EXCHANGING TRANSPORTATION NETWORKS BETWEEN TWO GISs VIA THE SDTS

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ABSTRACT

Performing meaningful network analyses is greatly dependent upon accurate and complete transportation network models, which are digitized into a GIS or, more often, imported from another GIS. Transportation networks can be converted thoroughly between different GISs if they model semantically similar features. Such is the case with Arc/Info Network (by ESRI) and MGE Network (by Intergraph). The graphic features modeled, associated attributes, topology, and metadata can be translated between the two GISs via the Spatial Data Transfer Standard (SDTS). In particular, the draft Transportation Network Profile (TNP) of the SDTS has been used to experiment with this type of conversion. This paper compares the two GISs' transportation network modeling capabilities, briefly discusses the functionality of a software utility (written for a Geography Master's thesis) to convert transportation networks between the two GISs, and assesses the usefulness of the Transportation Network Profile of the SDTS.

INTRODUCTION

This paper discusses an experience with translating transportation networks between two GISs, Arc/Info and Modular GIS Environment (MGE) via the Spatial Data Transfer Standard (SDTS). The experience began with a comparison of the two GISs' modeling capabilities and assessments of existing exchange programs (Schmidt, 1997). After a study of the Transportation Network Profile (TNP) of the SDTS, translation programs were written and conclusions were made about the TNP.

COMPARISON OF TRANSPORTATION NETWORK FEATURE TYPES

To compare network feature types, the important features of a transportation network should be understood. In Figure 1 (Schmidt, 1997), the cities of Nashville, Knoxville, and Chattanooga are called *nodes* while interstate highways 40, 24, and 75 are called *links*. This example transportation network contains three nodes and three links that link the nodes together. This example network is trivial but larger, more circuitous networks are too complex to solve shortest path, routing, location and allocation problems, all examples of transportation problems, without help of sophisticated algorithms that are programmed into GISs. Complete and accurate network models are required to solve these type of problems in a GIS. When the transportation network data is imported from another GIS, accuracy and completeness are just as important. If the two GISs model semantically similar feature types, the accuracy and completeness is more likely to be high.

Both Arc/Info and MGE model cities as points or *nodes* (ESRI, 1992). Both model highways, railroads, waterways, etc. as lines called *links* in Arc/Info and called *edges* in MGE (Intergraph, 1995). In addition, MGE models three other types of features potentially part of a transportation network: *on-node*, *on-edge*, and *on-net*. In Figure 1, the point of a 3-car accident, the bridge location, and the location of the University of Tennessee are examples of these MGE features types.

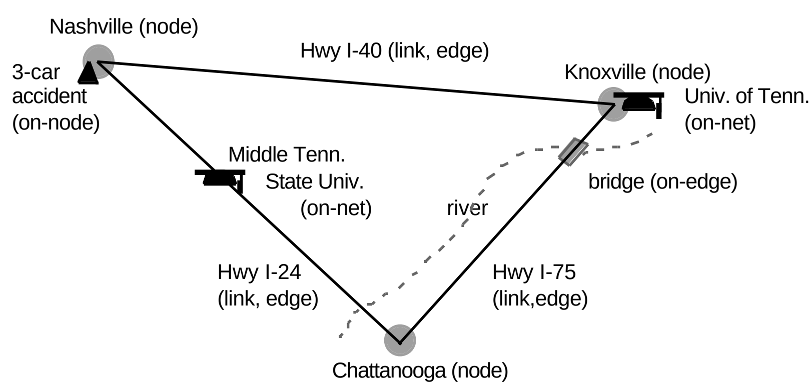

Figure 1 - Example Transportation Network Features

Table 1 (Schmidt, 1997) compares the feature types by name. Arc/Info and MGE nodes represent the same type of features. An Arc/Info link is not equivalent to an MGE edge, but is equivalent to an MGE construct called a *section* (Intergraph, 1995). One or more MGE sections make up an edge. The Arc/Info's section is closer to being analogous to the MGE edge, but Arc/Info's sections can be composed of fractional numbers of links while edges are composed of integer MGE sections. On-node, on-edge, and on-net feature types have no analogy in Arc/Info. While not distinctly separate feature types, it is interesting to see centers, stops, and turns have analogies in MGE.

Table 1 - Transportation Network Feature Types in Arc/Info and MGE

Arc/Info Feature Type	MGE Feature Type
node	node
link	section
(section)	edge
	on-node
	on-edge
	on-net
centers	on-node & center set table
stops	on-node & stop set table
turns	from/to edge pairs & intersection table

THE SDTS DATA MODEL

The Spatial Data Transfer Standard (SDTS) is a Federal Information Processing Standard (FIPS) created to advance the opportunities for exchange of spatial data (geographic and cartographic data) by encouraging the use of a single transfer format by all agencies, institutions, and companies who use many different GISs (Wortman, 1992). Exchanges of data occur both when data providers distribute data sets and when agencies share data among themselves. In an attempt to be thorough in the development of the SDTS, it became more than just a data transfer format (ESRI, SDTS, 1995). It includes structures, definitions, and a methodology to allow the preservation of all aspects of a single spatial data set as well as being capable of handling a variety of spatial data types while providing machine and media independence. This means SDTS can handle both vector and raster data types, primary attributes and other indirectly related database tables (secondary attributes), topology, quality reports, and other metadata, but not all concurrently. While the standard is written to define all aspects of each of these spatial and aspatial data types, profiles guide the use of the SDTS for a single class of spatial data (USDOT, 1996). Currently a Topological Vector Profile (TVP) is the only approved profile. It serves as a FIPS for the sharing of vector data with topology and attributes. A Raster Profile (RP) and a Transportation Network Profile (TNP) are awaiting approval. The TNP is the profile used in the exploration of spatial data exchange in this study.

Before trying to understand the TNP, one must look at the whole SDTS. It defines numerous spatial objects from zero dimensioned points to three dimensioned voxel spaces (USGS, Part 1, 1995). A sample of these spatial object types are listed in Table 2 in context of Arc/Info and MGE feature types. In addition, the SDTS defines how coordinate and attribute data are to be stored in SDTS files and allocates particular data types to particular modules. SDTS uses the term “module” in place of “file” because the media independence goal allows for the possibility of a file being transferred in pieces, which on any computer would also be called files. Most often modules are equivalent to files. A sampling of the modules (files) is listed in Table 3 along with brief descriptions of each and grouped into categories. Modules omitted from Table 3 include identification, security, statistics, quality, graphic representation, and additional spatial object modules. A complete list of all 37 SDTS module types and full descriptions of them are given in the SDTS Part 1, Logical Specifications (USGS, Part 1, 1995).

The next to last column, TNP, in Table 3 indicates with a “Y”, for yes, which modules are to be included in a TNP transfer (USDOT, 1996). These indicators should not imply that omitting a module will cause the transfer to fail but rather indicates a full set that completely preserves all content and characteristics of the original spatial data set. For example, an exchange of data can occur although the STAT module is not present. The last column, New, indicates with a “Y” which modules are used by the new translation programs written for this study. One non-TNP modules are created for pedagogic purposes and some other TNP modules are not created. Therefore the new data exchange program does not create a transfer that complies fully with the definition of the TNP. To do so would be an effort in preparing production-worthy software. To experiment with a core sample of the module types was the intent here and furthermore to carry the subset of data through a full cycle from Arc/Info to MGE and back.

Table 2 - Feature Types in Arc/Info, MGE, and SDTS

Arc/Info Feature Type	MGE Feature Type	SDTS Composite Object Type
point	point	entity point
node	node	node
arc	line	line segment
arc, link	section "	string "
(section *)	edge	chain
(arc)	(edge)	link
polygon "	area boundary "	G-polygon, GT-polygon
polygon label point	area centroid	area point
annotation	label	label point
		arc

* Arc/Info sections are topological features created using dynamic segmentation while all other features in this table are static, graphical features.

Table 3 - SDTS Modules

GLOBAL MODULES

Module*	Module Name	Description	TNP	New
-- *Catalog Modules* --				
CATD	Catalog / Directory	File names of all modules	Y	Y
CATX	Catalog / Cross Reference	Associates modules, e.g., which attribute module relates to which vector graphic module	Y	Y
CATS	Catalog / Spatial Domain	Relates modules to spatial domain, map, theme, or aggregate object	Y	
-- *Spatial Reference Modules* --				
IREf	Internal Reference	Internal coordinate scale and offset	Y	Y
XREF	External Reference	External coordinate system	Y	Y
RGIS	Registration	Registration points		
SPDm	Spatial Domain	Extent of coordinate data	Y	

(continued)

Table 3 - SDTS Modules (Continued)				
-- Data Dictionary Modules --				
DDDf	Data Dictionary / Def'n	Definitions of entities and entity attributes	Y	
DDOm	Data Dictionary / Domain	Attribute value domains and definitions	Y	
DDSh	Data Dictionary / Schema	Defines attribute data types	Y	Y
ATTRIBUTE MODULES				
Module	Module Name	Description	TNP	New
Axxx e.g., AP00	Attribute, Primary	Feature Attributes	Y	Y
Bxxx e.g., BP00	Attribute, Secondary	Other Attributes	Y	
SPATIAL OBJECT MODULES				
Module	Module Name	Description	TNP	New
-- Composite Module --				
FFxx	Vector, Composite	Aggregation of other spatial objects	Y	
-- Vector Modules --				
NAxx	Vector, Point-Node	Area Point features	Y	Y
NExx	Vector, Point-Node	Entity Point features	Y	Y
NOxx	Vector, Point-Node	Node (planar) features	Y	
NNxx	Vector, Point-Node	Node (non-planar) features	Y	Y
LSxx	Vector, Line	Line String features		Y
LQxx	Vector, Line	Link features	Y	
LExx	Vector, Line	Complete chain features	Y	
LWxx	Vector, Line	Network chain (planar) features	Y	
LYxx e.g., LY00	Vector, Line	Network chain (non-planar) features	Y	Y
PGxx	Vector, Polygon	G-polygon features		
PCxx or PRxx	Vector, Polygon	GT-polygon features	Y	

* lowercase letters are replaced by either uppercase letters or digits

Another use of the profile is to identify which spatial object types are to be exchanged in an SDTS file set. Table 4 lists a subset of the object types and shows which are required, which are optional, and which are not allowed by the TNP (USDOT, 1996). The rightmost column, New, identifies which spatial object types are transferable by the new translation programs. These spatial objects are network nodes and links plus two more point-type features and one more linear feature.

Table 4 - SDTS Object Types Transferable Via TNP

Code	Object Type Name	TNP Required	TNP Optional	TNP Not Allowed	New
FF	Composite		X		
NA	Area Point		X		Y
NE	Entity Point		X		Y
NO	Node, planar	X or			
NN	Node, non-planar	X			Y
LS	Line String			X	Y
LE	Complete Chain		X		
LQ	Link	X or			
LW	Network Chain, planar	X or			
LY	Network " non-planar	X			Y
PG	G-polygon			X	
PC	GT-polygon (chains)		X		
PR	GT-polygon (rings)			X	
G2	Raster			X	

The SDTS data model is implemented as a set of computer files created in the FIPS PUB 123 (ISO 8211) data descriptive format (ANSI, 1994). Each file contains one type of information. For example, one file contains the locational data while a separate file contains the definition of the coordinate system for the locational data. All file names begin with the same four characters thus effecting a distinct group of files. The module type adds an additional four characters to the file name and an extension is added resulting in a set of files named in the format of PPPPMMMM.DDF, where “PPPP” is the prefix, “MMMM” is the module identification, and “DDF” stands for data descriptive file. Groups of modules provide catalog and statistical information, identification and coordinate system information, data quality information, and data dictionary information (ESRI, SDTS, 1995).

THE NEW TRANSLATION PROGRAMS

Four computer programs were written to translate between Arc/Info and MGE as shown in the gray rectangles in Figure 2. They were written in C, C++, AML, and MDL programming languages. When run, the programs ask the operator to specify the GIS data set, a feature type, and an SDTS file set and then proceed to translate the data without further operator interaction. Running the two programs ARC2SDTS and SDTS2MGE completes a transfer from Arc/Info to MGE. Similarly, MGE2SDTS and SDTS2ARC complete a transfer.

The new translation programs transfer locational, attribute, attribute definition, and coordinate system information. Table 5 (Schmidt, 1997) lists the exact modules, fields, and subfields read and written by the new programs. Note the DDSH module contains attribute definitions. The XREF module contains the coordinate system specification. The AP00 module contains the attribute values. One of the last five modules is used to transfer the locational data.

To illustrate these modules, fields, and subfields, Figure 3 shows the contents of eight SDTS modules if two hypothetical roads were written by ARC2SDTS or MGE2SDTS to an SDTS file set with a file prefix of "FG34" (Schmidt, 1997).

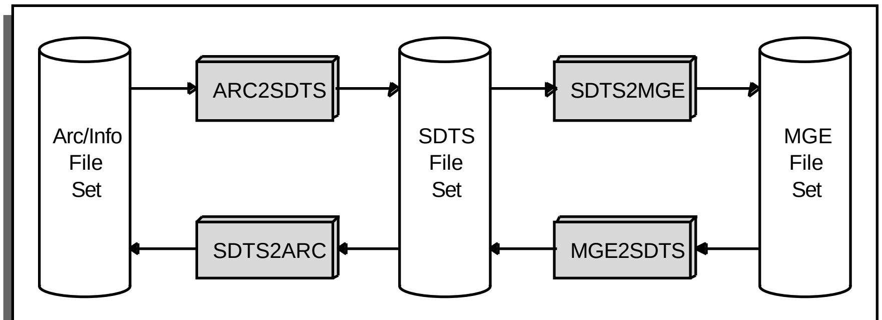

Figure 2 - The Four New Translation Programs

Table 5 - Fields/Subfields Per Module Used by ARCXMGE

	Field Mnemonic	Subfield Mnemonic	Description
CATD Module:	CATD	NAME	Module Name
	CATD	FILE	Name of File containing Module
CATX Module:	CATX	NAM1	Module Name
	CATX	NAM2	Related Module Name
DDSH Module:	DDSH	NAME	Name of Attribute Module
	DDSH	TYPE	Module Type
	DDSH	ATLB	Attribute Label or Name
	DDSH	FMT	Format of attribute data
	DDSH	PREC	Precision of numeric data
	DDSH	MXLN	Max. Length of character data
IDEN Module:	IDEN	PRID	SDTS Profile Identification
IREF Module:	IREF	SFAX	Scaling Factor along X axis
	IREF	SFAY	Scaling Factor along Y axis
	IREF	XORG	X coordinate of Origin
	IREF	YORG	Y coordinate of Origin
XREF Module:	XREF	RSNM	Reference System Name
	XREF	HDAT	Horizontal Datum
	XREF	ZONE	UTM, UPS, or SPCS Zone
	XREF	PROJ	Projection
	ATID	MODN	Projection parameter Module Name
	ATID	RCID	Projection parameter Identification
AP00 Module:	ATPR	RCID	Record Identifier
	ATTP	*	Attribute value (“*” is the attribute label)
LS00 and LY00 Modules:	LINE	OBRP	Object Representation
	ATID	RCID	Record Identifier of associated attributes
	SADR	X	X coordinate of vertex (repeats)
	SADR	Y	Y coordinate of vertex (repeats)
NA00, NE00, NN00 Modules:	PNTS	OBRP	Object Representation
	ATID	RCID	Record Identifier of associated attributes
	SADR	X	X coordinate of point
	SADR	Y	Y coordinate of point

CATD Module (FG34CATD.DDF):

NAME	FILE
LS00	FG34LS00.DDF
AP00	FG34AP00.DDF

CATX Module (FG34CATX.DDF):

NAM1	NAM2
LS00	AP00

DDSH Module (FG34DDSH.DDF):

NAME	TYPE	ATLB	FMT	PREC	MXLN
AP00	ATPR	composition	A		8

IDEN Module (FG34IDEN.DDF):

PRID
SDTS Transportation Network Profile

IREF Module (FG34IREF.DDF):

SFAX	SFAY	XORG	YORG
0.000001	0.000001	0.0	0.0

XREF Module (FG34XREF.DDF):

RSNM	HDAT	ZONE	PROJ	MODN	RCID
SPCS	NAX	4100			

AP00 Module (FG34AP00.DDF):

RCID	COMPOSITION
1	concrete
2	asphalt

LS00 Module (FG34LS00.DDF):

OBRP	RCID	X	Y	X	Y	X	Y	X	Y	X	Y
LS	1	1	5	6	7						
LS	2	1	2	3	1	5	1	7	3	9	4

Figure 3 - An Example Set of SDTS Modules

CONCLUSIONS

Arc/Info and MGE appear to model transportation networks adequately but not identically. Both GISs model nodes and links, but MGE has the three additional feature types called on-node, on-edge, and on-net. Both GISs can hold and use information about centers, stops, and turns. Arc/Info has the ability to model routes which are built from sections, both of which are a super-feature type. This is part of a capability called "dynamic segmentation" that was not examined in this study, except for the Arc/Info section feature type.

The use of the SDTS for the interim format in exchanging data between Arc/Info and MGE is more difficult than using simple ASCII files such as those created by Arc/Info's UnGenerate and UnLoad commands, but the SDTS is much more capable than elementary ASCII files. The SDTS is defined to contain topology, data quality statements, and secondary attributes and is intended for the exchange of GIS data among all GISs.

Only two weaknesses were seen in the SDTS. First, the SDTS has no date and/or time attribute type. To transfer dates and/or times, complete definitions of these attribute types must be placed in the Data Dictionary modules. This did not create difficulty in the new data exchange system because the new system does not attempt to transfer date/time attribute types unless they are stored as character type attributes, in which case they are treated unknowingly like character attributes. Second, a deficiency in the Transportation Network Profile (TNP) application of the SDTS is the lack of explicitly stated requirements for the inclusion of centers, stops, and turns information. While these tables can and should be transferred as secondary tables in an SDTS file set, the TNP does not require them to be.

Developing working knowledge of the SDTS was definitely the most difficult part of this endeavor. With only the printed standard itself and a few additional articles, it was not a subject to learn quickly. It was only after developing my first small segment of code to read an SDTS file that I became confident enough to proceed with SDTS as the interim file. The FIPS PUB 123 Function Library provided the file access functions and examples to begin working with SDTS files.

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