MAP TEMPLATES FOR RAPID MAPPING

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Abstract

As military mapping organizations move from hardcopy map production to digital spatial data production, there is an increasing demand for end users to rapidly convert their Digital Terrain Data (DTD) to a variety of custom softcopy and hardcopy products. This paper examines the rapid mapping problem in the context of a research effort at the U. S. Topographic Engineering Center, Alexandria, VA. The "Digital Chart of the World (DCW) Rapid Mapping Utility" prototype GIS application demonstrates an end-to-end capability to efficiently process DCW data in crisis situations. Data is loaded from CD-ROM, assembled into topologically consistent layers, and processed for the production of customized maps. Using an intelligent template, a single analyst can produce softcopy or hardcopy maps of areas anywhere worldwide at scales of 1:250,000 to 1:2,000,000 in less than an hour.

INTRODUCTION

Rapid Mapping Problem

Military mapping organizations are striving to produce digital spatial data in a timely fashion to meet the needs of crisis management, disaster relief, and emergency response. Typically, the goal is to rapidly generate data over the smallest useful critical area with a minimum amount of information initially, and then expand on the content and coverage over time. In situations where no previously collected data is available, imagery is often the data source for new information generation. A typical sequence of products in this situation would include uncontrolled imagery, controlled imagery, elevation data, orthophotos, and attributed vector information. Small amounts of vector information can be created after the imagery is controlled, but detailed vector data sets are very time consuming to create. Assuming that imagery is available, the production process can take from hours to days and involves participation from different groups within an organization.

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Rapid Mapping Constraints and Tradeoffs

Time   A critical constraint imposed in the rapid mapping operational environment is time. All functions are controlled by timelines established to meet mission requirements. Rapid map production is performed within the management framework of stepping efficiently through the pipeline with a minimal amount of uncertainty. This risk-adverse approach, contingent upon following pre-determined procedures ($f\{t\}$ = productivity), directly impacts the organization's standard production life-cycle. In this scenario, risk is defined as the level of effort focused towards implementing additional tasks or alternative methods. Quality assurance and value-adding activities become the most significant tradeoffs. The most detailed, accurate map product is of no value to the customer if not received in a timely manner.

Data Availability   Fortunately, spatial data users today usually have existing smaller scale data available, in the form of scanned map products, like ARC Digitized Raster Graphics (ADRG) from the National Imagery and Mapping Agency (NIMA) or Digitized Raster Graphics (DRG) from the U.S. Geological Survey. These products provide digital images of existing map products, capitalize on previous hardcopy map production, and meet the map data display requirements of many users. Worldwide coverage of scanned map data is currently available at the 1:1.000,000 scale. Despite these advantages, scanned maps lack the flexibility of attributed, vector data bases. Vector data bases allow users to control the map display based on the characteristics of the features being mapped. For users interested in using general purpose, thematic, vector data to respond to a crisis worldwide, the largest scale product with complete coverage is the 1:1,000,000-scale Digital Chart of the World data base.

Mission Requirements   Military organizations that are developing a rapid mapping capability must deal with a number of constraints and tradeoffs. The system design is controlled by the mission requirements, which define the time frame for map production, the sequence of map products, and the skill level of the personnel operating the system. The rapid mapping software design must trade off the flexibility and complexity of the system in order to create as simple and effective a system as possible. The remainder of this paper will focus on developing and evaluating a mapping system designed to produce hardcopy maps from the Environmental Systems Research Institute (ESRI)'s Digital Chart of the World on CD-ROM data. The primary goal of the prototype application was to allow a terrain analyst, with or without GIS training, to generate maps centered on a user-specified location at scales of 1:250,000 to 1:1,000,000 anywhere in the world in under an hour. This time would include loading the data from CD-ROM, merging and assembling the data, creating a plot file, and generating the final hardcopy plot. The key to meeting this goal was the development of a map template.

FUNCTIONAL DESIGN MODEL

Process Decomposition

Initial development of the intelligent map template concept was dependent upon designing the prototype application within the context of a rapid mapping mission. A structured model of the end-to-end rapid mapping production process and data flow was needed to identify the functional requirements prior to operational implementation. Similar DTD processing tasks were consolidated into an individual function, which in turn was translated into a separate programming module when incorporated into the rapid mapping prototype application software.

Rapid Mapping Application IDEF0 Model

The functional activities, ICOMs (Inputs, Controls, Outputs, Mechanisms), key interface links, and process decomposition required to construct the conceptual functional design model were integrated using IDEF0 diagram format conventions (*Appendix A*). A function is an activity delineated by a box. An input enters from the left, and represents what is transformed into an output, which exits from the right of the activity. The controls entering from the top constrain what transformations occur within the function. The mechanisms entering from below describe how the function is accomplished. The key interfaces define the interconnections between the functions.

THE MAP TEMPLATE CONCEPT

Map Template Considerations

Constraining the Problem   There are a number of alternatives for rapid map generation, ranging from interactive map construction to using automated map templates. A map template was selected for this research effort, because it speeds map production by pre-defining the locations of map elements, minimizes the amount of data entry needed to create a map, and automatically adjusts the characteristics of map elements to create a visually pleasing product. Ideally, a map template would accommodate map areas from a few square meters to worldwide on any page size, in an appropriate projection for the area mapped and intended map purpose, using the optimum amount of space on the page for the size and shape of the area being mapped. While such a system is a reasonable goal for cartographic research, the authors are not aware of any such system in existence today. Therefore, tradeoffs relating to the page size, use of fixed versus relatively positioned elements, ground area covered, and projection parameters must be made.

Tradeoffs were made early on for the rapid mapping application discussed here. Since the maps were intended for briefings to small groups or for use as wall maps, a fixed page size of 35 by 28 inches was adopted. This could easily be accommodated on the Hewlett-Packard DesignJet plotters that are generally available at TEC. Since the source data, the Digital Chart of the World, was collected from Operational Navigation Charts (ONCs) at a scale of 1:1,000,000, output scales of 1:250,000 to 1:2,000,000 were supported. For the scales of mapping required and general emphasis on mid-latitude areas, a Lambert Conic Conformal projection was selected. The standard parallels for the Lambert Conic Conformal projection are calculated on the fly for the specific area being mapped. The software was developed modularly to accommodate improvements and upgrades to the supported projections and scale selections for future enhancements.

Fixed Map Display in Projected Units   Perhaps most importantly, the area of coverage was rectangular and fixed in size in projected map units for all supported map scales. This differs from most traditional map series, which are generally defined by fixed sizes in geographic units, such as U.S. Geological Survey 7.5 minute quadrangles or National Imagery and Mapping Agency (NIMA) Joint Operation Graphics (JOGs), which are 2 degrees by 1 degree. The more common use of geographic rather than projected space results in the mapped area covering different sized areas on the output page depending on the projection and location of the mapped area. The use of projected space gives the user a fixed window in terms of ground coverage and simplifies the intelligent template design.

A technique to accurately fit the projected map area into the view display area was developed to automate the fixed map display capability of the intelligent template. The main routine calculates the map extent required to fit the user selected view into the fixed map display window on the template as a function of scale, latitude, longitude and hardcopy page size. The Arc Macro Language (AML) program uses WGS-84 ellipsoid parameters to determine the length of a radian of latitude and longitude based on a user selected Decimal Degree (DD) center point location, then converts these lengths into relative ground distances dependent upon scale and fixed map display size (*Appendix B*). This procedure is repeated uniquely for each view selection made by the user and saved to a file so other data can be projected and overlaid with the map.

Maintaining Flexibility   Furthermore, despite fixing a good portion of the design, some flexibility remains. The map designer can select the map scale from a list of pre-defined choices, center the map anywhere worldwide, select the thematic layers to display from a pre-defined list, select desired features to display from the thematic layers, and choose whether or not to display a geographic graticule.

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Evaluating Map Template Design

Map Template Overview   The map template can be evaluated in terms of its support for rapid mapping.   First, a framework for evaluation will be discussed, followed by a detailed assessment of a specific rapid mapping research system.   The goal in rapid mapping is to minimize the amount of human interaction required to make a map. The final map can be broken down into individual map elements, such as the thematic layers, title, legend, bar scale, overview map, etc.   Each map element can then be defined in terms of the level of automation in its definition, symbolization, and placement. This type of assessment provides useful information to the map template designer for evaluating the success of the design.

Map Elements   Map elements are the individual graphic and textual objects that are placed on the map.   There are two classes of map elements on a map: map display elements and marginalia elements.   Map display elements focus on the map graphic portion of the display and include the thematic layers, graticule, and any symbology or text overlaid on the map.   Marginalia includes all graphic and textual data outside the map display, such as the title, legend, bar scale, etc.

Element Definition   The first place that automation can be assessed is in the element specification, which is the content of the map element. Here, there are two major classes of specification, automatic or user-specified. Automatically specified elements are defined without any user interaction. An example of this might be a date/time stamp on a map, which automatically appears on all maps. User-specified, interactive, elements include the thematic layers and text, as well as grids and graticules.

Element Symbolization   The next step in evaluating automation is the symbolization of the specific map element (i.e., the method of specifying the symbolization). There are three methods that can be used to specify the symbolization of an element: dynamic, pre-defined, or interactive.   An individual element may be built of components that use multiple methods, so they are evaluated in terms of the least automated of the methods. Dynamic elements are symbolized automatically on the fly, depending on the input provided by the user or stored internally within the system.   Pre-defined elements are symbolized in advance and an appropriate choice is made at the time the map is made. Interactive elements have their symbols defined by the user at the time of map construction.   For interactive text, the user may be required to specify the size, font, or color of the type.

Element Placement   The element placement determines how the map element is placed on the output page. Elements that are automatically placed do not require any user input, while interactively placed elements are placed using a mouse, digitizer, or coordinate entry.

MAP TEMPLATE IMPLEMENTATION

DCW Rapid Mapping Utility

The rapid mapping template concept will be evaluated in the context of the DCW Rapid Mapping Utility mapping application template (*Figure 1*). Each map element of the template will be reviewed in terms of its definition, symbolization, and placement.
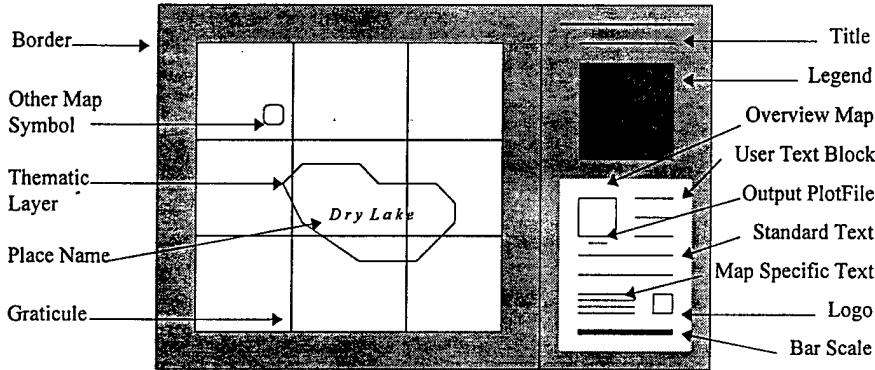

Figure 1. DCW Rapid Mapping Utility Template

Map Elements

Map Display   The map display elements are the graphic and textual elements falling within the map's neatline. These include the thematic layers, the graticule, place names, and other map symbols. The thematic layers are pre-defined from the large list of possible features in the DCW product and grouped into fourteen layers. The layers are selected from a check box list and symbolized according to the combination of layers selected. For example, selecting the hypsometric layer check box using the default display settings will generate color-coded elevation polygons at intervals of 1000 feet. The geographic coordinate graticule is also selected from a check box, which simply states whether or not the graticule is to be displayed. The spacing of the graticule lines is calculated by the template to display logical intervals.

Place names may be interactively specified or entered with computer assistance. The computer assisted method uses the DCW gazetteer information to provide the locations and names of the various major features. By selecting a point associated with a name, the name is selected and can be interactively placed. The map designer can select the font, color, and size for the text. Other map symbols that can be placed interactively on the map include military unit symbols, where the type of unit and level of command can be customized.

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Marginalia   The marginalia elements include the graphic and textual elements falling outside the mapped area. All the marginalia graphic elements are automatically placed. These include the legend, overview map, bar scale, logo, and border. The legend is dynamically created based on the selected features. It can contain one or two columns of features, with up to 44 features, and adjusts the size of the symbols and text based on the number of features selected. The overview map is automatically generated based on the extents of the loaded DCW data and the area covered by the map display. The bar scale is selected from a set of four pre-defined bar scales for the 1:250,000 to 1:2,000,000 standardized map scales. The TEC logo is pre-defined and placed without any user interaction, as is the border.

Textual elements include the title, user text block, standard text block, map specific text block, and output plot file name. Textual elements are either entered interactively or automatically determined. The fonts and text sizes for all the marginal text is pre-defined. The title and user text block are entered interactively. The standard text block is identical for all maps produced using the template and includes information on the source data. The map-specific text block is dynamically created and includes information on the software used to create the map, projection, datum, as well as the date and time of map creation for archiving purposes. The output plot file name is automatically included as well, providing the link between the hardcopy product and softcopy file.

Assessment of Level of Automation

Since the key goal of the map template is to reduce the amount of time needed to define, symbolize, and place map elements, it is useful to review the template in terms of these functions (*Table 1*).

Element Type	Element Subtype	Map Element	Element Definition	Element Symbolization	Element Placement
Map Display	Graphic	Thematic Layers	Interactive	Pre-Defined	Automatic
Map Display	Graphic	Graticule	Interactive	Pre-Defined	Automatic
Map Display	Textual	Place Names	Interactive	Interactive	Interactive
Map Display	Graphic	Other Map Symbols	Interactive	Interactive	Interactive
Marginalia	Graphic	Overview Map	Automatic	Pre-Defined	Automatic
Marginalia	Graphic	Legend	Interactive	Dynamic	Automatic
Marginalia	Graphic	Bar Scale	Interactive	Pre-Defined	Automatic
Marginalia	Graphic	Logo	Automatic	Pre-Defined	Automatic
Marginalia	Graphic	Border	Automatic	Pre-Defined	Automatic
Marginalia	Textual	Title	Interactive	Pre-Defined	Automatic
Marginalia	Textual	Standard Text Block	Automatic	Pre-Defined	Automatic
Marginalia	Textual	Map Specific Text	Automatic	Pre-Defined	Automatic
Marginalia	Textual	User Text Block	Interactive	Pre-Defined	Automatic
Marginalia	Textual	Output Plotfile name	Automatic	Pre-Defined	Automatic

Table 1. Map Element Evaluation
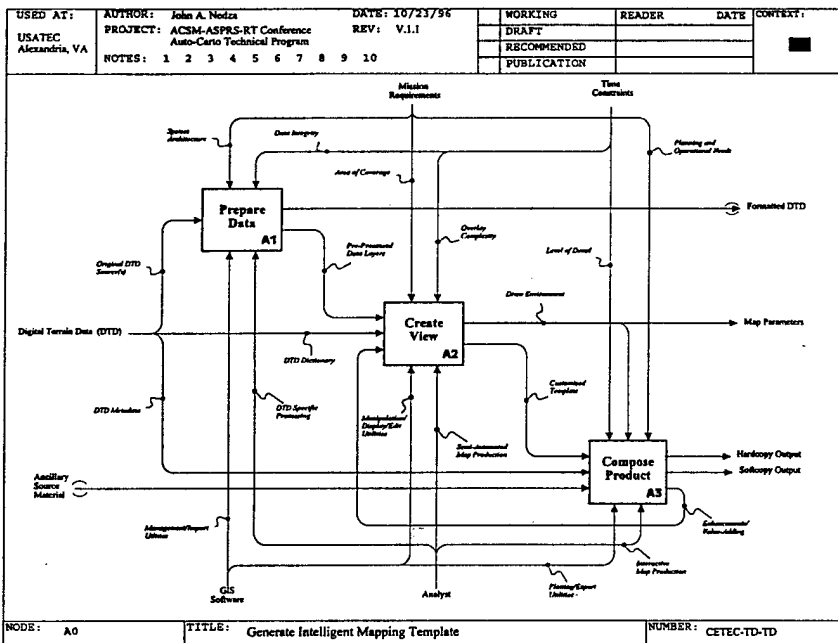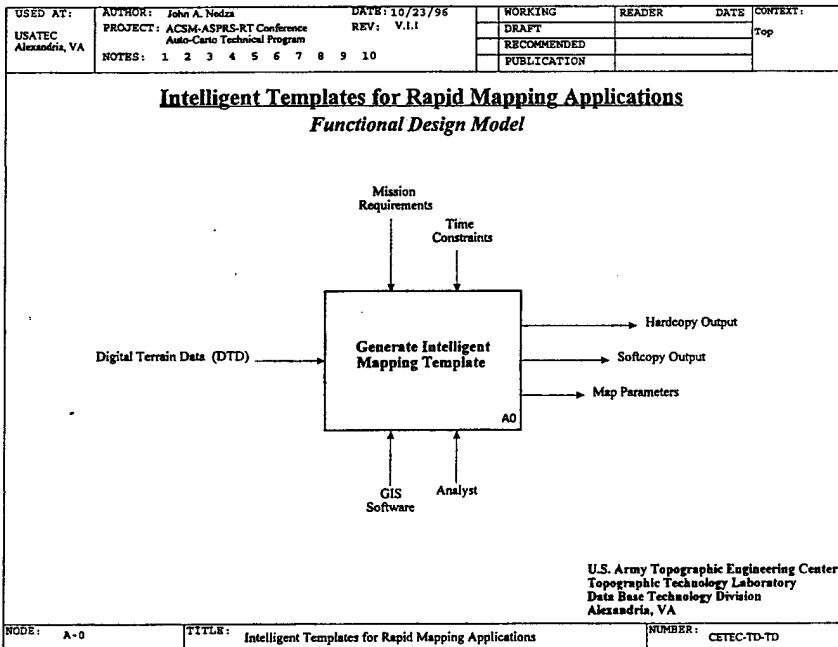
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Extending the Rapid Mapping Application

The rapid mapping application, which is written in AML for use with ARC/INFO, was designed with reuse of the map graphics and extensibility of the basic application in mind. Plot files are generated from map compositions, which are ARC/INFO display definition descriptions. These can be reused without having to recreate the display element by element. The application supports output to GRA, EPS, CGM, or RTL formats. This allows for reuse of the map compositions or GRA files within ARC/INFO. EPS and CGM files can be used by other graphic drawing and editing programs. The RTL files are typically used for plotting to the HP DesignJet plotters.

The research map template uses a modular coding style to provide flexibility if the map designer wishes to gain additional control over the application. All map elements can be modified in terms of their creation and placement. The map designer can use a custom set of features from the DCW and symbolize them in a unique way by simply modifying a few sections of code in the AML's. In addition, entire new data sets can be incorporated in the design. This was done recently to produce a shaded relief map of the North Korean-South Korean Border area, where the background is a shaded relief image generated from Digital Terrain Elevation Data (DTED) Level I, and feature data from the Digital Chart of the World (DCW) (*Appendix C*).

SUMMARY

The DCW Rapid Mapping Utility prototype application research effort has provided several notable contributions to improving the overall rapid mapping mission. Most importantly was the implementation of a working model from which to evaluate an end-to-end map production process. Testing and evaluation of the application provided significant feedback for identifying potential operational time sinks, functional design tradeoffs and refining specific-user requirements. Proof of concept for the map template design and integration into the rapid mapping process was also successfully achieved. These unique methods, developed to efficiently create and place key map elements, both automatically and interactively, significantly improved this particular rapid mapping production process not only in relation to time, but overall quality in terms of accuracy and presentation. Although this research effort was focused on implementation of the DCW data source, a fundamental GIS approach and production process framework was established for similar rapid mapping activities.

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APPENDIX A.

Intelligent Templates for Rapid Mapping Applications
Functional Design Model

Mission Requirements

Time Constraints

Digital Terrain Data (DTD) →

Generate Intelligent Mapping Template   A0

→ Hardcopy Output

→ Softcopy Output

→ Map Parameters

GIS Software   Analyst

U.S. Army Topographic Engineering Center
Topographic Technology Laboratory
Data Base Technology Division
Alexandria, VA

NODE: A-0   TITLE: Intelligent Templates for Rapid Mapping Applications   NUMBER: CETEC-TD-TD

Mission Requirements   Time Constraints

System Architecture   Data Integrity   Planning and Operational Needs

Area of Coverage

Prepare Data   A1 → Formatted DTD

Original DTD Source(s)

Pre-Formatted Data Layers   Overlay Complexity   Level of Detail

Digital Terrain Data (DTD) →

Draw Environment

Create View   A2 → Map Parameters

DTD Dictionary

DTD Metadata   DTD Specific Processing   Administrational Display/Edit Utilities   Customized Template

Semi-Automated Map Production

Ancillary Source Material

Compose Product   A3 → Hardcopy Output / Softcopy Output

Management/Import Utilities   Enhancement/Value-Adding

Interactive Map Production

GIS Software   Analyst   Planning/Export Utilities

NODE: A0   TITLE: Generate Intelligent Mapping Template   NUMBER: CETEC-TD-TD

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APPENDIX B.

```
/*<geo_mapsize.aml> ARCPLOT program calculates mapextent for hardcopy
/*map size based on scale and input DD view center point value in WGS-84.
/*GLOBAL Variable:  .calculated$view_mape
/*Original Coding:  John A. Nedza  2/96
&args map_scale dd_center_lon dd_center_lat map_width map_height
/*Calculate WGS-84 Ellipsoid Parameters.
&setvar phi_dd := %dd_center_lat%                    /*DD
&sv phi_rad := [angrad %phi_dd%]                     /*RAD
/* L{phi} = a(1 - e**) / (1 - e** sin** phi) ^ 3/2   /*Length Equations
/* L{lambda} = a cos phi / (1 - e** sin** phi) ^ 1/2
&sv a := 6378137                             /*Semi_major Axis
&sv e := 0.0818191908426                     /*Eccentricity
&sv esq := [calc %e% * %e%]                  /*Calculations
&sv eq1 := [calc %a% * [calc 1 - %esq% ] ]
&sv eq2 := [calc 1 - [calc %esq% *[calc [sin %phi_rad%] * [sin %phi_rad%]]]]
&sv eq3 := [calc %a% * [cos %phi_rad%] ]
&sv eq4 := [calc [sqrt %eq2%] * [sqrt %eq2%] * [sqrt %eq2%] ]   /* ^ 3/2
&sv eq5 := [sqrt %eq2%]   /* ^ 1/2
&sv lat_1_rad := [calc %eq1% / %eq4%]             /*1 RADIAN Lat
&sv lon_1_rad := [calc %eq3% / %eq5%]             /*1 RADIAN Lon
&sv convert_deg := [calc 3.1415926 / 180]         /*1 RAD to 1 DEG
&sv lat_1_deg := [calc %convert_deg% * %lat_1_rad%]    /*RAD to DD
&sv lon_1_deg := [calc %convert_deg% * %lon_1_rad%]
/*Calculate Relative Ground Distances.
&setvar plot_ground_dist$x := [calc %map_width% * %map_scale%]   /*Inches
&setvar plot_ground_dist$y := [calc %map_height% * %map_scale%]
&setvar plot_ground_dist$x := [calc %plot_ground_dist$x% / 39.370078]   /*M
&setvar plot_ground_dist$y := [calc %plot_ground_dist$y% / 39.370078]
&setvar dd_map_width := [calc %plot_ground_dist$x% / %lon_1_deg%]   /*DD
&setvar dd_map_height := [calc %plot_ground_dist$y% / %lat_1_deg%]
/*Calculate MapExtent to Fit Hardcopy Plotsize.
&setvar dd_width_offset := [calc %dd_map_width% / 2]
&setvar dd_height_offset := [calc %dd_map_height% / 2]
&setvar mape_dist$xmin := [calc %dd_center_lon% - %dd_width_offset%]
&setvar mape_dist$ymin := [calc %dd_center_lat% - %dd_height_offset%]
&setvar mape_dist$xmax := [calc %dd_center_lon% + %dd_width_offset%]
&setvar mape_dist$ymax := [calc %dd_center_lat% + %dd_height_offset%]
&format 6
&sv .calculated$view_mape := [unquote [format '%1% %2% %3% %4%'~
        %mape_dist$xmin% %mape_dist$ymin%~
        %mape_dist$xmax% %mape_dist$ymax%]]
&return  /*EOF
```

APPENDIX C.

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