The Electronic Cultural Atlas Initiative and Geographical Information Systems Technology (ECAI-GIS)

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This paper explores Geographical Information Systems (GIS) issues involved in establishing the Electronic Cultural Atlas Initiative (ECAI). They include the nature and utility of GIS, choices of GIS software, the need for a unitary base map coordinate system and standardised scales and projections, and ways to make ECAI GIS databases accessible over the Internet and on CD-ROMs. Attention is also given to how scholars who are not particularly computer oriented can access and contribute to ECAI-GIS materials, and the kind and degree of technical support they will required and how it can be delivered.

The Nature of Geographical Information Systems (GIS)

Something called an 'Electronic Cultural Atlas', rather than just a 'database', implies that the information it contains will be mapped or otherwise referenced or represented spatially. There is an existing technology that accomplishes precisely that, most generally referred to as Geographical Information Systems (GIS), for which a number of commercial software products are available. Those suitable for ECAI-GIS purposes utilize vector-based digital cartography (in the first instance, anyway -- see the discussions of raster images and output, below) in which spatial features or objects are represented by points, lines, networks of lines, and polygons (multiple lines, or vectors, that are joined end to end and ultimately join up to enclose a space). Because vectors (other than points) begin at one point and have both direction and straight-line length to another point, they also have a left and a right side and polygons therefore have insides and outsides. Such topological properties allow GIS software to determine whether objects intersect (as in the case of a point being contained inside of a polygon) or are otherwise related (as with adjacent polygons, for instance).

When GIS data are defined in a coordinate system that represents some portion of the earth's surface in some known map projection, the objects in the spatial database are said to be 'geo-referenced', and can be spatially analysed in relation to topographic or other geographic features of the landscape to which they therefore belong, as well as other objects it contains. So can the 'attributes' of GIS objects, which can be any kind of information about them held in linked databases (or even marked-up text files with embedded URLs (Universal Resource Locators, like WWW page addresses).

The advantages of organising ECAI databases with GIS geo-referencing are apparent to those who are familiar with the technology. Everyone involved with contributing data to ECAI's spatially integrated databases should understand the basic concepts of GIS, some of which were just sketched out above in order to introduce a little of the terminology.

ECAI's choice of GIS software

ECAI should probably settle on a standard GIS software package that will be used for accessing associated databases over the Internet, and which it will support through its central facility (see discussion below). However, that decision would not preclude individual researchers participating in ECAI from using other GIS software that they may already be familiar with, as spatial data can be translated from one format to another with specialised programs. If TimeMap (a product of the Department of Archaeology, University of Sydney) is adopted by ECAI as a standard database interface, that could have a bearing on the choice of its standard GIS software. However, if ECAI participants in many institutions in many countries are to both access and contribute to its standardised GIS data bases, then only those software programs that run on all personal computer platforms are suitable, eliminating from consideration much 'shareware' and some of the complex and very expensive GIS software available in the UNIX environment.

Programs that work in the Microsoft Windows environments (NT as well as Windows 95 and 98) are particularly suitable for ECAI because of the existence of Asian language versions of Windows as well as other third-party programs that allow CJK (Chinese, Japanese, and Korean) characters to be utilised along with roman characters. Ultimately, ECAI will need to adopt the 'Unicode Standard', a two-byte per character system that potentially accommodates all known orthographies, from hieroglyphics and Sumerian cuneiform to contemporary Tibetan and Mongolian. Unicode is likely to be implemented in Windows environments before many others (it has been announced that the next release of Windows NT will support it, and it is more than likely that the next release after Windows 98 will as well). However, the main hold up in implementing Unicode appears to be the scarcity of readily available fonts, particularly for the more arcane orthographies.

In terms of GIS software for ECAI, those considerations basically narrow things down to either MapInfo or ArcView, the former being the self-proclaimed 'Premier Desktop Mapping System' and the latter being an ESRI (Environmental Science Research Institute) product closely linked to ARC/INFO, the most prevalent 'industrial strength' GIS program, at least in university UNIX environments. There are, however, other possibilities such as Mapnificence from xxxxx, Bentley's GeoGraphics, and Autodesk's World.

Different software programs implement various GIS functionality in different ways, and can therefore be more or less apt at accomplishing various tasks ranging from vector data generation to spatial analysis and then producing acceptable hard or soft output. The following laundry list of MapInfo virtues will serve to describe the kinds of features that ECAI-GIS will need in one manifestation or another, and does not imply that other software, such as ArcView, is deficient in one or another regard.

MapInfo Features

MapInfo is available for Macs (and UNIX) as well as PCs in Windows environments. It is reasonably easy to learn, and its menus are basically 'user friendly'. A major strength is a powerful, inbuilt, menu driven SQL utility (Structured Query Language - the basis of Relational Data Base Management Systems, or RDBMS) that allow manipulation and Boolean analysis of the data in its attribute table files. It also uses MapBasic as a Macro/Programming language that can automate complex operations as well as create special interfaces. Map projections are readily manipulated, and translation between them is even automated for display purposes. It also has raster image facilities, both for display and output. Its drawbacks include the difficulty of creating or modifying some forms of existing spatial data, particularly complex polygons. Points and even simple lines, on the other hand, are very easy indeed to input and move, and text and other labels can be displayed in automated ways as well as placed interactively. MapInfo is particularly adept at generating and displaying attractive visual representations of GIS searches and analyses and in preparing data and analysis for hard copy output in the form of camera ready color maps. Finally, the academic price for MI is reasonably low, internationally, and many university have site licenses or other access to it.

Other software requirements

GIS software is primarily designed to handle the topological relations among vector entities, and most programs employ other database programs such as DBase or an adapted version thereof to organise and hold attribute data, using codes of some sort to relate the spatial objects to their attributes (some kind of unique identifiers are required whether they are hidden or not). MapInfo is a partial exception to this generalisation. Although it too can interface with powerful RDBMS software, such as ORACLE, it has its own SQL-based attribute data management facility, described above. Although its 'browser' tables look like Excel tables, they are actually more like Access data bases because of their relational functions, and some users would rather use MI browsers than Access because of its powerful menu-driven querying system and MapBasic programability. In any event, the MI attribute data structure is basically compatible with Excel, and data can be written back and forth between the two programs with ease. (Microsoft Map, which comes with the latest versions of Excel, is in fact a version of the MapInfo 'engine'.) Since most Windows and even Mac users already have Excel (and Access) as part of Microsoft Office, there would be no need to acquire, and learn, other expensive and complex database programs to use in conjunction with MapInfo. The only exception is the need for either CJK Windows environments or something like Chinese Partner (Twin-Bridge) or its Japanese or Korean equivalents necessary for using CJK characters with MapInfo.

ECAI-GIS base map requirement

ECAI needs a common basemap on which to build its GIS in addition to common software programs. If everyone contributing geo-referenced materials to the Initiative starts from scratch (even if using the same GIS software) and creates their own original digital cartography from heterogenous paper sources of unknown or unrecognised projections, the problems of eventual integration of ECAI spatial databases become virtually insurmountable. On the other hand, there are abundant advantages if ECAI establishes standard basemap parameters, such as projection and scale, and then adopts existing digital cartography from a single source as its fundamental basemap. First, all the various spatial objects that are incorporated into any ECAI databases, no matter where in the world they are located or who contributes them, will be geo-referenced in terms of a single coherent coordinate system with the same scale and projection parameters, meaning at a minimum that they will display together on screen and ultimately that they can be conjoined to cover continental sized regions. In addition, features contained in the base map will also be consistent and everyone can locate sites and other objects with reference to the same version of physical features, such as rivers, lakes, and mountain ranges, as well as with man-made objects such as political/administrative boundaries and an assortment of cities, towns, roads, and rails, etc. Without such a common base map, everyone digitising maps for ECAI would only be reproducing the electronic equivalent of their original paper maps, and there would be no overall spatial coherence to ECAI-GIS, or ECAI itself for that matter.

The Digital Chart of the World (DCW)

Fortunately, there is a source for worldwide digital cartography at an appropriate scale. In the early 1990s the US Defense Mapping Agency (DMA) contracted with ESRI to produce a digital version of the Operational Navigation Charts (ONCs), a 1:1,000,000 scale topographic map series covering the whole world that is universally used for jet aircraft navigation and is readily available from DMA listings in any large US Yellow Pages. The resulting Digital Chart of the World (DCW), which faithfully reproduces all the features on the ONCs, has its drawbacks discussed below, but it is the only digital map available at that, or any larger, scale with pan-Asian or worldwide coverage. Again, the price and availability are right, as there are DCW versions available in most GIS software formats, including MapInfo, from diverse sources and at generally affordable prices (or even free, but unfortunately not for MapInfo).

The drawbacks of the DCW do not include its 1:1m scale, which is neither too large nor too small for most national or especially international GIS use. At that scale, one kilometer (.6 of a mile) is equivalent to one milimeter (.04 of an inch) *on paper*. Scale is actually meaningless in digital cartography or GIS, as the software programs allow for virtually infinite zooming in and out on-screen or for output purposes, but the related resolution of spatial data *is* important for two reasons. One is the ability to represent spatial objects of relevant size, and 1:1m is adequate to indicate the outlines of objects such as all significant rivers, medium to biggish lakes, ranges of mountains or even hills if not every single small hummock, and even the outlines of largish cities.

If someone working on a single archaeological or religous site wants to show more detail, say down to say 1:1000 scale (one meter to one milimeter) or even one to one, then the zooming power of any contemporary GIS program will allow that degree of precision but will still hold the spatial relationships of even such microscopically large-scale data to the overall, worldwide coordinate system if that was used from the beginning. On the other hand, although the files holding reasonably complex 1:1m resolution data for places the size of China are quite large (the 1:1m boundaries of the 2,500 county-level administrative units of China alone occupy several Megabytes of disk space), they are not beyond the contemporary capabilities of normal personal computer hardware or software systems.

In fact, there is often too much detail at 1:1m resolution to produce attractive maps on standard (A4 or 8.5 by 11 inch) pages as, for instance, at that resolution the 1:1m detail of the southeast coast of China produces an ugly, thick blur of merged objects. Such overly detailed (for such purposes) digital cartography is easily and automatically simplifiable, if necessary, but to add more detail involves complex technical problems. ECAI could produce or obtain low resolution versions of the DCW for continent sized base maps, and then implement an automatic zoom system that will bring up more and more detailed specific coverages as the screen scale is enlarged and larger scale data for the particular regions are appropriate to display.

Deficiencies of the DCW

Unfortunately, the deficiencies of the DCW are legion. One is that the basic cartography is decades old, going as far back as WWII for at least some features in at least some places. The coast of China provides many examples, where Macao is still depicted as three separate islands instead of an artificially connected peninsula, and the same sorts of problems exist for many parts of Hong Kong and Amoy, etc. The built-up areas of cities and even towns are of similar vintage, and the meagre selection of places represented does not necessarily represent contemporary significance. Canals, road and rail networks are also very outdated, while many even quite large contemporary reservoirs are not represented and the detail of the hydrological data in general is not great in comparison with some other 1:1m sources which have an order of magnitude more small streams. Contour intervals, following aeronautical practice, are in feet by thousands, apart from some supplemental ones at 250, 500, and 750 feet, whereas the international scientific community now operates in meters and there are places such as North China where far narrower intervals are required for meaningful representations. Differences of land-cover are not well represented, and are also often of only historical interest by now in any event.

Standard DCW data are also not very easy to use, as the world is divided by a 5 degree by 5 degree latitude/longitude grid. Each such arcanely coded 'tile' consists of dozens of separate spatial/attribute files containing particular topographical and cultural features, often duplicating things (such as contours) in visually identical lines and polygons. There is a newly released, improved version of the DCW called VMAP0, but it mostly just fills in gaps in the original data, such as missing tiles in South America, and somewhat simplifies the data structure in terms of the annoying duplications, etc. However, it is presently available only in the US Government (military) Vector Product Format (VPF), and it will be so time consuming and therefore expensive to (re)produce MapInfo versions of the new version that ECAI cannot plan on using it.

All considered, the bottom line is that there is no substitute for the DCW (apart from such eventual improvements to it), despite its deficiencies, as available smaller scale data (usually 1:3m, like ArcWorld) are even worse, while larger scale data are either not available or not affordable for all of Asia, to say nothing of the world, and would be too voluminous to be practical if they were available. Where such data can be found, and are appropriate, nothing stops ECAI participants from using them provided that they know how to integrate them with DCW features, thus preserving the overall integrity of the ECAI databases, or appropriate technical support is available to help them accomplish that. However, the DCW should provide adequate resolution and detail of features for most ECAI-GIS purposes, and where its detail is too great simplified versions can be produced.

Administrative boundary data

One major deficiency of the DCW from the ECAI perspective not mentioned above is its lack of administrative boundaries below the ADM0, or international, level. In addition to the point locations of cities, towns, or archaeological sites, the polygons representing low-level administrative units, historical as well as contemporary, are perhaps the most salient spatial objects for ECAI purposes. The Australian Centre of the Asian Spatial Information and Analysis Network (ACASIAN) has for the past seven years or so specialised in producing administrative boundary GIS databases for most of Asia, and in addition to county-level (ADM3) data for China that incorporate all changes to the administrative system of the PRC from 1980 through 1996, also has rayon and gorsoviet (now technically mostly ADM2, but equivalent to China's ADM3 xian and shi) boundaries for the entire former Soviet Union as of the last census in 1989. ADM2 or ADM3 data are also available from ACASIAN for all mainland Southeast Asian countries, plus the Philippines, as well as Mongolia and both Koreas. Work is near completion on similar data for Indonesia and all South Asian countries (apart from India, for which excellent commercial data are available) including Afghanistan and even Iran, while Turkey has also been completed. So, ACASIAN can soon supply ECAI with administrative boundary data for all of Asia apart from Israel, the Arab countries of the Near East, and India and Japan (otherwise available), while the Worldwide Map Consortium, in which ACASIAN participates, can add Oceania, Africa, Europe, and the Americas. Although such data cannot be supplied to ECAI without cost, ACASIAN at least is willing to negotiate very favorable terms for ECAI, and its Director is always willing to consider participating in collaborative activities such as the one planned with Thomas Hahn to geo-reference all of the local histories of China for the ECAI 'China Atlas'.

Other kinds of available data potentially relevant to ECAI-GIS

In the last several years various agencies, particularly those involved with the scientific 'global change community' have produced or are producing worldwide coverages of data derived from remote sensing, which in this context means satellite imagery or other observations. Although some of the older data sets are at scales/resolutions smaller than 1:1m, that is becoming the basic defacto standard, and, for instance, the Japanese government is promoting global thematic mapping at that scale, which generally equates to minimal resolutions of approximately one kilometer (or 30 arc seconds in mid latitudes). Some results, such as the Global Ecosystems Database (produced by the World Data Center, NOAA) are available on CD-ROM, but most others such as the DTED (Digital Terrain Elevation Data) and other data sets such as those for vegetation cover distributed by the EROS Data Center in Sioux Falls, SD, are mainly available on 9mm tape data cartridges. With few exceptions, such datasets require specialised and sometimes quite expensive software to access, and are not suitable for 'amateur' operation on PCs or Macs due to the enormous sizes and complexities of the files and the need to learn to operate the complicated software programs.

Problems with Raster Data

In addition, most such data sets are in raster, not vector, format. A raster image is bit-mapped, like a fax, with variation in individual pixels, or minimal display units, constituting patterns that the human eye can discern. However, unlike an image generated from mathematically defined vectors, there is actually no more real structure to raster images than there is among grains of sand on a beach, apart from the order in which they are stored and displayed. Nonetheless, certain kinds of spatial analyses are far richer in the raster environment than they are when vector data are employed. Most GIS and desktop mapping software will handle geo-referenced and projected raster imagery, but specialised software programs are usually required to prepare them. A more fundamental drawback to raster data is that zooming is inherently limited by pixel size, so that at some point the individual square pixels become visible, and if they are each one kilometer square that is a severe limitation as more finely grained, local data cannot be included or combined in the same database as it can in a vector GIS. On the other hand, unless one has very powerful workstation computer hardware/software, continental scale raster images are usually produced by generalising the data in one way or another in order to produce even larger but fewer pixels.

Satellite Imagery

Remote sensing is all raster based, which limits its utility for ECAI. Resolution of the more recent Landsat Thematic Mapper (TM) images is around 50 meters, which can be resampled to produce minimal pixels of around 30 meters, while the French Spot images have 10 meter resolution. How wonderful, as one can in principle even discern individual houses and terraced rice paddies at such fine resolutions (some military satellite images would allow one to count fence posts). However, at the equivalent of 1:100,000 scale, the pixels in Landsat images become visible, and annoying. In addition, file sizes and costs multiply inversely with resolution, so producing country scale, let alone continental scale, satellite coverages requires the resources of governments, not communities of like-minded scholars. Although some individual research projects could well make good use of 'local' satellite images, they require skilled if not professional interpretation, which often involves producing vector representations of features of interest. In addition, either the original raster images or the interpreted vectors still need to be integrated into whatever base-map framework ECAI-GIS will employ before they will be useful.

This is not to say that rasterised photographs will not be an important part of the ECAI databases. However, unless draped over a vector based landscape for some aesthetic purpose, photographs will be part of the attribute information pertaining to geo-referenced objects of one sort or another.

Technical support required for ECAI-GIS

If ECAI is to adopt a standard GIS-based approach to organising its databases, technical support facilities will be required. Most large universities have some kind of GIS activity these days, and often more than one GIS lab is in operation. However, the more sophisticated and elaborate those facilities are, the less likely that their staff will be interested in supporting the use of GIS by scholars in the humanities and social sciences who do not have a professional computer science background. In the exceptional cases where such help might be readily available at affordable costs, there would still be problems of overall ECAI-GIS systemization and integration. Therefore, if ECAI is to formally adopt GIS as its basic technology for organising spatial data (and there would seem to be no available alternative), some expert support facility or facilities will be needed to provide at least the following technical functions in addition to normal, ongoing support and encouragement:

1. Basic design of the ECAI-GIS database framework. Although the adoption of something like MapInfo, the DCW, and ACASIAN administrative boundaries simplifies many database design issues, there are still many decision to be made to establish procedures and techniques that all ECAI-GIS participants should adopt in order to produce overall coherence and compatibility. That is as necessary for the organisation of attribute data (information about spatial objects) as it is for the spatial data themselves. A sophisticated ECAI-GIS database design would allow for spatio-temporal relations and changes, a subject too complex and technical to elaborate on in this context, apart from what is covered in the next point.

2. Establishing systematic coding systems to link spatial and attribute data is an important central database design function. It deserves special mention because an

adequate coding system will have temporal aspects that will allow historical entities that are not (or are no longer) included in the official coding systems (if any) used by national governments (like China's Guobiao Administrative Codes), which should always be employed if available and used as the basis for additional historical coding systems. 'Official' ECAI-GIS coding systems for countries and historical periods will go a long way to eliminate problems that would otherwise arise from variant spellings and orthographies, alternative names, and different languages.

3. Producing, distributing, and maintaining a base map framework, for Eurasia at least. In this proposal for ECAI-GIS, this would be based on the DCW PONET (Political and Ocean) data, with corrections and modifications as required (for Macao, for instance). Selected topographical and hydrological features (perhaps simplified greatly, as for mountain ranges) would be provided as separate MI files as part of the base map and for use in producing maps for publication. A DCW tile grid would be included as a key to the additional full data coverages that are available to be called up in the background.

4. Establish and support standard projection parameters. The DCW data are supplied in unprojected format (decimal degrees, latitude/longitude, or geographical coordinates are some near synonyms, although there are some technical issues that make them incompatible in some contexts). However, some standard ECAI-GIS projections need to be centrally defined, and their parameters distributed with the base map materials so that everyone using the system has access to the same ones. MapInfo in particular makes this very straightforward, and will even automatically project additional or background map data to match the projection of the first map on the screen. However, there are some basic decisions about whether ECAI-GIS will normally use or at least support equal area projections, equal distant projections, conformal projections, or all of the above.

5. Supporting the incorporation of additional spatial features in ways compatible with the overall ECAI-GIS database design. Objects that ECAI-GIS data bases need to include from the outset are best created by its technical facilities. However, many participants will want to add their own spatial objects as well as specialized attribute data. In most 'desktop' GIS environments the addition of point features very easy, and individual participants should have no difficulty in mastering this although they should do it in the standard ways, particularly with respect to their coding. Line objects are somewhat more complex, particularly if they need to precisely join other features. Adding, deleting, or modifying polygon features are another matter entirely in most GIS programs, and in fact this should normally be done initially using a CAD (Computer Aided Drafting, or Design, software program such as MicroStation or AutoCAD) rather than in the GIS itself, although there are add-on utilities that, for instance, make such operations far easier than with MapInfo as it comes out of the box. The technicalities involved go way beyond basic issues of original map scales and projections to arcane technical problems such as sliver polygons, as gaps or overlaps between adjacent polygons are called, to such things as 'bleeding' polygons and dangling nodes. Alignment and rubber sheeting of additional data so that it fits seamlessly with existing features is not a simple task, either. The integration of additional complex spatial objects from paper maps into the ECAI-GIS data bases should usually be left to its technical facilities, which can advise participants on how to prepare such materials in order to facilitate the work (ideally they should be drawn

by participants on paper versions of the base map materials).

6. The technical support facilities would also be able to provide ECAI-GIS participants with raster files, such as satellite images and extracts from things like the large EDC datasets that would fit the projections and local areas of the base maps that they are working on.

7. Participants would be supported in making their data available in standard ECAI-GIS formats on CD-ROMs and over the Internet.

8. A final, but by no means trivial function of the ECAI GIS expert facilities would be to develop or support a common interface for accessing the ECAI databases, particularly on the WWW. TimeMap (the University of Sydney development mentioned above) would seem to provide an excellent existing solution to this need.

Equipment and training required by ECAI-GIS participants

Unlike the central technical support facilities, the equipment needs of ordinary ECAI-GIS participants are so modest that nowadays most academics would already have what is required. A pentium PC with lots of RAM and a large hard disk is now the standard entry-level machine, but even an old 386 (remember them?) or 486 can usually be upgraded with a new 586 or better motherboard, 32 Mb of RAM, and a 1 Gb Hard Disk for less than $1,000. Macs are not so readily upgradable, but powerful Mac clones are now available too. A high quality 15" or especially 17" screen is nice to display spatial data on, but is not absolutely essential, while color bubblejet or inkjet printers are now cheap. The only other item of equipment that someone needing to input their own point or line objects would probably require (although it can be done entirely on screen relative to base map features) would be a small (12" by 18") digitising tablet, which costs under US$400. A scanner with OCR software might or might not be helpful in capturing attribute data, but would be useless for generating new vector data without specialised technical support.

Training in using MapInfo or ArcView is readily available from their suppliers on frequent schedules at a cost that can be as high as $500 per day but is usually less expensive. Short courses can also be found at some universities at very low or no cost. Five days of quality training is both desirable and sufficient for most ECAI contributors, whereas those accessing the databases may need no specialised training whatever, depending on the sophisication of the ECAI interface.

Outputting, distributing, and accessing ECAI-GIS data

Participants in ECAI-GIS who have had minimal software training will have no difficulty in preparing whatever maps the databases, including their own individual data, will support. Such maps can be output either as paper versions through standard printers or in the form of raster files. This is probably the major role for raster images in ECAI-GIS, as such bit-mapped images can be transferred to practically any graphics or desktop publishing program for further manipulation for publication, or transformed into HTML 'clickable' on-screen maps using any number of proprietary programs that have become available in recent years and even months.

Public distribution of ECAI data on CD-ROMs and over the Internet could (and perhaps should) be limited to such derivative raster images, which need no specialised GIS software to display or explore through clickable features and regions, as only standard Netscape or Explorer are required. There are severe limitations to the use of clickable maps to access complex data sets, but that does not mean that the underlying vectors need to be made freely available. In other words, access to the ECAI-GIS databases themselves could be limited to bone fide academic participants, while all the features of HTML and Java aplets could be utilised in the public distribution of prepared raster 'views' of the underlying, and restricted, data themselves.

Software that will allow remote interactive searches of GIS spatial and attribute data to produce on-line output are becoming available, but the programs are and probably will remain rather expensive. The ECAI-GIS technical support facilities could acquire and operate such software, allowing public access to the GIS databases themselves, but careful consideration would need to be given to the desirability as well as the expense of doing that. TimeMap may provide some other solutions to this issue.

Conclusion

If ECAI is to realise its potential to integrate information relevant to the spatial distributions of cultural activities, artefacts, and sites, it needs to be GIS based. It also needs to establish standards for creating and accessing the databases that will become recognised components of the 'Initiative'. Existing expertise and spatial data and software programs developed at places such as the Australian Centre of the Asian Spatial Information and Analysis Network, Griffith University, and the GIS Laboratory, Department of Archaeology, University of Sydney, could be taken advantage of in order to catapult ECAI to the forefront of the international state of the art in GIS base map development and in software for accessing GIS data interactively over the Internet.

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