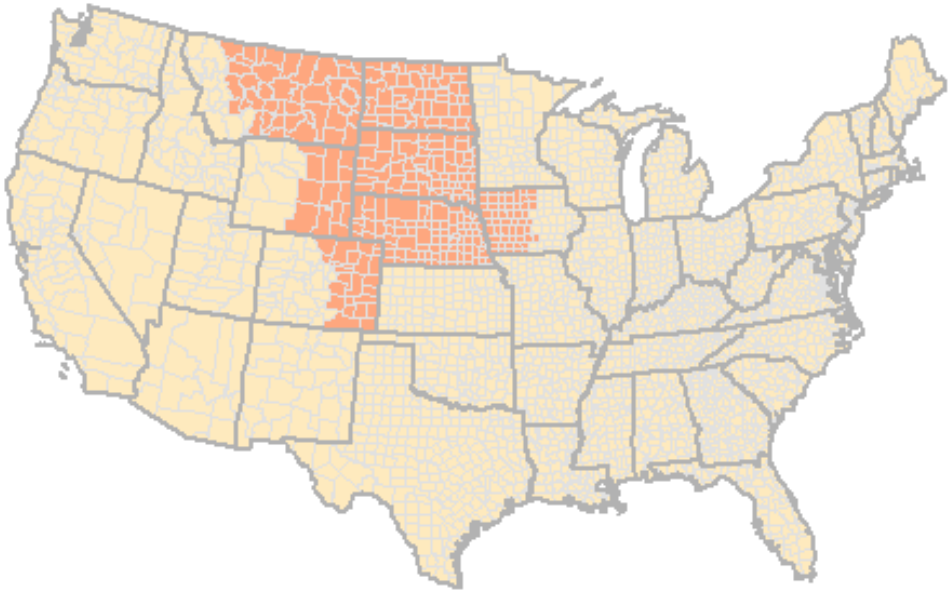
Location List:
Geography
Person List:
ST F
Person ST F at Location Geography:
ST F stayed at Geography from 11:08:00 to 12:03:00 for 55 min(s)
ST F stayed at Geography from 12:56:00 to 15:10:00 for 134 min(s)
Click on one of the records in the list to find out what was going on for ST F at the moment.
working in the lab
Save the results to a DBF file:
C:\ZZZ\Output_table.dbf
OK

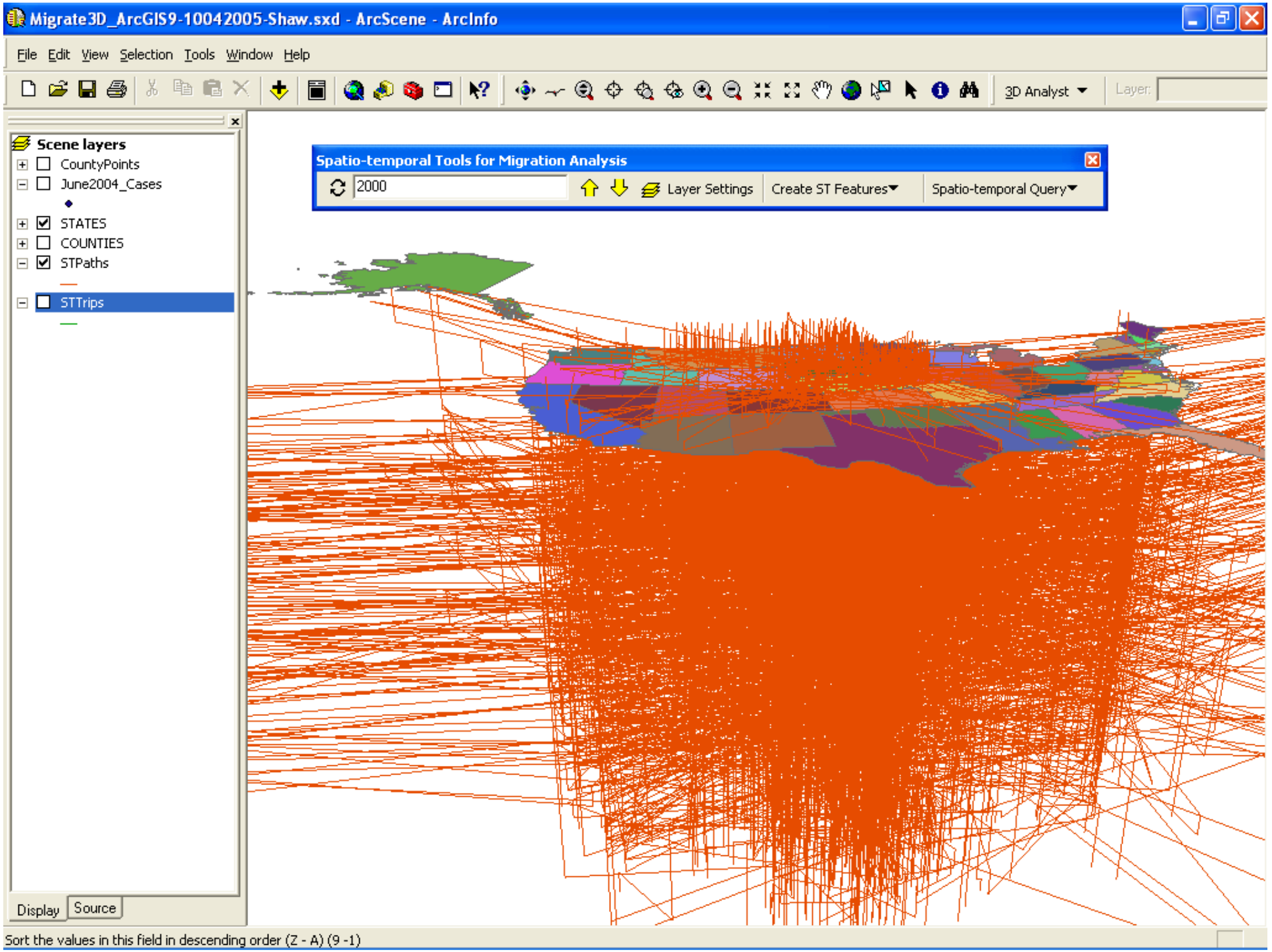
Uncover Space-Time Patterns in Large Data Sets:



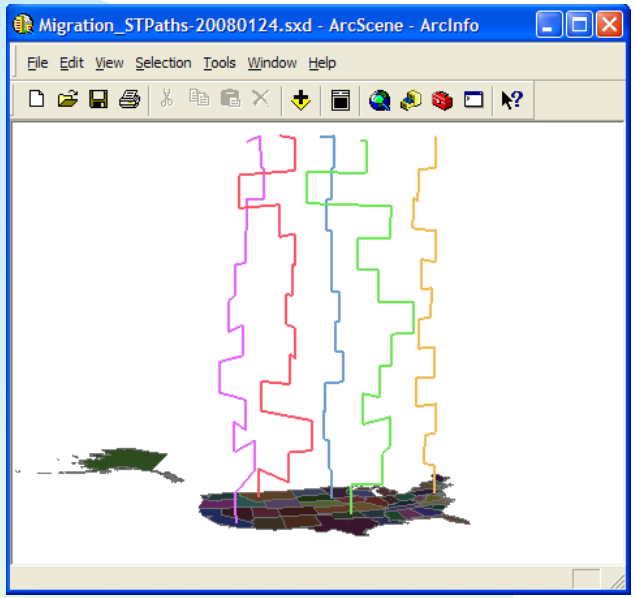
Migration Data Set: Northern Plains survey data

- area of wide-spread and persistent population loss
- survey of socio-demographics & attitudes
- migration history data:
  - roughly 400 respondents per state
  - over 2800 individuals
  - more than 11,000 migration moves

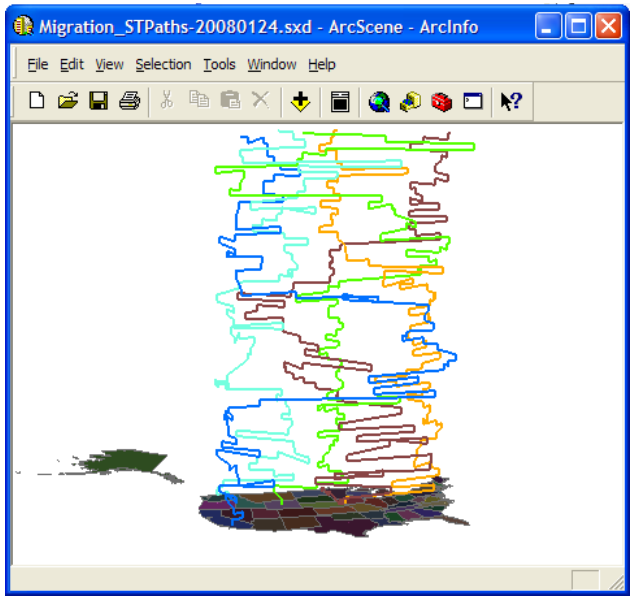
Survey data collected by the Bureau of Business and Economic Research at The University of Montana and funded by Congressional Appropriation secured by Sen. Byron Dorgan (North Dakota). Data set was provided by Dr. Christiane von Reichert at The University of Montana.


Migrate3D_ArcGIS9-10042005-Shaw.sxd - ArcScene - ArcInfo
File Edit View Selection Tools Window Help
3D Analyst
Layer:
Scene layers
CountyPoints
June2004_Cases
STATES
COUNTIES
STPaths
STTrips
Spatio-temporal Tools for Migration Analysis
2000
Layer Settings
Create ST Features
Spatio-temporal Query
Display
Source
Sort the values in this field in descending order (Z - A) (9 -1)

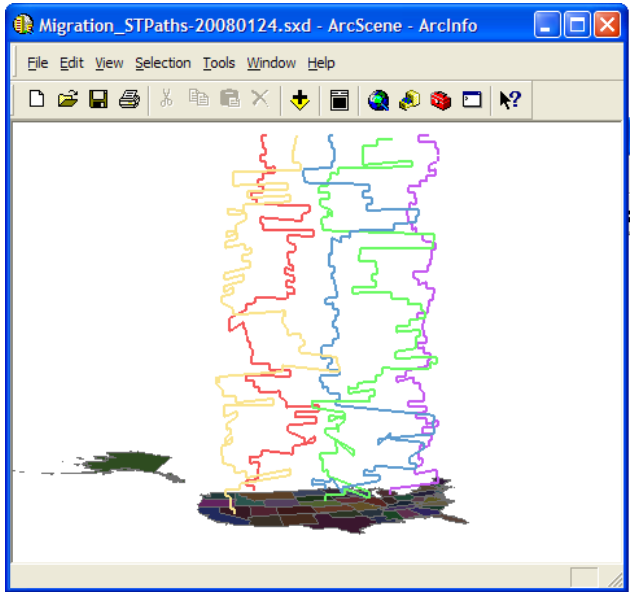
Generalized Space-Time Paths



Five-year interval

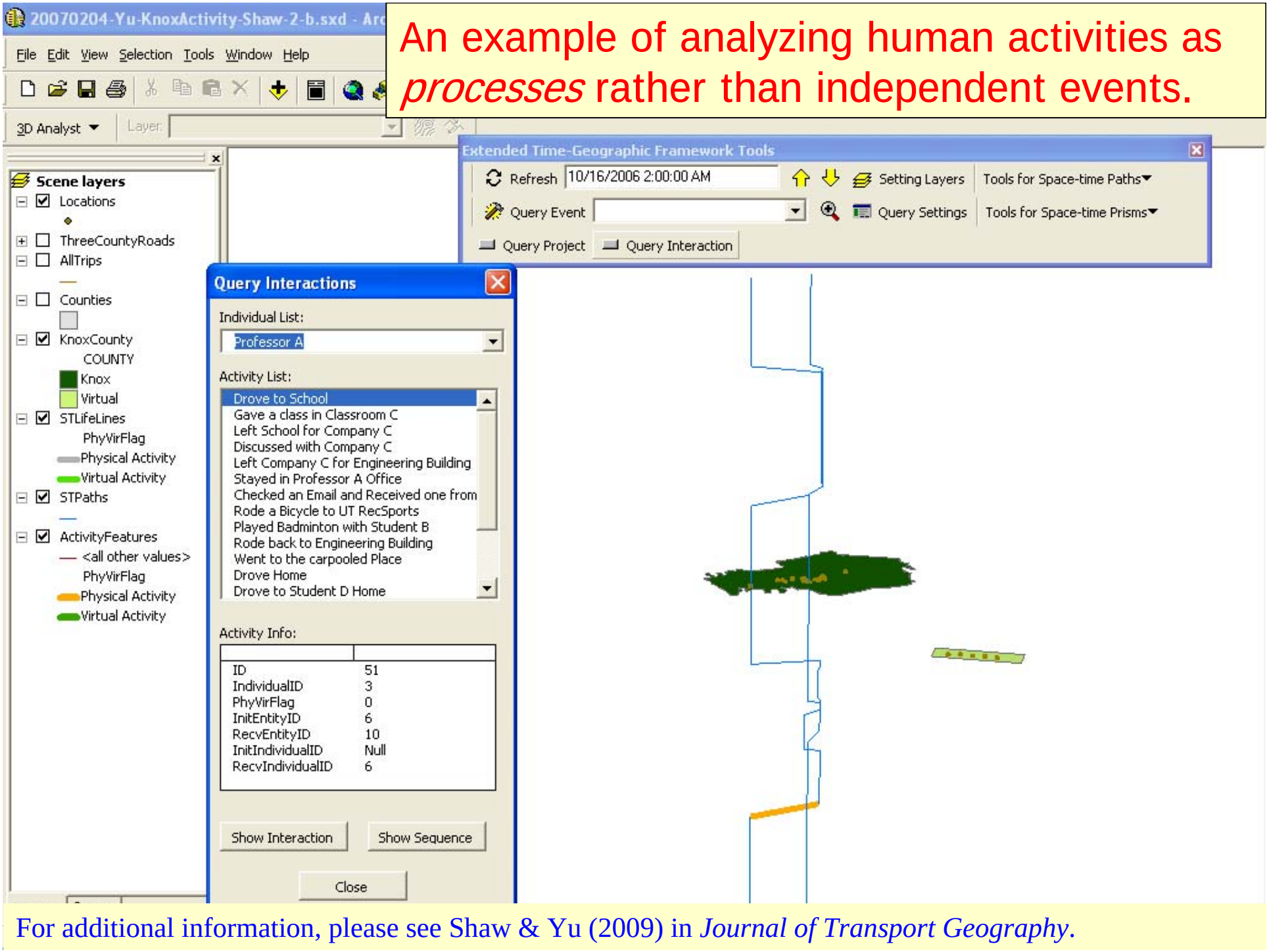


Individual-year interval



Three-year moving window

For additional information, please see Shaw, Yu & Bombom (2008) in *Transactions in GIS*.



An example of analyzing human activities as *processes* rather than independent events.

For additional information, please see Shaw & Yu (2009) in *Journal of Transport Geography*.

Conclusions and Potential Applications:

- This space-time GIS has potential of encouraging GIS research in the humanities and social sciences to:
  - move from an “aggregate” approach towards a “disaggregate” approach,
  - move from a “static” approach towards a “dynamic and real-time” approach, and
  - move from a “space-centric” approach towards a “space-and-time-centric” approach.

- Potential applications of this space-time GIS include examples such as:
  - Analysis of individual activity space (spatial and temporal patterns)
  - Analysis of use of urban space (i.e., aggregate patterns of individual activities – hot spots)
  - Analysis of interactions among individuals (e.g., social networking)
  - Studies of migration patterns, social equity, disease spread, ...

Thank you!

To download a free space-time GIS visualization extension for ArcGIS 9.3 and/or access additional information about this project, please visit our NSF project website at:

http://web.utk.edu/~sshaw/NSF-Project-Website/default.htm