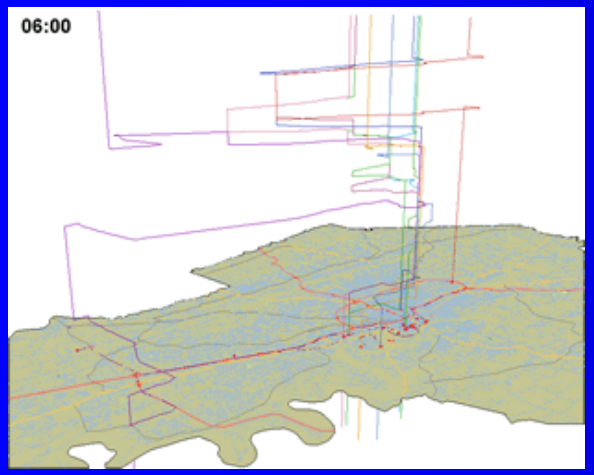
An Extended Time-Geographic Framework for Human Activities and Interactions in Physical and Virtual Spaces



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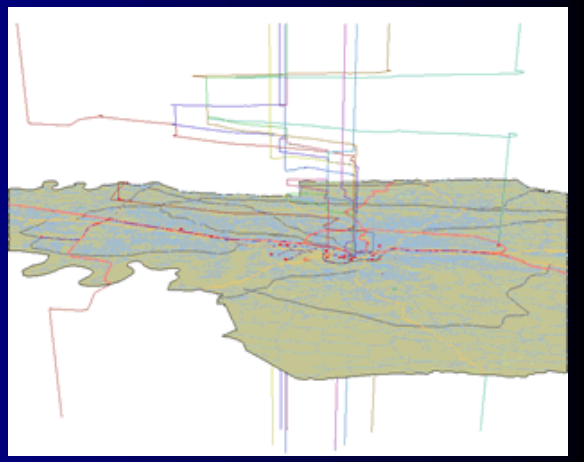

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Hongbo Yu, Geography
Univ. of Tennessee

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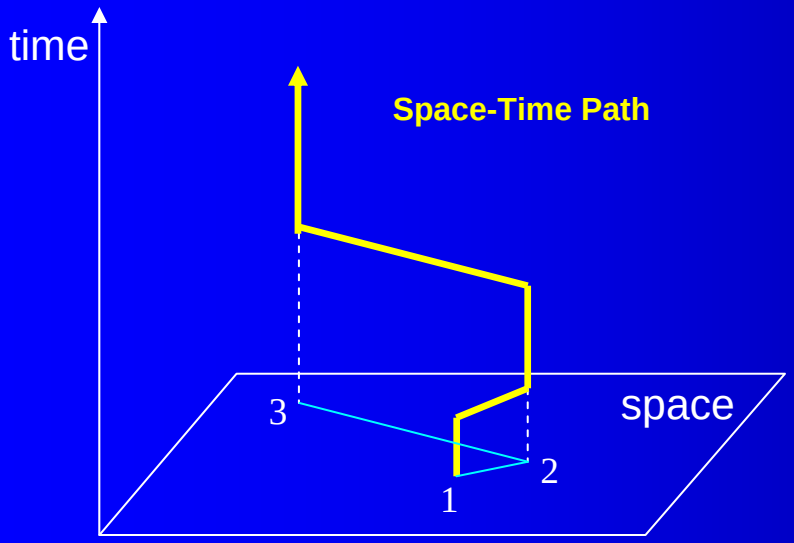
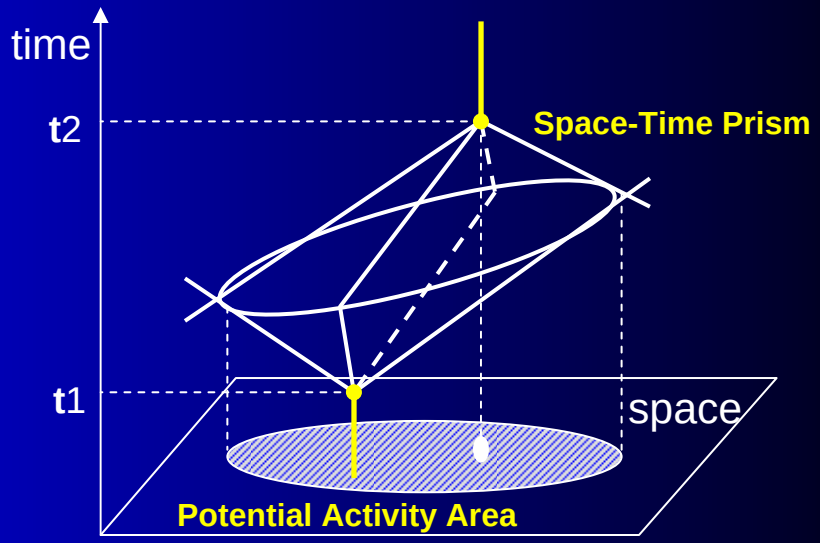
Denver, Colorado

Hägerstrand's Time Geography:

- Hägerstrand's (1970) time geography provides a useful framework for studying individual activities under different constraints (capability, authority, and coupling constraints) in a *space-time context*.
- Space-time path (ST path), space-time prism (ST prism), and potential activity area (PAA)





Information and Communications Technologies (ICT):

- *Information and communications technologies (ICT)* have introduced important changes to the ways that activities are carried out.

- For example,
  - Mobile phones provide people with *new freedom in space* because we are no longer constrained by the fixed locations of landline phone service.
  - We now can purchase air tickets or search for literature even when travel agencies and libraries are closed for business. This represents *new freedom in time* due to the use of ICT.

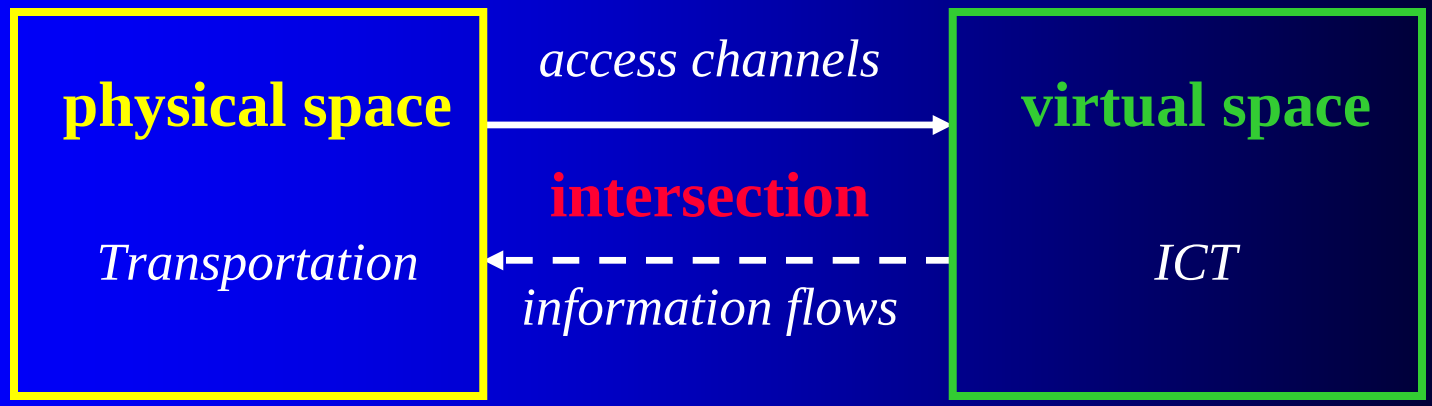
- While *transportation* serves as the means of carrying out individual activities in physical space, *ICT* provide the means for individuals to perform activities in virtual space.

- Activities performed in virtual space go beyond the traditional concept of *spatial proximity*, and require modifications to the conventional space-time path, space-time prism, and potential activity area.

An Extended Time-Geographic Framework:

- This study extends Hägerstrand's time-geographic framework to explicitly consider both *physical* and *virtual* activities.
- It also develops a spatio-temporal GIS framework to represent and manage the physical and virtual activities carried out by individuals.
- In addition, the spatio-temporal GIS framework supports *exploratory analysis* of interactions among individual activities in physical and virtual spaces.

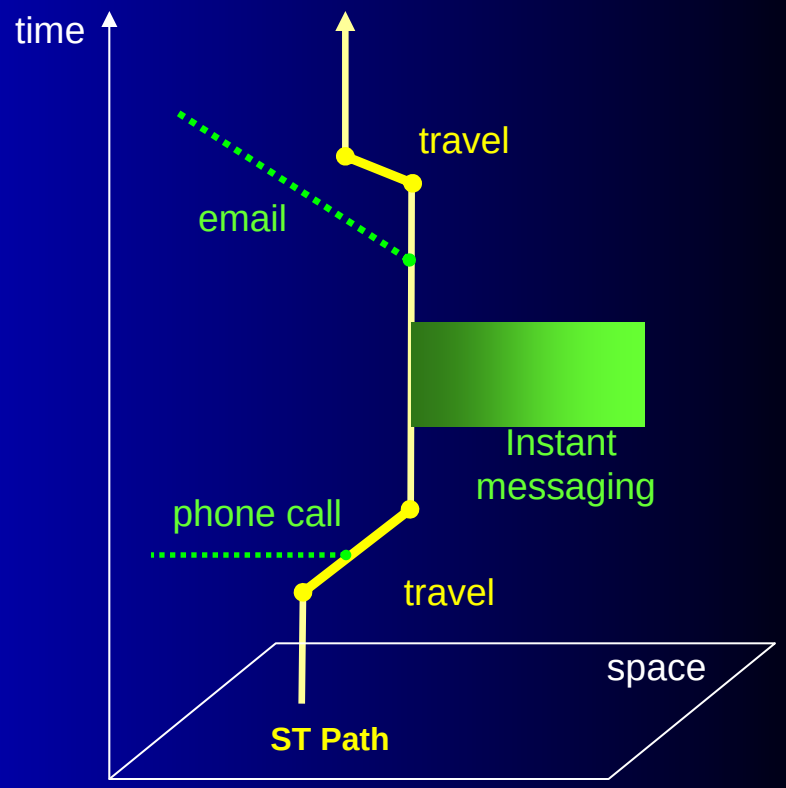
- Intersection of physical and virtual spaces:
  - *Physical space* provides access channels to virtual space
  - Virtual space feeds back information to impact activity and travel patterns in physical space



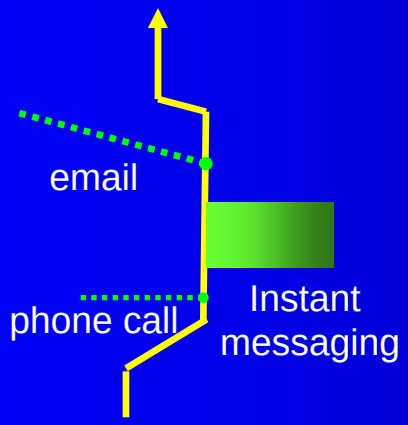
Human as Extensible Agents:

- ICT allow people to interact with others beyond the physical proximity in virtual space (i.e., the *concept of extensible agents*; Adams, 1995, 2000; Kwan, 2000).

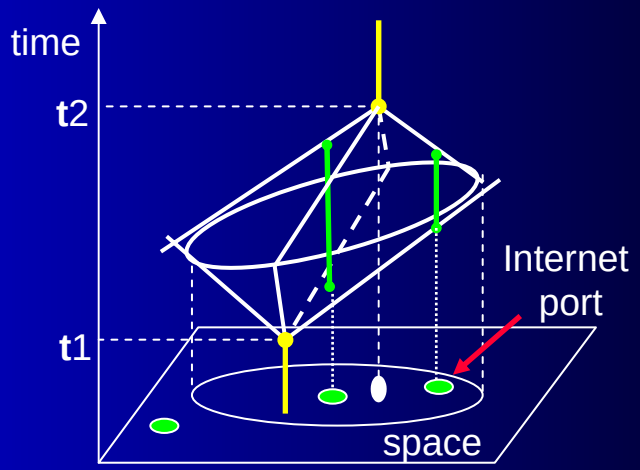
- Based on the concept of extensible agents, Hägerstrand's space-time path concept is extended to represent both physical and virtual activities, with virtual activities represented as *relations* reaching out from a space-time path.



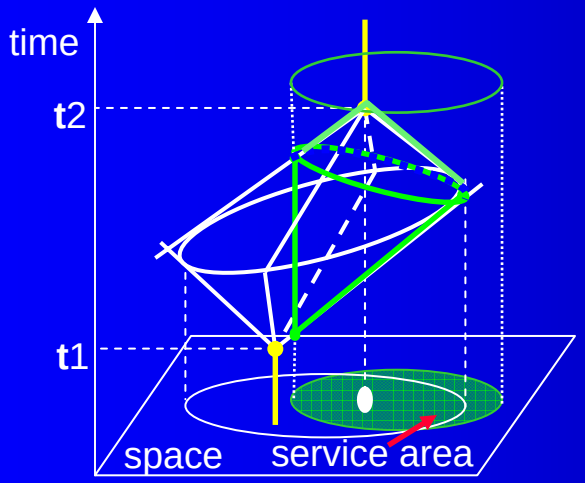
- ST Path and ST Prism of Physical and Virtual Activities:



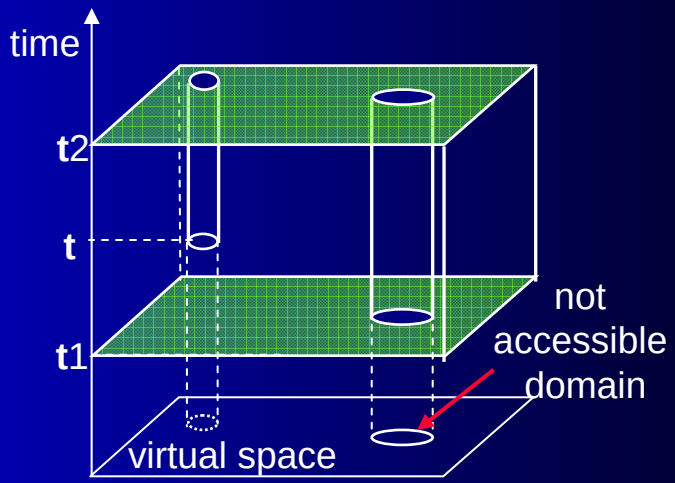
ST Path



ST Prism for wired access



ST Prism for wireless access



ST Prism for virtual activities

Four Types of Communication Modes:

- With ICT, people can participate in activities through *tele-presence* in addition to the conventional physical presence.
- Literature identifies four types of communication modes based on their spatial and temporal characteristics (Janelle, 1995; Harvey and Macnab, 2000; Miller, 2003) .

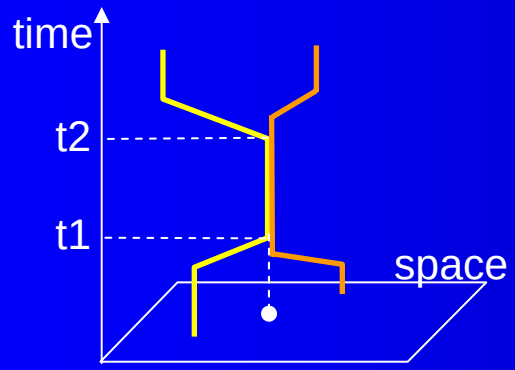
Spatial / Temporal	Physical presence	Tele-presence
Synchronous	**SP** ▪ Face-to-face meeting	**ST** ▪ Telephone ▪ Instant messaging
Asynchronous	**AP** ▪ Post-it note ▪ Bulletin board	**AT** ▪ E-mail ▪ Voice mail

(Source: Miller, 2003)

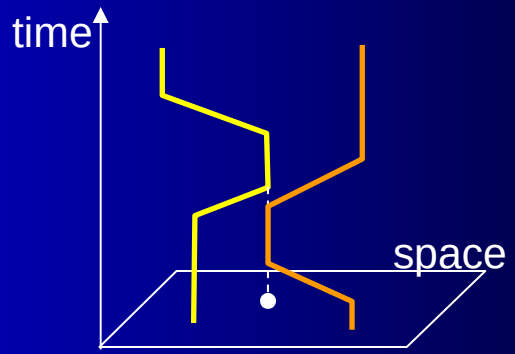
Spatio-temporal Relationships of Human Activities:

- Four types of human interactions based on their spatio-temporal relationships and represented by extended space-time paths:

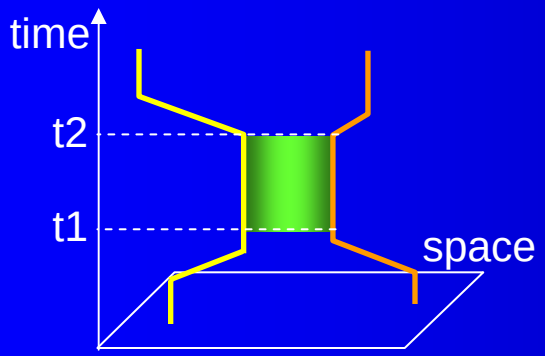
SP (co-existence)



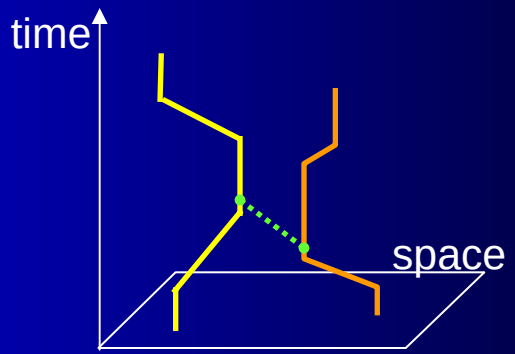
AP (co-location in space)



ST (co-location in time)

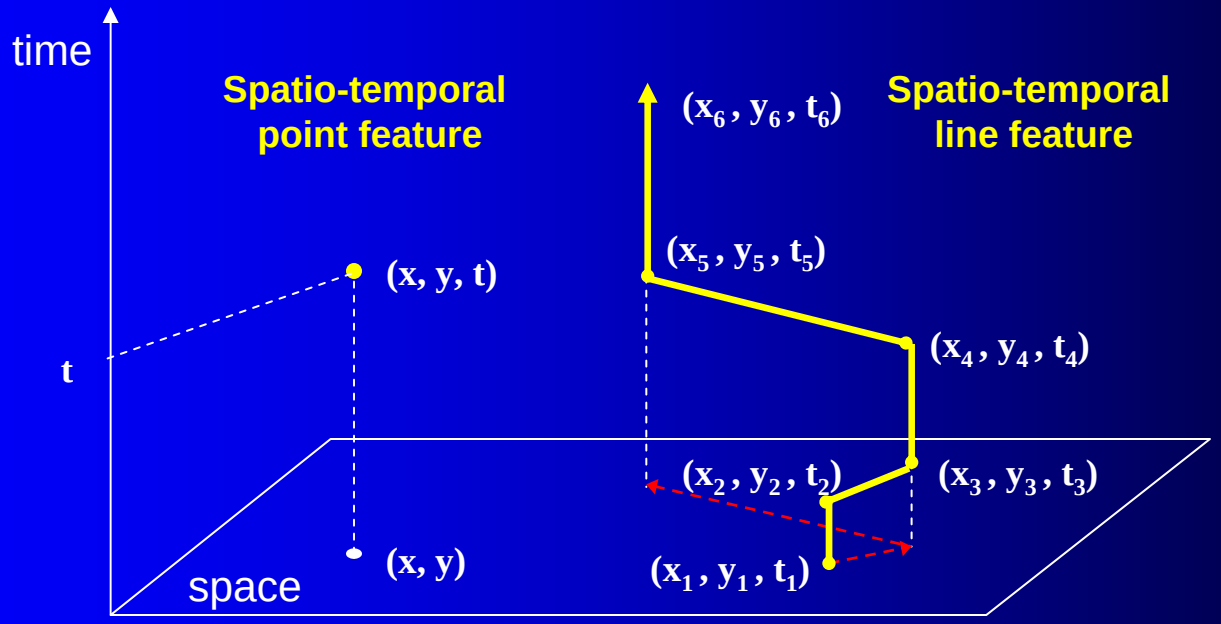


AT (no co-location in either space or time)



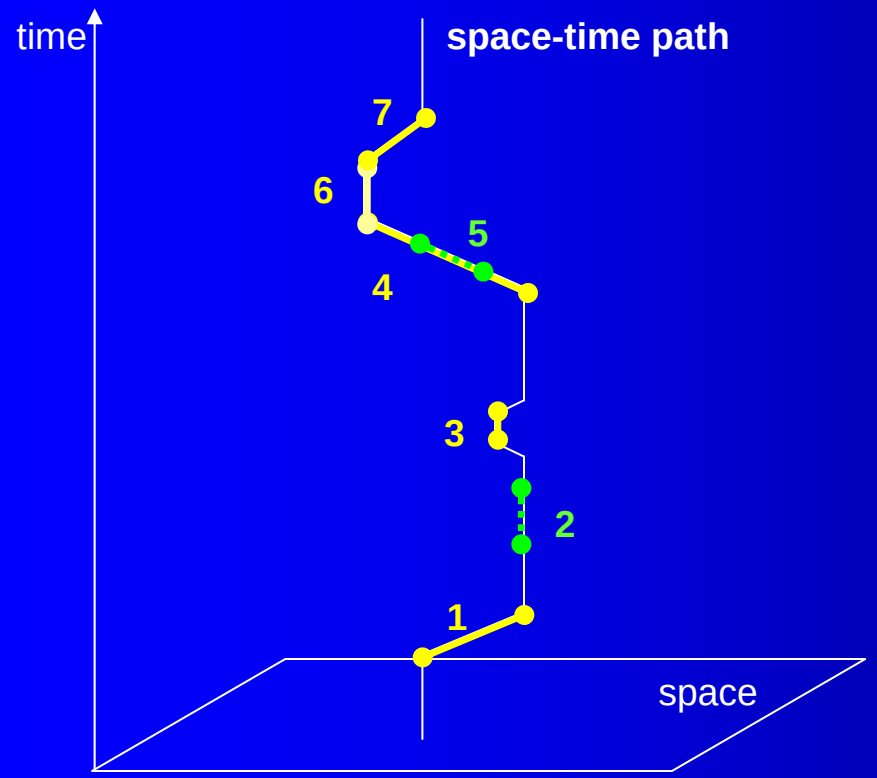
Spatio-temporal Representations in GIS:

- 3 dimensional spatio-temporal features: 2D space + 1D time
  - ST point feature: (x, y, t)
  - ST line feature: $\{(x_1, y_1, t_1), (x_2, y_2, t_2), \ldots, (x_n, y_n, t_n)\}$, where $t_1 < t_2 < \ldots < t_n$.



Representation of Individual Activities in GIS:

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



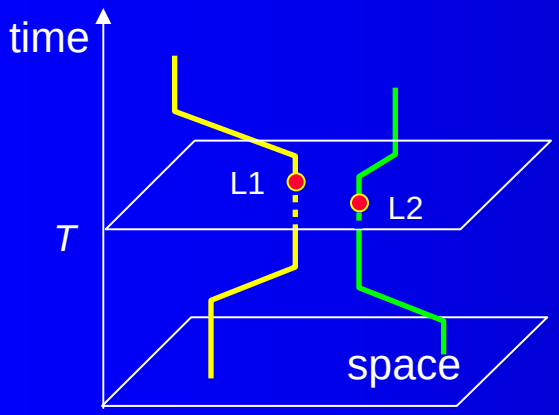
Physical activities:

1. Drive to work
3. Have lunch
4. Drive back home
6. Grocery shopping
7. Return home

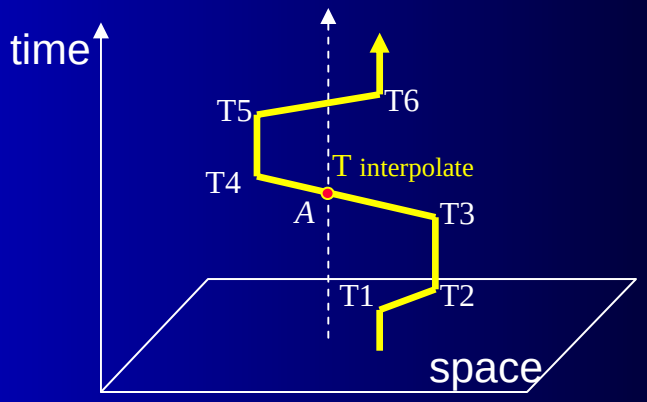
Virtual activities:

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

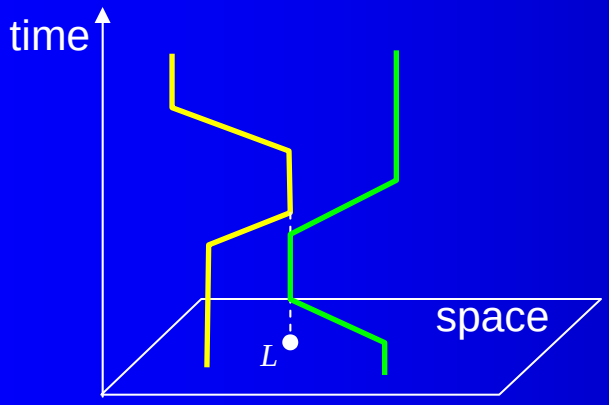
Exploratory Analysis of ST Relationships:



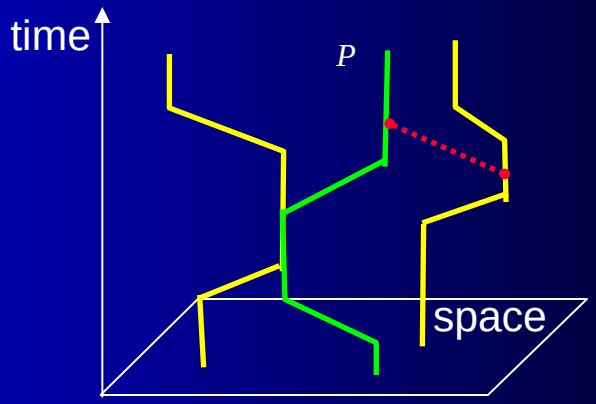
Find locations of ST paths at time *T*



Locate time for point *A* on the ST path



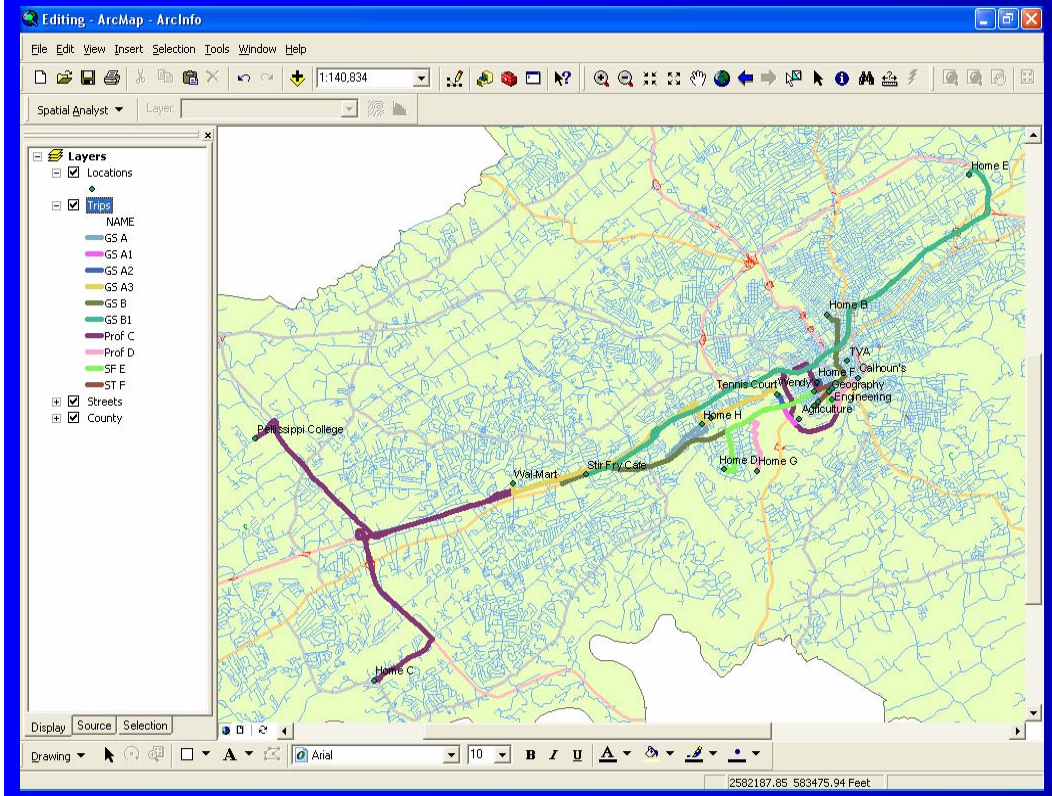
Find ST paths visiting location *L*



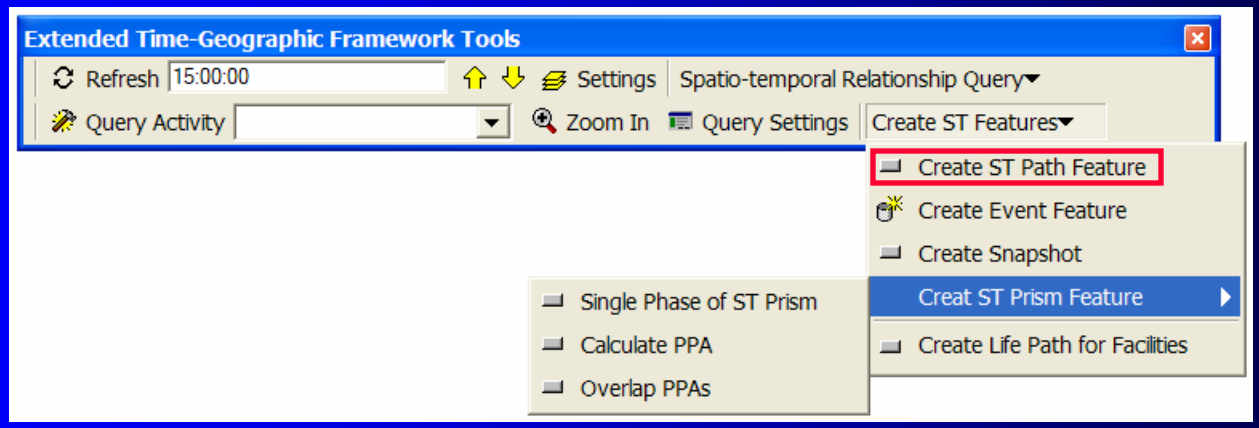
Find ST paths interacting with person *P*

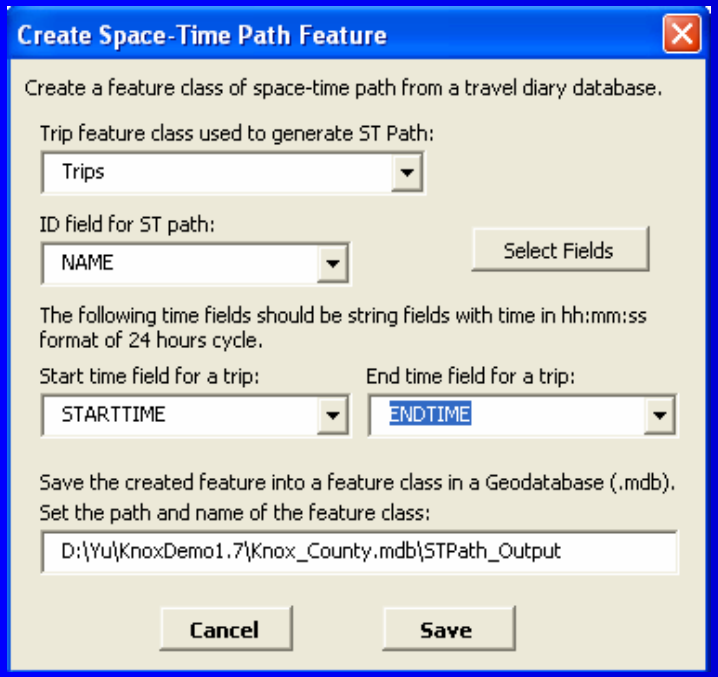
ArcGIS Implementation:

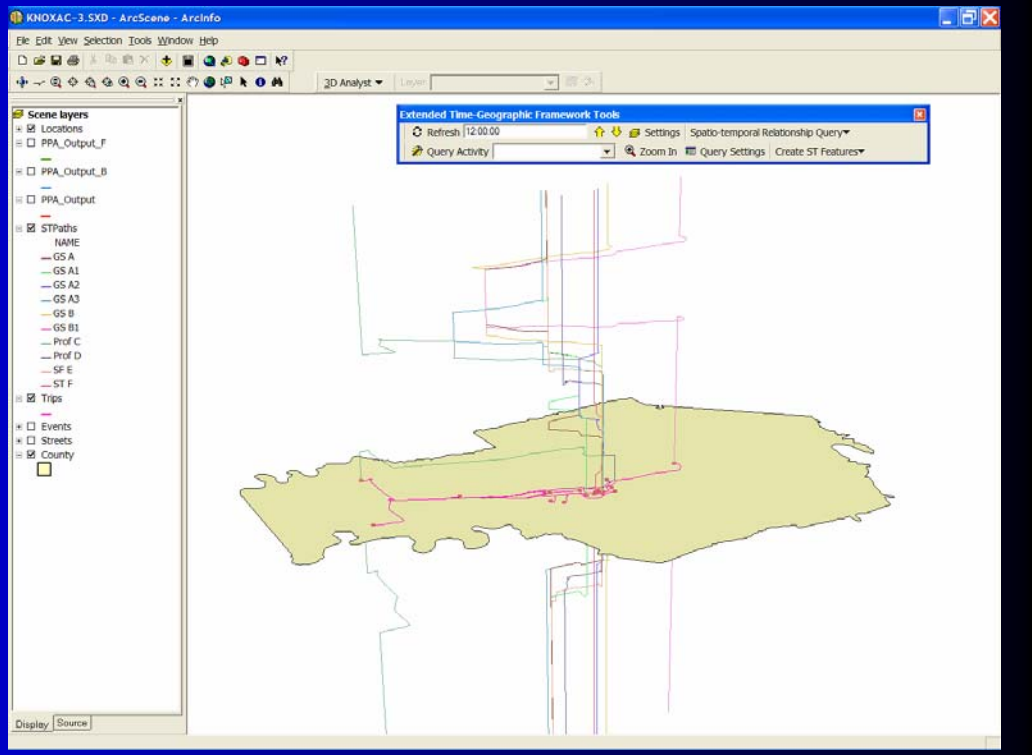
- ArcScene for 3D visualization of spatio-temporal features
- ArcObjects programming for custom functions

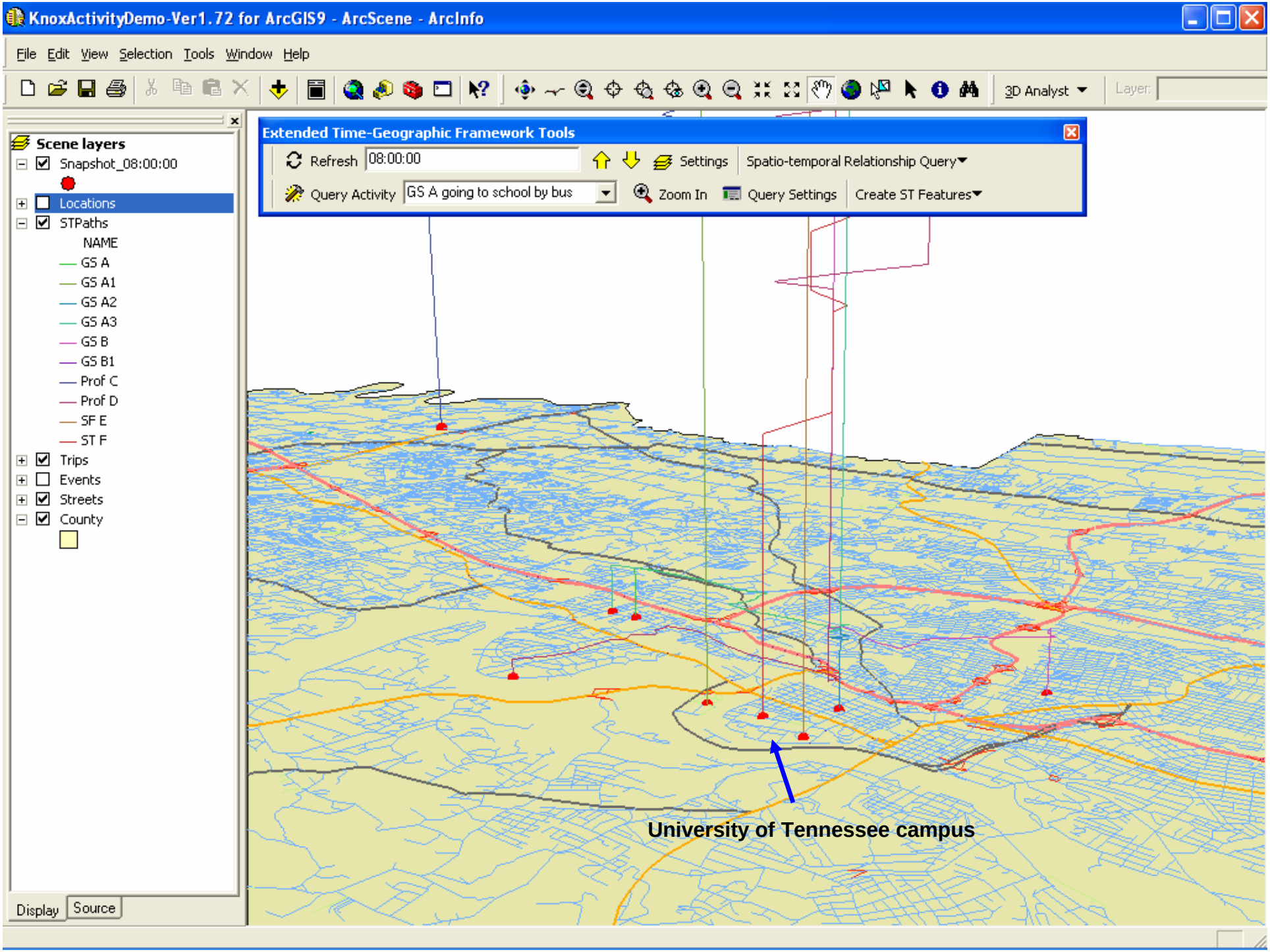


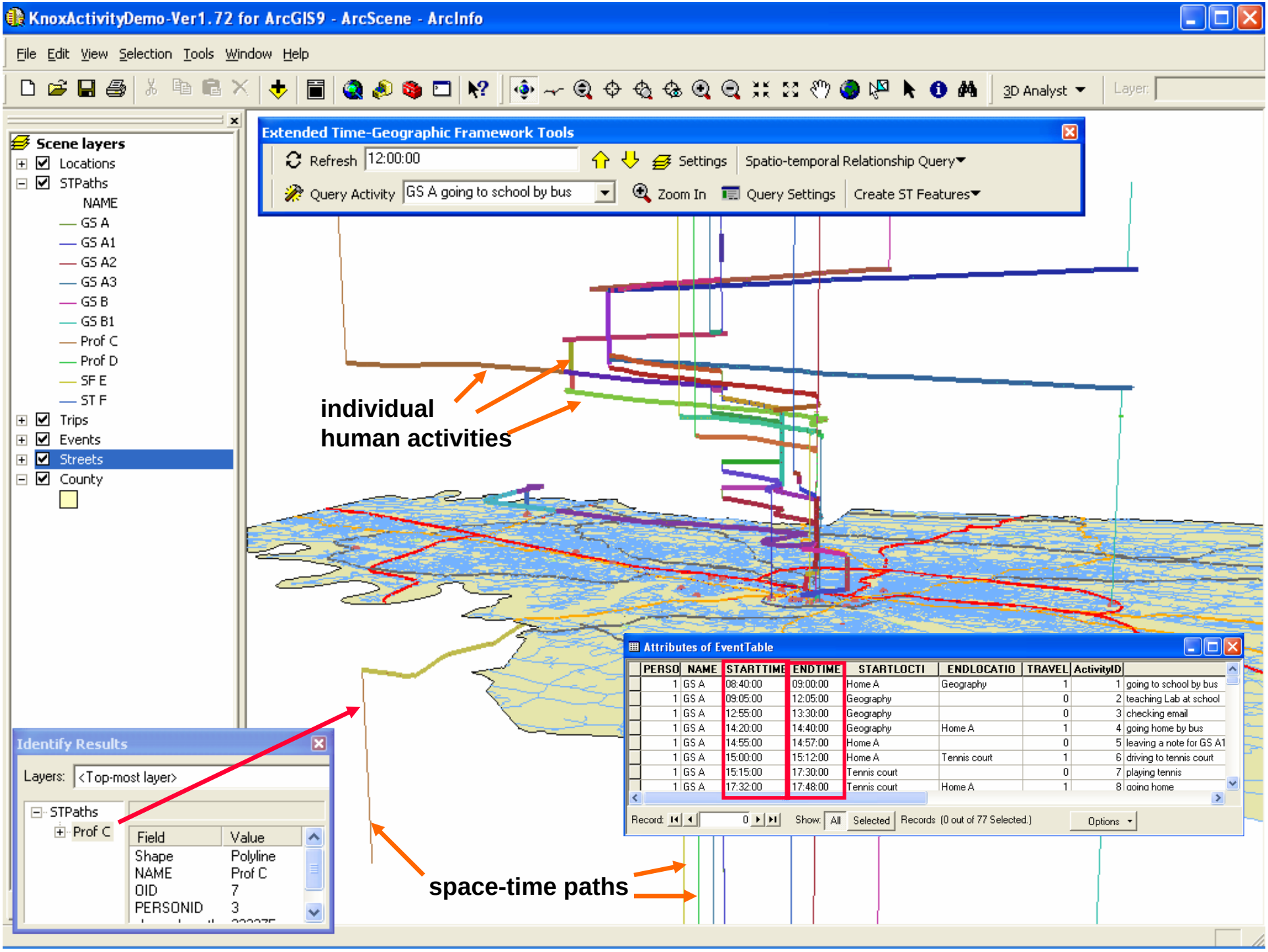
- Creation of 3D spatio-temporal features from 2D data








KnoxActivityDemo-Ver1.72 for ArcGIS9 - ArcScene - ArcInfo
File Edit View Selection Tools Window Help
3D Analyst
Layer:
Scene layers
Snapshot_08:00:00
Locations
STPaths
NAME
GS A
GS A1
GS A2
GS A3
GS B
GS B1
Prof C
Prof D
SF E
ST F
Trips
Events
Streets
County
Display
Source
Extended Time-Geographic Framework Tools
Refresh
08:00:00
Settings
Spatio-temporal Relationship Query
Query Activity
GS A going to school by bus
Zoom In
Query Settings
Create ST Features
University of Tennessee campus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GS A
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ST F
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Events
Streets
County
Extended Time-Geographic Framework Tools
Refresh
12:00:00
Settings
Spatio-temporal Relationship Query
Query Activity
GS A going to school by bus
Zoom In
Query Settings
Create ST Features
individual
human activities
Attributes of EventTable
PERSO NAME STARTTIME ENDTIME STARTLOCATI ENDLOCATIO TRAVEL ActivityID
1 GS A 08:40:00 09:00:00 Home A Geography 1 1 going to school by bus
1 GS A 09:05:00 12:05:00 Geography 0 2 teaching Lab at school
1 GS A 12:55:00 13:30:00 Geography 0 3 checking email
1 GS A 14:20:00 14:40:00 Geography Home A 1 4 going home by bus
1 GS A 14:55:00 14:57:00 Home A 0 5 leaving a note for GS A1
1 GS A 15:00:00 15:12:00 Home A Tennis court 1 6 driving to tennis court
1 GS A 15:15:00 17:30:00 Tennis court 0 7 playing tennis
1 GS A 17:32:00 17:48:00 Tennis court Home A 1 8 going home
Record: 0 Show: All Selected Records (0 out of 77 Selected.) Options
Identify Results
Layers: <Top-most layer>
STPaths
Prof C
Field Value
Shape Polyline
NAME Prof C
OID 7
PERSONID 3
space-time paths

Attributes of EventTable

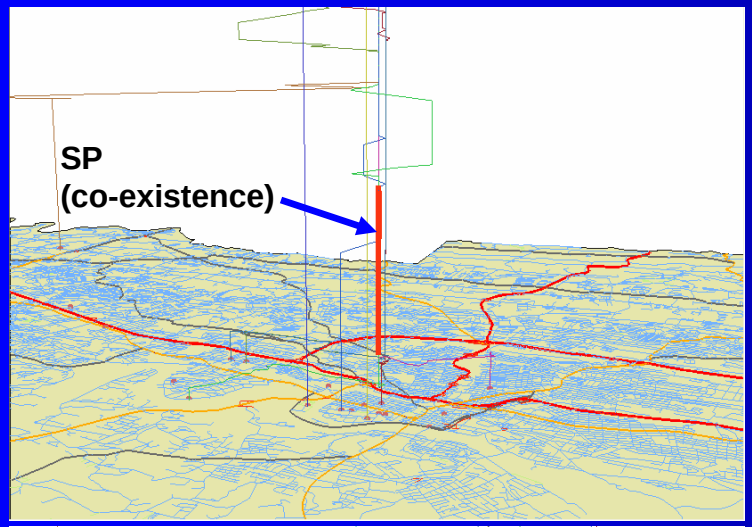
OBJECTID	PERSO	NAME	STARTTIME	ENDTIME	STARTLOCATI	ENDLOCATIO	TRAVEL	ActivityID	
1	1	GS A	08:40:00	09:00:00	Home A	Geography	1	1	going to s
42	5	GS A3	08:38:00	09:00:00	Home H	Geography	1	1	going to s
2	1	GS A	09:05:00	12:05:00	Geography		0	2	teaching
15	2	GS B	09:05:00	12:05:00	Geography		0	2	teaching
69	10	ST F	11:10:00	12:00:00	Geography		0	2	having lal
3	1	GS A	12:55:00	13:30:00	Geography		0	3	checking
50	6	GS A2	09:38:00	09:50:00	Engineering		0	3	sending e
4	1	GS A	14:20:00	14:40:00	Geography	Home A	1	4	going hor

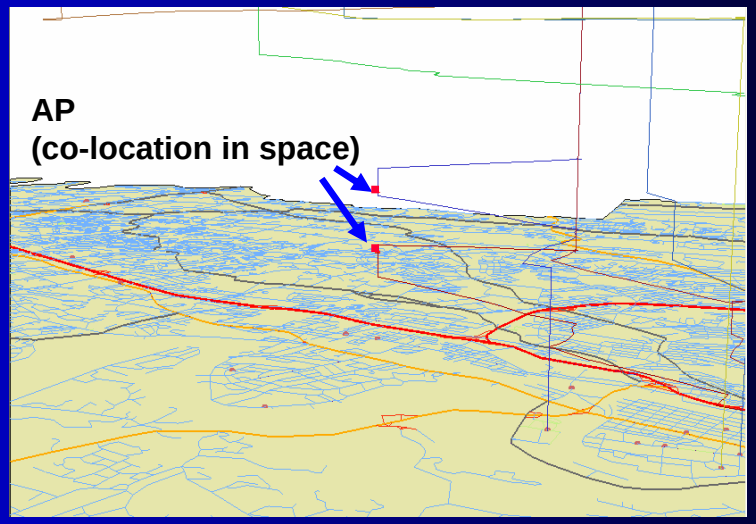
Record: 1 Show: All Selected Records (0 out of 77 Selected.) Options

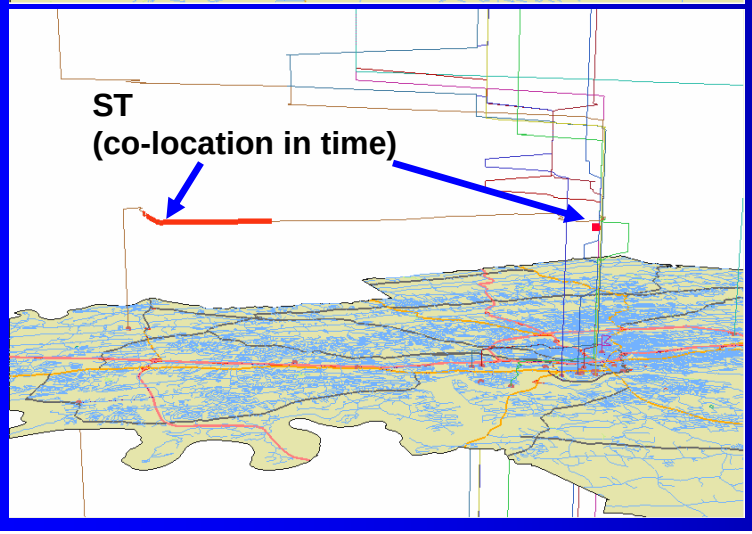
Attributes of ActivityTable

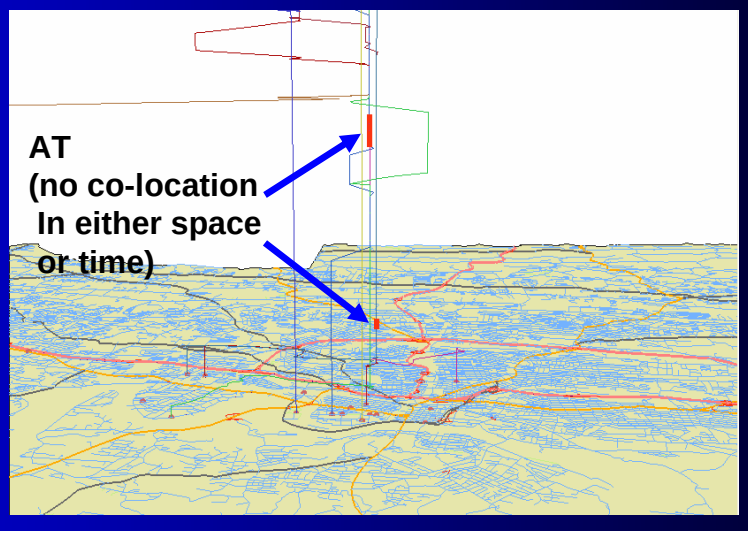
OBJECTID*	ActivityID	Description
1	1	GS A going to school by bus
2	2	GIS Lab
3	3	Email between GS A and GS A2
4	4	GS A going home by bus
5	5	Note from GS A to GS A1
6	6	GS A driving to tennis court

Record: 0 Show: All Selected Records (0 out of 60 Selected.

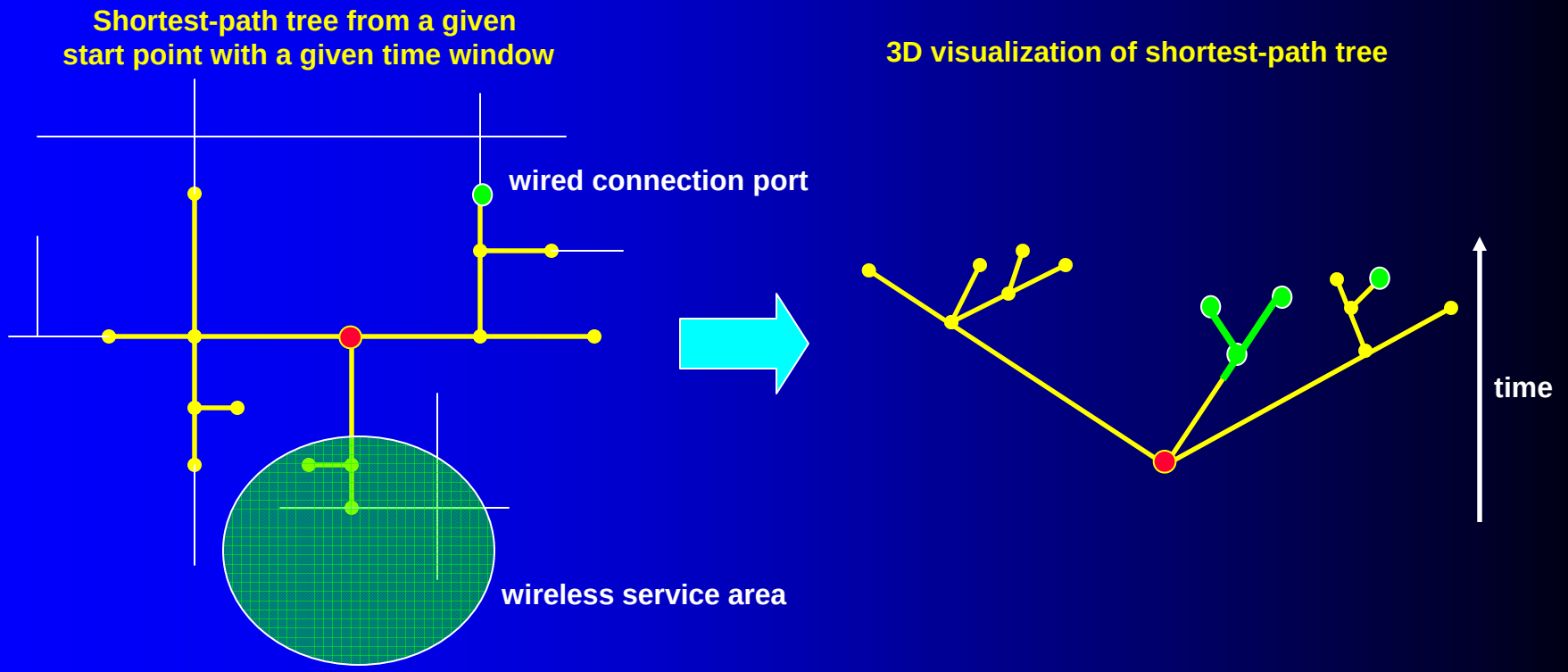


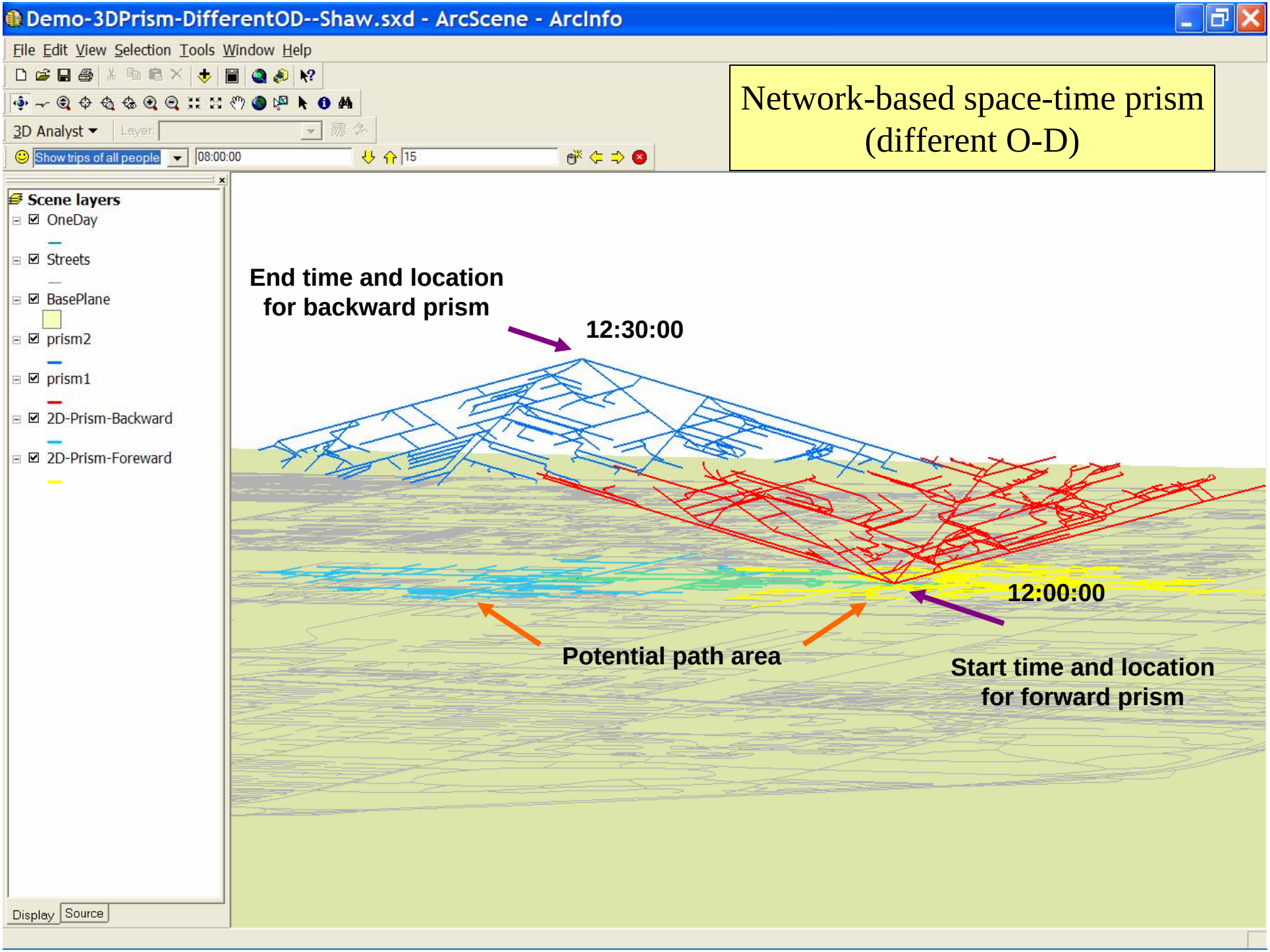


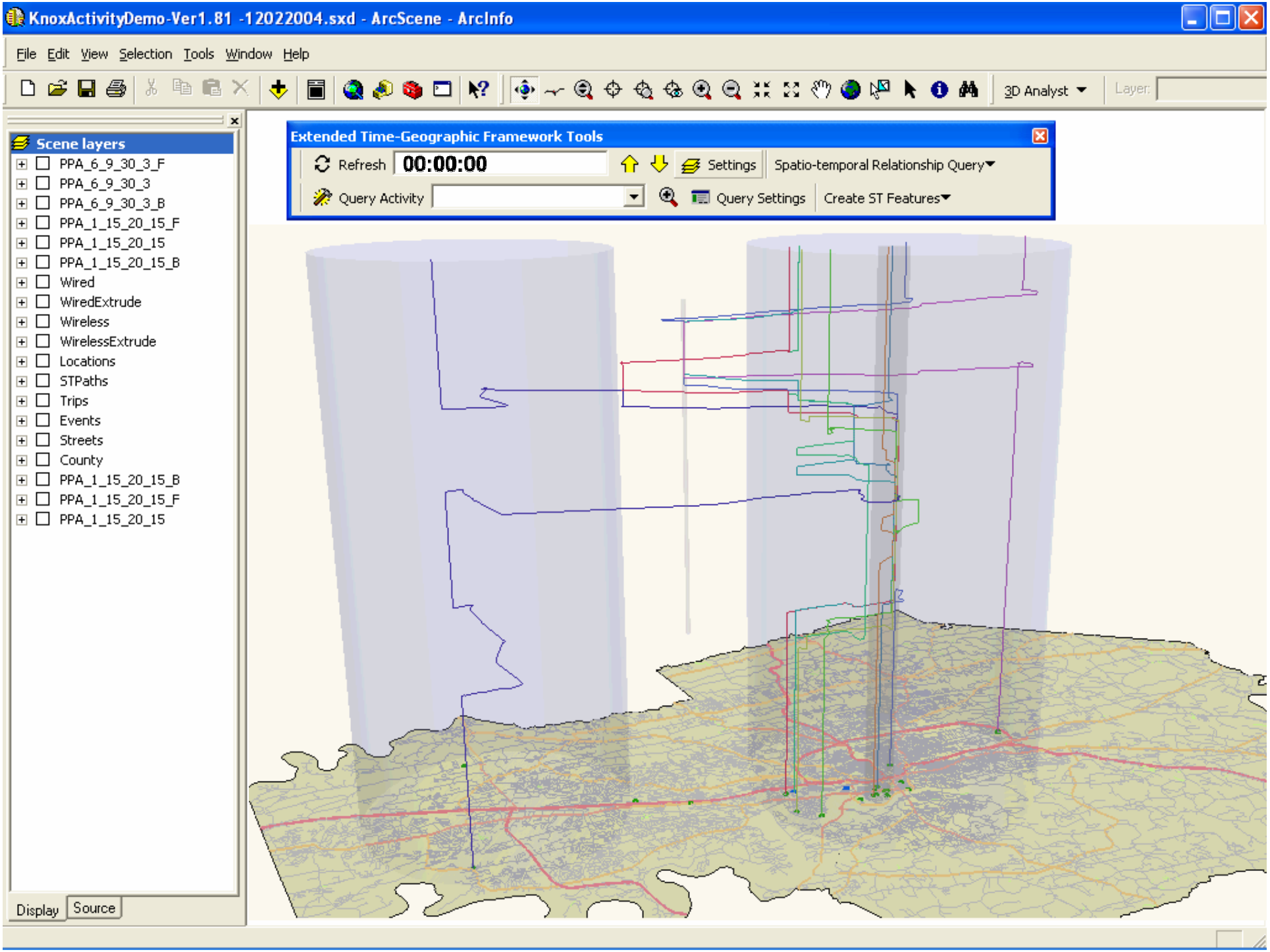




- Create and Represent Network-based ST Prisms in 3D Environment
  - ST Prism for *physical activities*: from shortest-path tree to polylines with *z* and *m* values
  - ST Prism for *virtual activities*: subset of shortest paths tree that can access virtual space




Demo-3DPrism-DifferentOD--Shaw.sxd - ArcScene - ArcInfo
File Edit View Selection Tools Window Help
3D Analyst
Layer
Show trips of all people
08:00:00
15
Scene layers
OneDay
Streets
BasePlane
prism2
prism1
2D-Prism-Backward
2D-Prism-Foreward
Display
Source
Network-based space-time prism
(different O-D)
End time and location
for backward prism
12:30:00
12:00:00
Potential path area
Start time and location
for forward prism


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

Concluding Remarks

- Based on an extended time-geographic framework, this study provides a spatio-temporal GIS framework for exploration of human interactions in both physical and virtual spaces. It offers useful representations and functions to investigate *spatial-temporal patterns* of individual activities.

- This framework and its GIS implementation can be useful for applications that involve spatio-temporal individual activities, e.g., *modeling spread of infectious diseases*, *tracking terrorist activities*, and *providing location-based services (LBS).*

Thank You!