FEATURE CLASSIFICATION SYSTEM AND ASSOCIATED 3-DIMENSIONAL MODEL LIBRARIES FOR SYNTHETIC ENVIRONMENTS OF THE FUTURE

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ABSTRACT

This paper describes a new hierarchical data structure used to store natural and man-made feature data for use in modern and future real-time simulation systems. This system is not based purely on a map oriented feature set as are the DFAD and FACC based feature classification structures. This scheme is based on visible man-made and natural features (tangible features) and a wide assortment of intangible objects that are encountered in geographic information system (GIS) databases. Also, a unique part of this classification scheme is the existence of an integrated feature-objects/3D-Model objects relationship. An integral part of the system is a set of 3D models, in standard OpenFlight format, each associated with a feature object.

This classification system is an object oriented classification system. The feature and attribute objects included in this new system are based on earlier, more traditional feature classification systems such as DFAD/FID, DIGEST/FACC, SEDRIS/EDCS, USGS/Anderson, and USFWS/NWI. However, this classification scheme has been expanded with the express intent of opening up the real-time simulation field to a wide variety of scientific (and not so scientific), research, and production fields of study. This classification system is not limited to a specific discipline but allows internal cross-referencing between the various "standard" feature classification systems currently in use today. This not only makes the new classification system usable in the traditional Modeling and Simulation (M&S) environment. It also will allow the real-time simulation capability to migrate into many other disciplines – disciplines totally outside the M&S environment.

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Feature Classification Systems and Associated 3-Dimensional Model Libraries for Synthetic Environments of the Future

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INTRODUCTION

During the last decade, the development of technologies for spatial data acquisition and integration has revolutionized the way that we perceive and understand the integrated elements within our diverse cultural landscape. However, graphic display technology has lagged behind spatial data acquisition and integration. Displaying large volumes of spatial data in an understandable manner and integrating the cultural landscape into the same graphic display could revolutionize the use and perception of geographic information. Using existing and new technologies, the graphic synthesis of geographic information with the actual cultural landscape can transcend the current roadblocks to understanding complex spatial relationships.

Today's challenge is to develop advanced techniques to rapidly capture and display large volumes of spatial data about a cultural landscape. For this to be a viable technique, the cultural landscape must be displayed with photo realistic scene quality. At the same time, processes must be developed to display geographic information in such a way that it is spatially correlated and integrated with the cultural and natural landscape, but at the same time, aesthetically pleasing and informational. Seeking a balance between photo-realism and the full meaning of the spatial information is similar to the dilemma that has long faced the traditional cartographer – balancing the volume of map information with the cognitive abilities of the target audience. This requires the insight and effort of cartographers, sociologists, environmental scientists, computer engineers, urban planners, and many others involved with geographic information systems.

However, creating realistic synthetic landscapes also requires the ability to inventory actual natural and man-made objects at the same level of detail as they exist within the real-world landscape. To do this, a feature classification system that contains detailed categorizations of natural and manmade objects is essential. Using current feature classification systems, it is impossible to store spatial information on many of the more common manmade features encountered. In the classification schemes commonly used in the Modeling and Simulation (M&S) environment, no categories are available to store feature information about the most common non-pavement highway features – regulatory and informational signs. Try and find a classification code for a stop sign, or any other standard traffic sign. Search in vain for a classification code for a covered bus stop, or a park bench.

These are but a few examples of features that cannot be stored using current feature classification systems. To use these and many other commonly occurring features, special procedures must be implemented to allow the storage of no-standard feature classifications within feature databases. As the power of hardware and software increases, the list of non-standard feature types will continue to increase. Because current classification schemes are rooted in map symbology, it will soon be impossible to rapidly and efficiently create synthetic environments at a feature level of detail demanded by the customer base. For this reason, it is imperative that a landscape-based feature classification system be developed to replace map symbology-based classification systems.

BACKGROUND

The military, NASA and the airline industry have been using real-time simulation for more than 30 years. However, by today's hardware and software standards, much of the past history of real-time simulation has resulted in rather primitive, "cartoon" quality visual displays. Feature throughput and available virtual memory have been the hardware and software factors that limited visual display capabilities. With the introduction of advanced PC computer technologies, many of these barriers have been removed. The result has been inexpensive and more realistic real-time simulation capabilities. However, many of the database generation tools used to create synthetic environments are still based on heritage technologies and have not kept-up with hardware capabilities.

The synthetic environment is a critical part of real-time simulation since it forms the virtual world in which the actual simulation takes place. Depending on the nature of the simulation, the synthetic environment can take many forms. In classical high fidelity simulation, for example war-gaming simulation, the synthetic environment must realistically represent all facets of a real or notional landscape. This realistic representation would include the natural and manmade cultural landscape, weather and weather effects, time of day and the resulting ambient lighting, and the temporal effects of conflict on the environment. Traditionally, the synthetic environment can be divided into three broad components (Table 1).

Static Environment	*Environmental Effects*	*Behavioral Effects*
Terrain Skin	Ambient Effects of Light	Moving Models
Ground Texture	Weather	Situational Models
Feature Data	Haze Smoke	Operational Models

Table 1. The Basic Components of a Synthetic Environment.

The Static Environment encompasses all visual and non-visual objects that make up the natural and cultural landscape. This includes detailed elevation data describing the "lay-of-the-land" – often termed the terrain skin. It also includes all forms of ground texture that are applied to the terrain skin to enhance visual recognition of a scene. This includes both artificially created ground texture and ground texture derived from airborne and space-borne sensors. Feature data includes all man-made and natural objects that rest on or above the terrain skin. This data takes the form of a detailed digital inventory of point, linear, and areal features that populate the area of interest.

The Environmental Effects component models the transitory effects of ambient lighting, weather and atmospheric particulates. Usually, this component is a hardware- and software-based solution that is applied to the Static Environment at run-time.

The Behavioral Effects are generally that component of the gaming scenario that occurs during the actual real-time simulation. A set of situational and operational scenarios is devised that enact some state of affairs. These situations can include dynamic and moving 3-D models or can be purely situational in nature.

The most important of these three components and the one that requires the most effort is the static environment. The effort expended in creating this component reflects directly on the level of realism that will ultimately result during the real-time simulation. The level of detail that is stored to describe the static environment is a reliable measure of how realistic the final graphic displays will be. This phase of the simulation process is usually termed database generation, is the most costly phase, and also takes the longest time to complete.

In the past, database generation for real-time simulation was based on both a format-focused approach and also on specific hardware display systems. Databases were designed based on a particular proprietary database format that accompanied a particular manufacturer's simulation display system. The manufacturer usually designed the database generation system based on a specific set of source data formats. A wide array of raw source data describing a specific geographical setting was often not available. Early in the history of simulation, because feature counts were limited by hardware throughput capabilities, the variety of feature data that could be handled was often limited to those feature classes that appeared on small and medium scale maps. The U.S National Imagery and Mapping Agency (NIMA), formerly the Defense Mapping Agency, was the primary source of wide area feature data for the real-time simulation industry. Their solution was to provide feature data that was extracted from medium-scale topographic maps – a data format called Digital Feature Analysis Data (DFAD). Since the early simulation hardware systems could not process many features, this was a viable and acceptable solution. DFAD has since evolved to include feature data extracted from large-scale maps and feature information extracted from higher resolution imagery.

Throughout the history of real-time simulation, customers have continually demanded more detail. As the required level of detail of visual databases has increased, so to has the number and variety of features that must be stored. For this reason, the visual database generation community realized that NIMA's feature data was not an adequate means of storing features for real-time simulation. The feature classification system used within the DFAD specification was originally designed to store feature information from medium and large scale topographic maps. It was limited to a maximum of 999 distinct feature objects, of which only 700 were defined. Modeling a detailed and realistic virtual environment with so few discrete objects was and still is impossible.

The Feature and Attribute Coding Catalogue (FACC) is the feature classification system used in DIGEST and SEDRIS and is a vast improvement over the DFAD feature classification scheme. FACC was adopted as the preferred classification scheme for database generation to increase the fidelity of feature databases. However, after a critical analysis of the FACC classification and attributing system, it becomes readily apparent that the system was also designed to store feature data based on large-scale topographic map symbology. Feature data derived form topographic maps, no matter what the scale, cannot meet the needs of today's real-time simulation customer. Feature data extracted from even large-scale topographic maps will never be able to provide the detail and realism that is demanded.

For this reason, as the demand for higher detail in real-time systems has increased, FACC has not been able to meet the demands for increased feature specificity. Today's real-time simulation capabilities can handle the wide array of features one sees as walking through a typical cultural landscape. However, the current feature classification systems are not designed to store the wide variety of features encountered on the ground.

No longer can we limit ourselves by storing feature data with feature classification systems designed for storing map feature symbology. Higher resolution display systems can handle feature details like park benches, parking meters, grocery stores, and the corner bar - features that will never appear on topographic maps. And, real-time database developers are limited to classification systems that do not approach these levels of feature specificity. For this reason, it is essential that a new feature classification system must be developed. This system must be designed to meet the increased level of detail requirements of today's real-time simulation technology and also the needs of real-time systems of the future.

History of Feature Classification. All real-time simulation systems require visual databases. Visual databases contain a detailed digital description of the natural and cultural landscape and are used to create a virtual environment that will display on the simulation hardware. An integral part of any visual database is a detailed inventory of man-made and natural feature through out the database area of interest. These inventories contain both spatial and attribute data on individual features that sit on the terrain. A standardized database format is an essential part of this detailed inventory and an essential element of any database is its feature classification system.

The purpose of a feature classification system is to allow a systematic categorization of feature objects using a generalized set of class objects. Then by creating a logical and orderly grouping of classes and subclasses, it is possible to identify relationships about objects contained in the categories.

Historically, feature classification systems for manmade and nature features can be traced back to the landmark conceptual work of Albert Z. Guttenberg. His research into the language of planning laid the groundwork for the basic concept of land use classification. It was not until his monograph entitled "*A Multiple Land Use Classification System*" (Guttenberg, 1965), that there was a precise and logical way of dealing with land uses. Since then, his research has led to many other aspects of land-use including the development of the major component dimensions of land use (Guttengerg, 1965). The Standard Land Use Coding Manual (SLUCM) and the Land-Based Classification Standard (LBCS) are derived directly from this monumental work.

Year	*Event*
1930s	U.S. Standard Industrial Classification (SIC) System
1959	*Multiple Land Use Classification* – Al Guttenberg
1965	*New Directions in Land Use Classification* - Al Guttenberg
1965	Standard Land Use Coding Manual (SLUCM),
1973	Anderson Land Use Land Cover Classification System
1987	Revised U.S. Standard Industrial Classification (SIC) System
1980s	Object based classifications systems • Digital Line Graph (DLG) • Digital Feature Analysis Data (DFAD) • Feature and Attribute Coding Catalogue (FACC)
1999	Land-Based Classification Standard (LBCS)
1999	North American Industry Classification System (NAICS)
2000	SEDRIS - EDCS

Table 2. Historical Events in Feature Classification.

U.S. Standard Industrial Classification (SIC) System. The Department of Commerce, in the 1930s developed the Standard Industrial Classification (SIC) System to logically group commerce and industry. This industrial and commercial classification system is an integrated mixture of categories based on production and market oriented economic concepts. Still used today, this system is in a semi-hierarchical listing format.

Standard Land Use Coding Manual (SLUCM) The Standard Land Use Coding Manual (SLUCM) was the first implementation of Dr. Guttenberg's concept of the component dimension in land use classification. Primarily designed for the classification of the urban landscape, this system also had a limited capability to classify the rural landscape. It integrated a significant portion of the SIC industrial and commercial categories as an integral part of the SLUCM.

Anderson Land-Use/Land-Cover Still used today in a slightly modified form, the Anderson Land-Use/Land-Cover Classification System is a multi-tiered hierarchical land-use classification system designed for use with data derived from remotely sensed imagery. It was developed based on a combination of functionality and image interpretation characteristics. The following top-level categories are standardized throughout the industry:

1 Urban or Built-Up Land
2 Agricultural Land
3 Rangeland
4 Forest Land
5 Water
6 Wetland
7 Barren Land
8 Tundra
9 Perennial Snow and Ice

This classification system was developed based on the ability to identify features from various scales of aerial photography/imagery.

Digital Line Graph (DLG). The U.S. Geological Survey's Digital Line Graph (DLG) data files contain selected base categories of cartographic data in digital form. Data files of topographic and planimetric map features are derived from cartographic source materials using manual and automated digitizing methods. Attribute codes are used to describe the physical and cultural characteristics of DLG node, line, and area elements. The codes are based on cartographic features symbolized on source maps. Each DLG element has one or more attribute codes composed of a three-digit major code and a four-digit minor code. The attribute scheme is open-ended, so that additional codes may be added as needed. It is not necessary for each element to have associated attributes. In general, attribute codes are not assigned to an element if the attributes can be derived based on relationships to adjacent elements.

Digital Feature Analysis Data (DFAD). The National Imagery and Mapping Agency (NIMA), formerly the Defense Mapping Agency (DMA), was instrumental in real-time simulation display capabilities, when in the early 1980's they published the Digital Feature Analysis Data (DFAD) Level 1 and Level 2 specification (DMA, 1986). This document defined a very basic feature classification scheme for the development of geographical databases. DFAD is a map symbol based system and was originally designed to allow the digital storage of only man-made and natural features that appear on topographic maps.

This scheme is still widely used today for the development of virtual environments used in real-time simulation – a scheme based on map features that appear on medium- and large-scale topographic maps. DFAD uses a Feature Identification Code (FID or FIC) as the basis for feature classification. This scheme is a fixed-length system of no more than 900 feature types, of which less than 700 explicit feature types have been defined. Locally, at many different sites this scheme has been expanded to increase the variety and clarity of feature database definition. However, local extensions to the classification scheme are not universally accepted or recognized. This limitation on the number of discrete feature types that can be stored, restricts the level of detail that can be attained from simulation databases using DFAD as the basis for feature data inventory.

NIMA has realized that feature data stored in DFAD format cannot provide the detail, feature density and clarity necessary in modern and future simulation systems. Digital data in DFAD format, although still available is no longer produced by NIMA. Two new products have been developed to replace DFAD – Vector Smart Map (VMAP) and Foundation Feature Data (FFD). These products are stored using the Vector Product Format (VPF) specification. For the classification of feature data, VPF uses a modified form of the Feature and Attribute Coding Catalogue (FACC).

Feature and Attribute Coding Catalogue (FACC) The **DI**gital **G**eographic Information **E**xchange **ST**andard (DIGEST) is a comprehensive set of data standards designed to support the exchange of raster, matrix, and vector data (and associated text) among producers and users. The DIGEST data standard is the primary spatial data exchange standard for the military communities of many nations, including NATO nations. DIGEST is also now the exchange standard of the civilian transportation community in Canada. DIGEST was prepared by and issued under the authority of the Digital Geographic Information Working Group (DGIWG), an organization supporting but not directly affiliated with the North Atlantic Treaty organization (NATO).

For feature classification, the DIGEST standard uses the Feature and Attribute Coding Catalogue (FACC) feature classification system - a “comprehensive” coding scheme for features, feature attributes, and attribute values. As a coding scheme, FACC provides a standard means for identifying feature and attribute types. Although it enables exchange of data, it does not demand a discrete set of attributes for any particular feature type, nor does it demand a specific set of attribute domains when an attribute is used to describe a feature. These characteristics of the DIGEST FACC allow for many instances where a single geospatial entity can be coded in several different ways to derive the same meaning. For example, a heliport may be described as a feature, GB035 Heliport, or as an attribute, APT 9 Heliport. Allowing multiple paths to the same meaning does not enforce standardization and is not computationally efficient.

Because the FACC classification scheme is essentially a fixed-length system, it does not allow for universal expansion of the classification system. There are provisions that allow users to locally extend the classifications scheme. However, local extension of the classification scheme does not allow for easy exchange of data without a local data dictionary.

National Wetland Inventory (NWI) Designed by the U.S Fish and Wildlife Service, the National Wetlands Inventory (NWI) is a comprehensive land use/land cover classification system for the classification of wetlands and deepwater habitats. It is mentioned, because it is a fine example of a classification scheme using a categorization that is rigid, comprehensive, and semi-hierarchical. Also, the NWI provides a very concise classification scheme for wetlands to include coastal, lake and other inland aquatic habitats.

Land-Based Classification Standard (LBCS). The Land-Based Classification System (LBCS) model is based on the Guttenberg conceptual model of land use. The LBCS updates the 1965 Standard Land Use Coding Manual (SLUCM), a standard that was widely adopted for land-use classifications. LBCS provides a consistent model for classifying land uses based on their characteristics. The model extends the notion of classifying land uses by refining traditional categories into five dimensions; activities, functions, building types, site development character, and ownership constraints. Each dimension has its own set of categories and subcategories. These multiple dimensions allow users to have precise control over land-use classifications. However, because the system classifies land-use based on five dimensions, potentially five different data values must be stores within each data record – one value for each dimension. Although this system is comprehensive in scope, it is not computationally efficient.

Synthetic Environment Data Representation and Interchange Specification (SEDRIS) was envisioned to be the one-stop solution to many of the correlation and data incompatibility problems encountered in the Modeling & Simulation community. SEDRIS is a standardized “transmittal medium” not a storage medium. SEDRIS serves as a centralized intermediary between differing M&S formats thereby providing a conduit for their interchange. The intent of SEDRIS is to create one standard method to interchange environmental databases “in a consistent fashion across the widest possible range of heterogeneous simulation systems that incorporate synthetic environments.” Within the SEDRIS concept, the feature classification schema is termed the Environmental Data Coding Specification (EDCS). EDCS is based on the FACC classification and attributing system. EDCS was developed within the confines of the Modeling and Simulation (M&S) community and for this reason has limited use with data created in other environments. As is the case with FACC, the classification system employed in EDCS is largely a map and chart symbology based classification system.

North American Industry Classification System (NAICS). NAICS is the first industry classification system developed in accordance with a single principle of aggregation, the principle that industrial and commercial producing units using similar production processes should be grouped together into closely aligned classifications. NAICS uses a 6-tiered-hierarchical classification scheme to classify the commercial and industrial sector. This is the first industry classification system developed in accordance

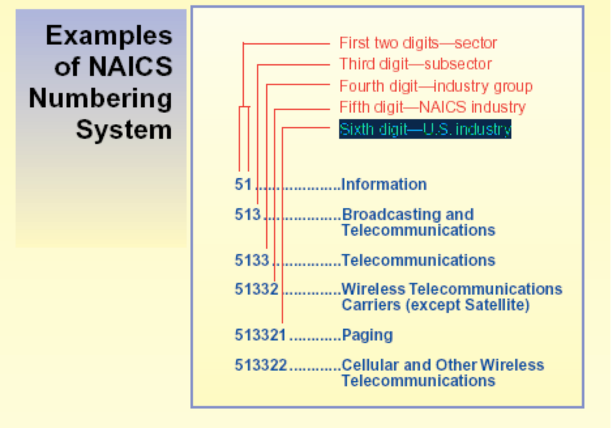

Figure 1. Feature Classes within the North American Industry Classification System (NAICS).

with the principle of aggregation, the principle that the production of units using similar production processes should be grouped together in the classification scheme. In this scheme, businesses and industries that use similar production processes are grouped together.

United States Imagery & Geospatial Information Service Conceptual Data Model–E (USIGS-CDM-E)
In December 2001, NIMA unveiled its newest conceptual data model for the acquisition, storage, transmission and exchange of imagery and geospatial information – the United States Imagery & Geospatial Information Service Conceptual Data Model – E (USIGS-CDM-E). In the USIGS-CDM-E, a modified FACC classification and attributing system is defined as the future standard means of storing feature data. This modified version of FACC still contains many of the same limiting factors inherent in the standardized FACC system.

METHODOLOGY

The primary problem with existing feature classification systems is that they are not comprehensive enough to store feature data at a level demanded by the current Modeling and Simulation (M&S) customers. Those systems that contain sufficient categories to adequately differentiate between feature characteristics are usually too restricted in scope. Other drawbacks encountered with current classification systems are:

- Flexible categories.
- Flexible coding rules.
- Classification involves multiple attribute encoding.
- Computationally inefficient.
- Lack of maintenance programs.

There is no such thing as the ideal feature classification system. However, in the M&S arena, a classification scheme with the following characteristics would provide a far better solution to the current feature classification dilemma:

- Explicit, discrete categories.
- Comprehensive in scope.
- Expandable.
- Hierarchical.
- Functional/applicable at all scales and levels of detail.
- Designed for translation between other classification systems with no loss of detail.

The process of developing an operational classification system for future real-time simulation systems must not only proceed from an object-specific perspective, but also embody a comprehensive methodology that addresses identification, measurement, and data collection, and classification issues. This suggests that the classification system should be designed based on a methodology that incorporates the following seven activities or steps:

1. Developing a systematic concept defining the scope for the classification system.
2. Identify/define broad top-level classes of features.
3. Determine appropriate but logical sub-classes
4. Define logical low-level feature objects.
5. Develop formal definitions for each identified objects.
6. Design software to allow translating between other systems.
7. Create interfaces to the classification system that allows users to:
    - Logically identify a particular feature within the system.
    - Import data from other systems with minimal loss of feature specificity.

The approach to the development of a systematic concept for this new classification system was two fold in nature. The primary intent was to devise a system that allowed the logical inventorying of natural and man-made features to such a level of detail that all manmade and natural features seen while walking through a typical natural or manmade landscape could be inventoried. These features, for lack of a better term are **tangible features** because they have substance and occupy visible space on the landscape.

A secondary intent was to be able to exploit many other forms of readily available geospatial information generated outside the M&S sector. The widespread use of Geographic Information System (GIS) technology has introduced a wealth of geospatial data into the public sector. However, the GIS community is concerned with a more diverse set of objects than just those object visible on or above the terrain skin. Routinely, GIS practitioners map information on **intangible features**, i.e. events, situations, phenomena, and objects that are hidden from view.

Every effort has been taken to design categories so that all major map-feature based classification systems would have an exact translation into this new classification system. DFAD, DLG, NWI, and Anderson LULC systems would translate directly into the new classification system without any data loss.

FACC feature codes would also be translated directly without data loss. However, the attributing flexibility built into the FACC may not fully translate into the new system.

In designing the classification system, it would be ideal if direct compatibility with other existing systems would be maintained. Every effort has been made to provide as much compatibility with other systems. Because many of the existing systems contain an optimized feature categorization, and a comprehensive set of feature categories within their discipline, existing naming conventions have been adopted in the new system whenever possible.

At the same time, a careful accounting of equivalent values in existing systems was also maintained throughout the project. In addition to the development of a new classification system, detailed cross-referencing information was maintained between systems. These cross-referencing tables will be used in the future to assist in the creation of translation software routines to allow rapid import of feature data into software using this new classification system.

After the conceptual design phase, broad top-level classes of features were defined. For tangible objects, top-level classes are functional in nature and are based on many of the more traditional categories used in previous systems. Intangible class categories are generally based on the field of study or profession from which they originate. We will be using a 4-tiered hierarchical system that allows for 99 broad top-level classes. So far, 38 top-level classes have been identified (Table 3).

Subclasses within each top-level class were developed based on functional or logical groupings. The creation of feature subclasses for tangible classes was a relatively simple process. Because most existing feature classification systems deal with tangible objects, the existing systems were often used as templates for the new system. When developing the new subclasses, categories from many existing classification system were used. All feature categories within the National Wetlands Inventory were included. Most feature categories of the DFAD, DLG and FACC system were also included.

Creating sub-classes for intangible features proved to be a bit more difficult. Research into map legends used in many of the traditional GIS disciplines provided extensive listings of mapable features. The listings generated from map legends were the basis for subclasses and low-level feature objects selected to categorize intangible features.

Tangible feature objects have been categorized based on functional, architectural, and most importantly visual characteristics. However, because low-level, intangible object are often events or conceptual in nature, outward visual characteristics (and of course architectural characteristics) could not be used in the categorization process.

Tangible	*Intangible*
Industry	Parks
Transportation	Elevation
Commercial	Hazmat
Recreation	Utilities
Residential	Crime
Military	Map Symbology
Governmental	Water Quality
Institutional	Air Quality
Agricultural	Conservation
Storage	Animal Studies
Hydrography	Survey Control
Bathymetry	Real Estate
Surface Features	Landscaping
Vegetation	Demarcation
Miscellaneous	Landmarks
Vehicles	Archeology
Human Forms	Weather
Animal Forms	Disease & Health
	Forestry
	Geology
	Wetlands

Table 3. Top-Level Feature Classes within the new classification system.

After the definition of subclasses and low-level feature objects, detailed definitions of all classes, subclasses, and object names were required. This phase is still on-going. Because this classification system covers a wide spectrum of disciplines and fields of study, the low level object definition phase has been difficult, particularly for the intangible feature classes/subclasses.

An eight-digit hierarchical numeric code was designed to describe each discrete object. This numbering scheme would allow 9,999,999 unique feature classifications. Because the scheme is numeric, hierarchical, and does not depend on additional attributes to define unique feature classes, it is computationally efficient.

Figure 2 shows a typical example of the numeric structure used in the proposed classification scheme. The left most two numeric digits define the top-level classes. Two more numeric digits define subclasses which are further delineated by two numeric digits for functional units. The right most two digits, the subunit, define a discrete object.

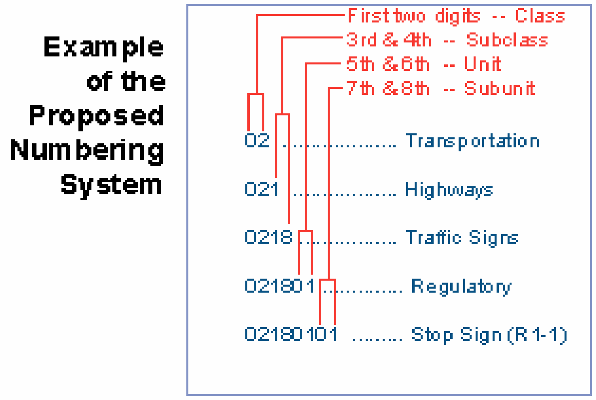

Figure 2. An example of the proposed classification scheme showing the highway traffic stop sign object.

RESULTS

Shapefile Attribute Scheme Development A formal Shapefile attributing specification has been developed that defines a set of standard attributes for use in the visual simulation environment. This Shapefile format was designed based on the concept that feature data from a variety of sources, and in a variety of different formats would be imported. The primary concern during the design stage was that during import, minimal data loss must be assured. For this reason a fixed-length standard Shapefile structure was chosen. To preserve attribute information during the conversion process, many of the standard FACC/EDCS attribute fields and all DFAD attribute fields were incorporated in the attribute set. This would allow the import/conversion of a wide array of feature file formats with minimal loss of feature data. Within each feature record, this final attribute scheme also includes an explicit pointer to a corresponding 3D model. This was essential to insure the transfer of an explicit feature object definition to heritage, current, and future simulation systems.

3-D Model Library Development. A static 3-D model library of over 400 government-owned feature models has been developed. This initial modeling effort concentrated on the development of static 3-D models that represent features as they might appear within the North American environment. As with any modeling effort, this model library is constantly increasing in size and now includes over 700 generic feature models of both tangible and intangible objects.

Software Development Database generation software in the form of a set of Avenue scripts has been developed into an provisional extension for ArcView Version 3.2. These tools allow rapid collection of spatial data in support of real-time simulation efforts. These tools, designed specifically for generating visual databases, are still in rudimentary stages. They are a set of ArcView engineering scripts that must still be refined into an integrated, fully functional extension.

The tools expand on the standard ArcView capability with the following broad functionalities:

- Import a variety of raster and vector data formats.
- Export 2D and 3D Shapefiles, GeoTiffs, and DTED.
- Create and populate standardized attributed Shapefiles.
- Digitize attributed point, line, and area features.
- Create tiled products.
- Create raster elevation data from contour lines.

Feature Classification System. Initial classification system development was performed using an existing 3-tiered classification system and then attempting to expand the classification scheme to increase feature clarity and specificity. However, this resulted in a disjointed and illogical assemblage of feature classes. Database engineers had major difficulties understanding the system and were not able to logically conceptualize the organization of the classification scheme. The conceptual base of the classification system has since been modified. Instead of modifying and expanding the scope of an existing hierarchical classification system, an entirely new design has been devised. This system is still under development.

However, using a preliminary version of classification system with data in the standardized Shapefile format, visual databases have been successfully created. These visual databases have then been successfully post-processed into run-time databases using a variety of commercial-off-the-shelf (COTS) software. COTS tools by TERREX, TerraSIM, MetaVR, Lockheed Martin TopScene, Lockheed Martin-Target were used to test the viability of the classification system and the Shapefile format. Using these post-processing tools, run-time databases for Lockheed Martin PC-IG, Compuscene, ModSAF, Lockheed Martin TopScene, and Flight Safety have been generated. When run-time databases were created using the North American static 3-D model library, the increase in fidelity resulting from the variety of feature models was clearly evident.

CONCLUSIONS

Existing classification systems used in the real-time simulation arena, to include those used by SEDRIS, have served their purpose. All of today's fully functional real-time simulation systems are dependent on either a variant of the FACC and/or the DFAD feature classification systems. However, due to an increased demand for feature richness in visual databases, a more comprehensive classification system is warranted.

Early efforts at expanding an existing locally developed feature classification system to accommodate a wider range of features, had proven to be a futile task. Over the last year, a 4-teired, hierarchical classification system has been designed that encompasses a wide range of tangible and intangible features. This system is still in the formative stages, but under limited testing has proven to be a feasible concept. The expandable nature of this system should allow it to serve the real-time simulation environment for years to come.

The richness of feature types in this new classification scheme extends far beyond the scope of the EDCS/FACC feature classification capability. However, it will be possible to pass this extended feature capability within a SEDRIS transmittal. Because each feature object in the collection contains a valid comparable FACC and DFAD code, it is unlikely that there will be problems during a translation into the SEDRIS transmittal. Features with no exact FACC equivalent will be carried through into the transmittal with a generalized FACC classification. Instead of a grocery store feature, the final result would be a generic commercial building. However, the design of the system includes explicit mapping of each feature object to an actual 3-D model. The SEDRIS transmittal would carry the pointer for an explicit 3D model across to the run-time system. The explicit feature classification might be lost within the SEDRIS processing, but the appropriate 3-D model will appear at run-time. To date, this concept has not been fully tested. However, preliminary testing shows this concept to be valid.

In addition to formal testing and final development of the classification system, extensive 3-D modeling work is still required. As the final feature classification system matures into a viable entity, more generic models will be necessary. Additionally, regional 3-D model libraries are being designed. Four more libraries, Middle Eastern, Northern European, Southern European, and the Far Eastern, are now in planning stages. Each of these libraries will include a set of region-specific generic models that would convey the "local color" and architectural characteristics of their respective regions.

To date, the concentration has been on air- and ground-based visual systems. A need exists for undersea and space visual simulation capabilities. At this time, there are no valid requirements for this research to extend the capability to incorporate the maritime and space environment. However, there exists a potential need to extend this classification and modeling concept to incorporate the maritime and also the outer space regimes. Real-time simulation is not just limited to air- and ground-based systems.

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