GeoCoastPilot: A better way of organizing and displaying information in support of port familiarization

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Abstract - GeoCoastPilot **is a research software application built to explore techniques for simplifying access to the navigation information a mariner needs prior to entering or leaving a port. GeoCoastPilot is intended to demonstrate what is possible with current technology and to facilitate technology transfer. We started with the question, "What might a digital application based on the NOAA Coast Pilot look like if other marine data sources were combined with it?" Along these lines, GeoCoastPilot introduces two new capabilities to existing marine information products: multiramas and microlinks. These capabilities are intended to help the user develop a more complete and integrated mental model of a port before encountering it for the first time. Operational benefits of GeoCoastPilot include:**

- **decreased time in searching for relevant information;**
- **fewer errors in interpreting the information; and**
- **increased awareness of important navigation aids, hazards, and regulations.**

In order for commercial software applications to more easily adopt multiramas and microlinking, we advocate two paradigms for data collection and management. First, pertinent marine information sources should be tagged with consistent feature-level metadata. Second, simple mappings of object and attribute names between different information sources should be published and maintained without necessarily being tied to the requirements of any one information source.

I. Introduction

GeoCoastPilot is a research software application built to explore techniques for simplifying access to the navigation information a mariner needs prior to entering or leaving a port. GeoCoastPilot is not intended to be used directly for navigation purposes, but instead is intended to demonstrate what is possible with current technology, and to facilitate technology transfer. It is intended primarily for operators of smaller vessels, and not those vessels that must comply with the Safety of Life at Sea (SOLAS) Convention [4], [5].

When worked first stated on GeoCoastPilot, the basic question was "What might a digital application based on the NOAA Coast Pilot look like if other marine data sources were combined with it?" In the course of exploring this question, we found ourselves addressing two problems: 1) how the mariner interacts with the information (display), and 2) how information from different data sources is organized to work together (integration).

A. The Information Display Problem

The first problem that GeoCoastPilot addresses is how to display marine information in such a way that the mariner can easily develop an integrated mental picture of a port before entering or departing. With existing sources, it is often necessary to go back and forth between the Coast Pilot and the corresponding charts and light lists. For example, one may read about a lighthouse that marks the entrance to a port, and be interested to see where the safe water is in relation to it (on the chart), as well as find out what visible, audible, and/or radar signals emanate from the lighthouse (from the light list). While it is not hard to look up a particular item of interest, it can be time-consuming to look up many items. Furthermore, it can be difficult to see how all the individual items fit together into a unified sense of the whole approach to the port. For example, none of these information sources identifies which buildings and lighted navigation aids would appear near the lighthouse when approaching from the northwest—nor whether these buildings and aids actually help locate the lighthouse, or instead contribute to confusion.

B. The Data Integration Problem

Overcoming the information display problem requires the integration of information from several sources that are not designed to work together—a problem of data integration. This problem consists of two major facets: 1) insufficient metadata, and 2) incompatible metadata. Both can hamper the creation of integrated display tools such as GeoCoastPilot. Along the lines of insufficient metadata, the Coast Pilot currently lacks any metadata beyond presentation markup (such as indicating text should be bold or blue). The Coast Pilot may mention a landmark that appears in an electronic navigational chart (ENC), but without metadata in the Coast Pilot, there is no clue present for computer applications to indicate that this is a reference to a particular landmark. ENC's do a good job of integrating chart and light-list information with metadata indicating function, but the metadata lacks the kind of information that would make it compatible with other data sources. For example, while the

ENC is likely to include a landmark referenced by the Coast Pilot, in many cases the landmark is unnamed or has a different name from that used by the Coast Pilot. Currently, any potential vendor of a tool like GeoCoastPilot has the difficult task of making sense of all the data. Further, this process must be repeated every time a data source is updated.

II. Information Display

Our approach to addressing the information display problem is to have GeoCoastPilot present the mariner with windows on each of several data sources that work in a coordinated fashion. These windows are illustrated in Fig. 1 and include a simplified 3D representation of the port (top), NOAA Coast Pilot text (bottom-left), and light-list information from the ENC (bottom-right).

GeoCoastPilot introduces two new major capabilities to existing marine information products: multiramas and microlinks.

A. *Multiramas*

GeoCoastPilot introduces a new display technique called a *multirama*. A multirama is a collection of photographs of a landmark or navigation aid taken from multiple vantage points. The intended purpose of a multirama is to be situated inside a simplified 3D representation of a port and display only one of the photos at a time. As a mariner explores the virtual port, the image that best represents the feature from the current virtual perspective is shown (see Fig. 2).

While there is an option to have mulitramic images display at actual size, the default is to exaggerate their size according to relevance to navigation. The effect is similar to focusing a set of binoculars on each important feature—with the largest views showing the most important features. This visualization technique helps the mariner become familiar with the relative location of critical navigation-related features within a port without the "clutter" of other less important background visual features.

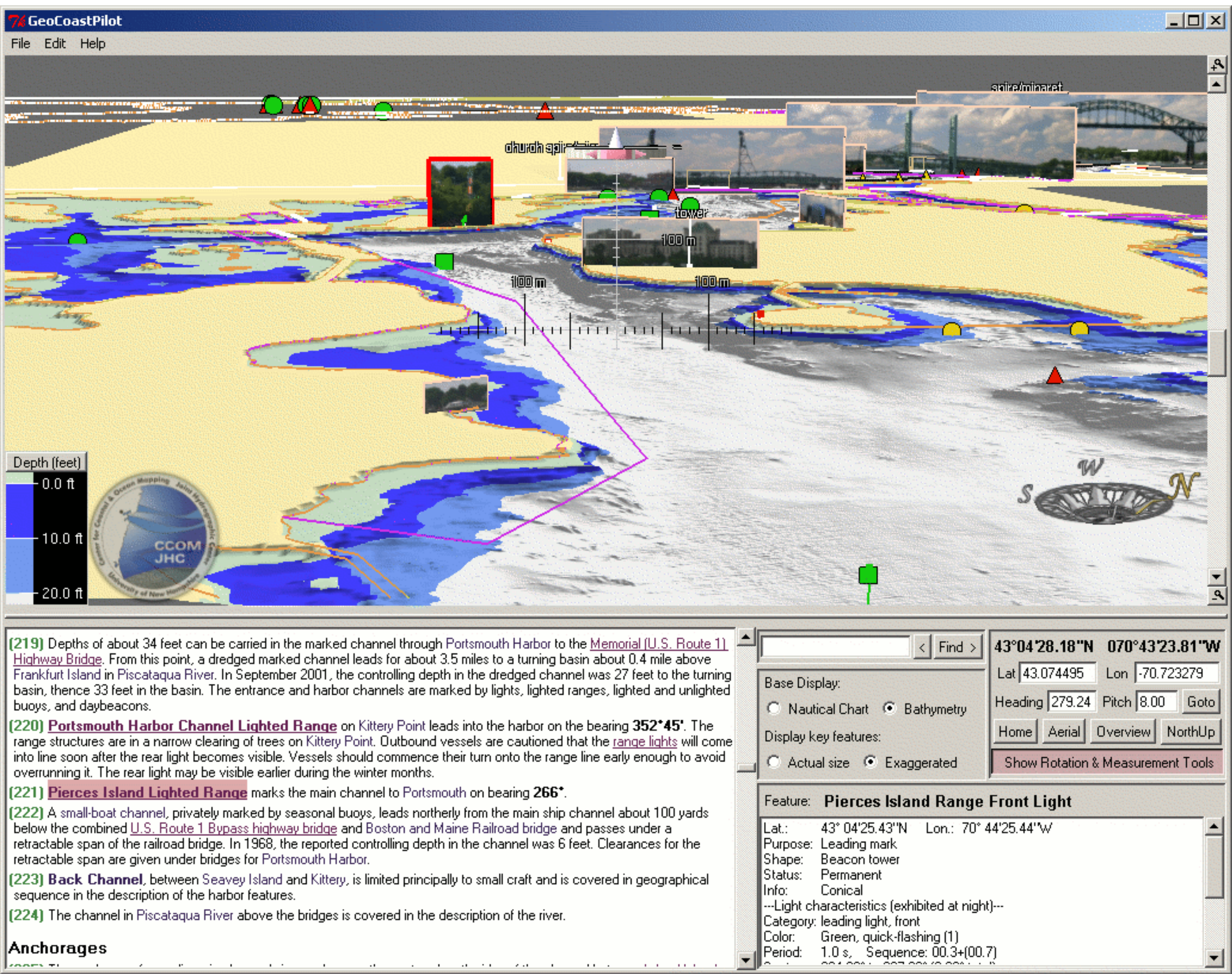

Figure 1. A sample screenshot of GeoCoastPilot. The 3D scene (top) includes photos in the form of multiramas, ENC information, bathymetry colored by depth area, a 3D compass, and can also display a chart. Text from the Coast Pilot (bottom-left, from [15]) and light-list information from the ENC's (bottom-right) are linked to the 3D scene so that selection of an item in one causes the same item to be highlighted in the others.

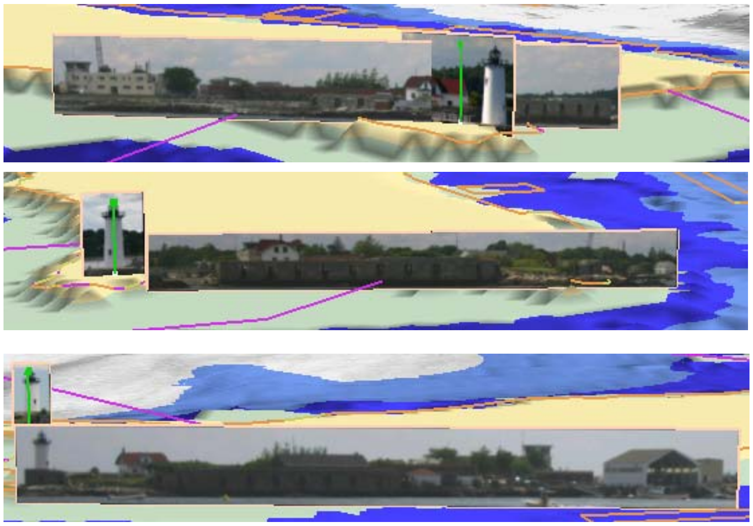

Figure 2. Multiramas of Fort Constitution and Portsmouth Light, as viewed from roughly the northeast (top), north (middle) and west (bottom)

Multiramas evolved from visualization techniques described in the computer science literature [2], [3], [6], and [13]. Other related work includes Porathe's 3-D landmark representations [11] and Millan's use of annotated video [8], [9], and [10]. Multiramas avoid the distortion issues associated with image curtains, panospheric images [17], and cylindrical projections (e.g., Google Earth in Moon and Mars modes).

B. *Microlinks*

A second capability of GeoCoastPilot is micro-scale hyperlinks between the NOAA Coast Pilot publication text, S-57 electronic navigational charts (ENC's), multiramas, and the U.S. Code of Federal Regulations (CFR). These are called *microlinks*, a term described by [7]. When the mariner clicks on a photograph in the 3D scene, it highlights the first place in the Coast Pilot text that the related feature appears. It also brings up the associated ENC information such as lights and signals. Clicking on boldface text in the Coast Pilot area causes the perspective on the 3D scene to smoothly move until it is centered on the associated feature, and also displays any related ENC information. When a CFR microlink is clicked, the full text of the specific federal regulations referenced in the Coast Pilot text is displayed (see Fig. 3). Further, GeoCoastPilot includes hyperlinks to other information resources that can be accessed via the web.

This use of microlinks creates the effect of a feature-oriented view of the port at hand. It is as if the mariner generated a query into a database using a feature of interest as the index, and got back a report composed of the 3D scene, excerpts of the relevant Coast Pilot text, and ENC signal data. The time and attention required of the mariner to perform this query is small, making relationships between items of interest much easier to discern and remember. Furthermore, this approach allows search terms to be accepted, so that a mariner can correlate information received from outside sources with the information available in GeoCoastPilot.

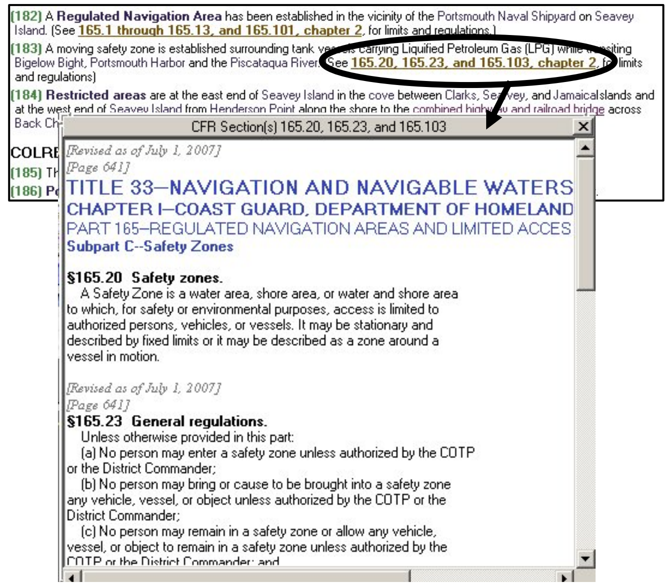

Figure 3. If a user clicks on a reference to regulations in the Coast Pilot text (top portion, [15]), the relevant regulations appear in a popup window.

C. *Additional Capabilities*

GeoCoastPilot also has some additional capabilities.

3D Compass. A 3D compass indicates direction regardless of the direction of view in the 3D scene, as shown in the bottom right corner of the top part of Fig. 1 and in Fig. 4. There are three key characteristics that make it more effective than a flat compass image:

- A concave "bowl" shape in the center of the compass that allows the forward-most directional points to be more easily seen at shallow viewing angles
- Letters at the four major compass points that always remain upright and facing the viewer, regardless of view direction.
- An 11% bias away from being displayed from the side. In other words the compass appears flat when the view is looking straight down, but when viewed from 90° off vertical, the compass only appears to have been rotated 80°.

Bathymetry colored by depth area. We included capabilities of GeoZui4D [1] for displaying high-resolution bathymetry, and coloring it according to depth areas. In GeoCoastPilot, the mariner can set the boundaries of the depth areas based on a paper chart color scheme: safe water (white) safety margin (light blue), and unsafe water (darker blue). This can help a mariner quickly see where the safe water is for his or her own

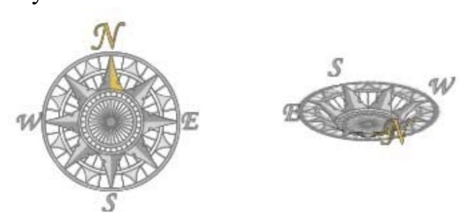

Figure 4. The 3D Compass as it appears when looking on the scene straight down with north up (left), and from an oblique angle facing a southerly direction (right).

vessel in relation to the aids and hazards of interest at the time.

Raster Chart. For the situations in which reference to the paper chart is important, GeoCoastPilot provides a way to quickly switch from 3D bathymetry to a standard raster chart. ENC information and multiramas are still visible over the chart in order for the microlinking capabilities to remain intact.

Automatic CFR updates. The Code of Federal Regulations (CFR) officially updates four times a year. Since the update schedule is consistent and the CFR text is freely available on the web, GeoCoastPilot automatically updates the CFR text so that it displays the most up-to-date regulations when the user clicks on a reference to these regulations.

III. Data Integration

Our desire to create feature-oriented microlinks across data sources for GeoCoastPilot exposed two major facets of a data integration problem: insufficient metadata and incompatible metadata. In order for commercial software applications to more easily incorporate multiramas and microlinking, we believe two paradigms for data collection and management should be observed to address the problem. First, pertinent marine information sources should be thoroughly tagged with consistent feature-level metadata. Second, simple mappings should be published that connect object and attribute names between different information sources.

A. *Thoroughly Tag Data with Consistent Feature-level Metadata*

Ideally, all pertinent data should be tagged with intrinsic metadata (e.g., attributes that describe an entire data set such as date of collection, quality, liability, and reproduction rights). Similar metadata issues were first addressed for the NOAA Coast Pilot by Tucker and Nyberg [14]. However, we believe that additional metadata should be created for all salient objects (e.g., places, features, and regulations) found within a data set. If certain requirements are met on such metadata, it could support the creation of rich extrinsic metadata by third parties. In concept, metadata meeting these requirements can be created and maintained with low effort, and can help identify errors, omissions, and ambiguity in descriptive text.

One important requirement for feature-level metadata is for objects to be tagged with names or identifiers (ID's) that are consistent internally to the data set. Internal consistency means that if an object like a lighthouse or regulation is referenced multiple times in a dataset, then either the same metadata ID is used for every occurrence, or there is an efficient, known way to resolve the metadata ID with that object. For example, this means that "Portsmouth Light" might be used as the ID in metadata tags even when the underlying data itself may refer to the synonymous "Portsmouth Harbor Light" or "Newcastle Light". As another example, a reference to regulation ID "165.11" could be inferred by a reference to a range of ID such as "165.1 through 165.13".

Another key requirement for feature-level metadata is for objects to be tagged with ID's that are consistent temporally across versions of the data. Temporal consistency means that if an object has a particular ID in one version of the data, then every reference to the object in later versions of the data uses the same ID. Also, it is important that the ID is not retired and then re-used for references to other objects. S-57 ENC data is an example of a data set that is internally consistent, but not necessarily temporally consistent. Certain objects are unnamed in the metadata and are given internal reference numbers, but these numbers are not guaranteed to be the same between revisions of S-57 data sets.

B. *Publishing Simple Mappings between Data Sets*

The second paradigm for data integration involves publishing simple mappings of object and attribute ID's between different information sources. Trying to create one overarching standard to regulate names across all data sources would be counterproductive, if not impossible to achieve. Instead, indexes or tables of certain relationships between metadata ID's should be created and maintained to ensure interoperability between data sources.

The most basic relationship between metadata ID's is that of equivalence: the feature with ID *X* in one data set is (roughly) the same as feature *Y* in another data set. A table of equivalences between metadata ID's in different data sets acts as a virtual Rosetta Stone, allowing a computer to recognize which different pieces of data belong to the same object (see Fig. 5). This relationship provides so much interpretive power to a computer that it is the only one we actually implemented for the first versions of the GeoCoastPilot.

Several other relationships between metadata ID's can also be important. For example, it may be worthwhile to know that feature *X* is "near" feature *Y*. Or that feature *X* is "part-of" feature *Y*. Or perhaps attribute *A* "pertains-to" features *X*, *Y*, and *Z*. Or regulation *X* "refers-to" feature *Y*. For most such relationships, it does not matter if *X*, *Y*, and *Z* are in the same data set or in different ones. These relationships are possible to create once enough consistent feature-level metadata has been put in place.

By relying on mappings of ID's between information sources, items that are the same across sources can be identified. In addition, the organizations that maintain the information can do so independently. For example, NOAA and the Coast Guard do not have to confer with each other as to what tags to use to identify a new set of buoys. Instead, they can choose an internally consistent name, and let the third-party publisher know about the new items. In addition, new data sources can be accommodated without impacting the existing information infrastructure. As long as each data source is internally and temporally consistent, and an equivalence mapping between sources can be kept up-to-date, software applications can then more easily integrate the data in ways similar to GeoCoastPilot.

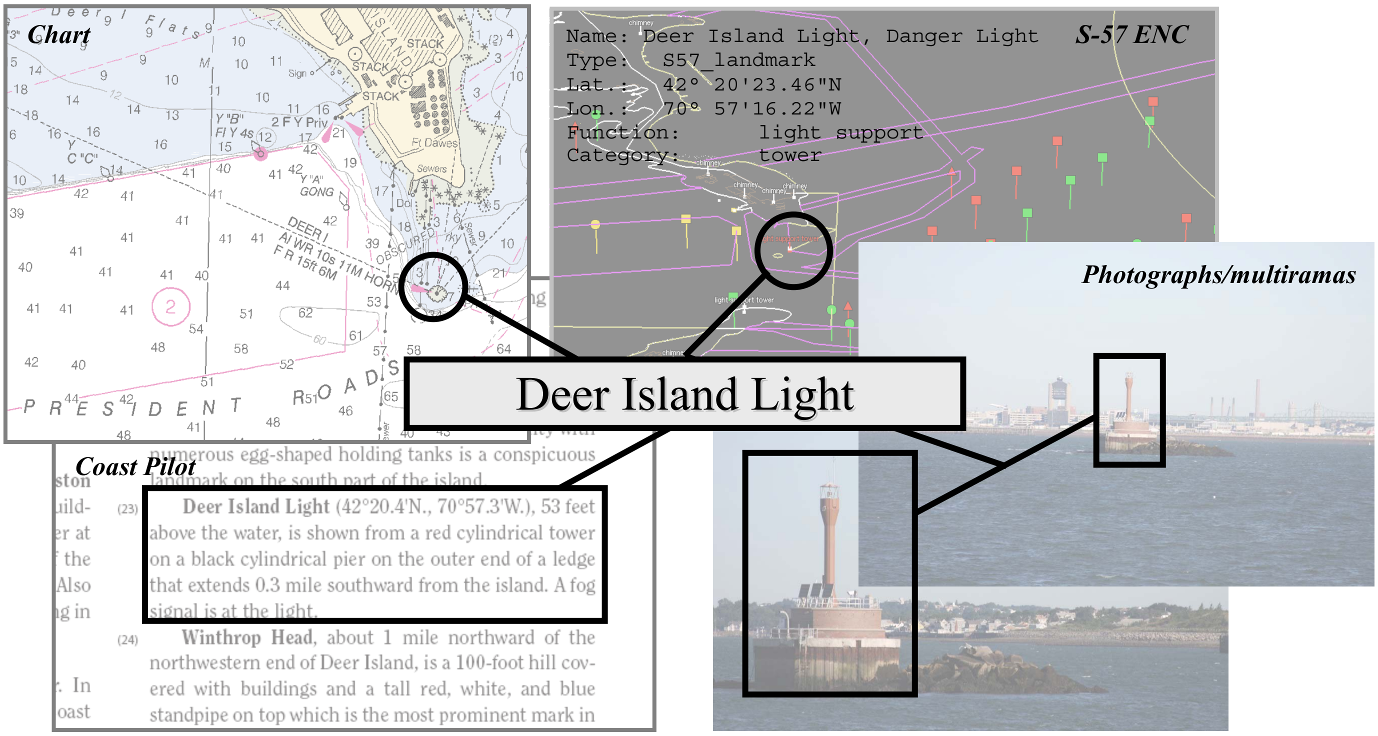

Figure 5. An illustration of how feature-level metadata is mapped between the paper and electronic charts, the Coast Pilot (text shown from [16]), and photographs or multiramas.

C. Tools for Computer-Aided Tagging of Feature-level Metadata

Tools for creating and managing metadata are necessary to keep costs and errors to a minimum. However, existing tools tend to provide help with either intrinsic metadata at the level of an entire data source, or they produce low-level semantic metadata based on natural language processing. In order to add metadata for known features in a geographic context, we found that we had to create our own tools. These tools fall into two main categories: text-tagging and image-tagging.

Text-tagging Tool. We developed a mostly-automated process for adding tags Coast Pilot text, starting with the NOAA Coast Pilot chapters in Rich Text Format (.rtf) and ending with XML. This process takes cues from the consistent formatting aspects of the Coast Pilot. After automatically recognizing and tagging headings and subheadings as formatting-related items, it searches for references to CFR regulations. These references appear as a bolded range of numbers in various formats, followed by a comma and the text "chapter 2" (indicating that the regulation appears in Chapter 2 of the Coast Pilot book). These references are parsed and tagged in a consistent XML format as illustrated in Fig. 6.

After recognizing CFR regulations, most of the remaining bolded terms are features of interest. These terms are automatically identified and inserted into a separate table of candidate features. After the table is created, each term is searched for through the remainder of the document, and each instance is tagged as being a reference to the feature named by the term (see Fig. 6). In addition, the text immediately after the found term is analyzed to see if geographic coordinates are present. If so, the coordinates are incorporated into the table of candidate features. This table can be expanded manually, so that additional features are automatically tagged even though they do not appear in boldface anywhere in the document. The table can also have entries deleted, so that text bolded for another reason is not erroneously marked as a feature. For the few cases where a name is used to mean two different features (e.g., "Fort Point"), the tags are made unique by adding a location to the tag ("Fort_Point:New_Castle"). These tags require manual intervention.

The table generated during this process was used as the basis for an equivalence mapping between the Coast Pilot text and the ENC data and multiramas.

```
…
  <CPText>
    <paragraphnumber>192</paragraphnumber>
    <basetext>The <CPFeatureRef
ref="Charlestown_Bridge">Charlestown Bridge
</CPFeatureRef> crosses the river just below the
…
Dam have a clearance of 5 feet. (See <CFRRef>
<sections start="117.1" end="117.59"/><sections
list="117.591"/><CFRRefText><strong>117.1 through
117.59 and 117.591,</strong></CFRRefText></CFRRef>
chapter 2, for drawbridge regulations.)
    </basetext>
  </CPText>
…
```

Figure 6. Portions of a paragraph converted from Rich Text Format (.rtf) of [16] to XML using our text-tagging tool. The feature tag for Charlestown Bridge appears in bold above, and the tags for the CFR regulation reference appears in bold below.

Image-tagging Tool. We recently developed a research tool called *GeoNavTagger* to facilitate conversion of geo-tagged photographs into feature-oriented multiramas. As shown in Fig. 7, the tool has four main areas corresponding to the four main stages of the processing flow.

First, a feature is either chosen from the ENC view (in the top left area), or a new feature is created at a chosen position. With a feature selected, GeoNavTagger updates the feature view (bottom left) to display any information tagged thus far, and updates the image collection view (top right) with images according to the filters selected. It also places a marker in the chart to show where the feature is in the world.

In the second stage of the processing flow, thumbnails of candidate photos from the collection of images are selected. The thumbnails that are shown can be filtered based on distance from the selected feature, based on the GPS tags embedded in the photo (in JPEG EXIF headers). When a thumbnail is clicked, a larger version of the image is shown in the image view (bottom right), and a blue marker is added to both the ENC and feature views. The blue marker indicates where the photo was taken in the ENC view, and the bearing from which the photo was taken of the feature in the feature view. When the user selects thumbnails to be marked as candidate multirama images, they are displayed with yellow borders, and yellow markers appear in the feature view to indicate the bearing of these from these photos to the feature. Once enough candidate images have been selected, the image collection view can be filtered to show only candidate images.

In the third stage, the next most promising candidate is edited for inclusion in the multirama. Tools are available to crop and rotate the image into position, apply simple contrast and color saturation operations, identify where the ground plane intersects the feature in the image, and resize the image down to a more usable size. The tools provide a way to preview the image while making adjustments, and a way to check distances in the image against known lengths near the feature.

When the image has been satisfactorily processed, a press of the "Commit" button creates a new copy of the edited image in a separate storage area for multiramas (the original image is never modified). In addition, the feature view is updated with a thumbnail of the new image in place of its candidate yellow

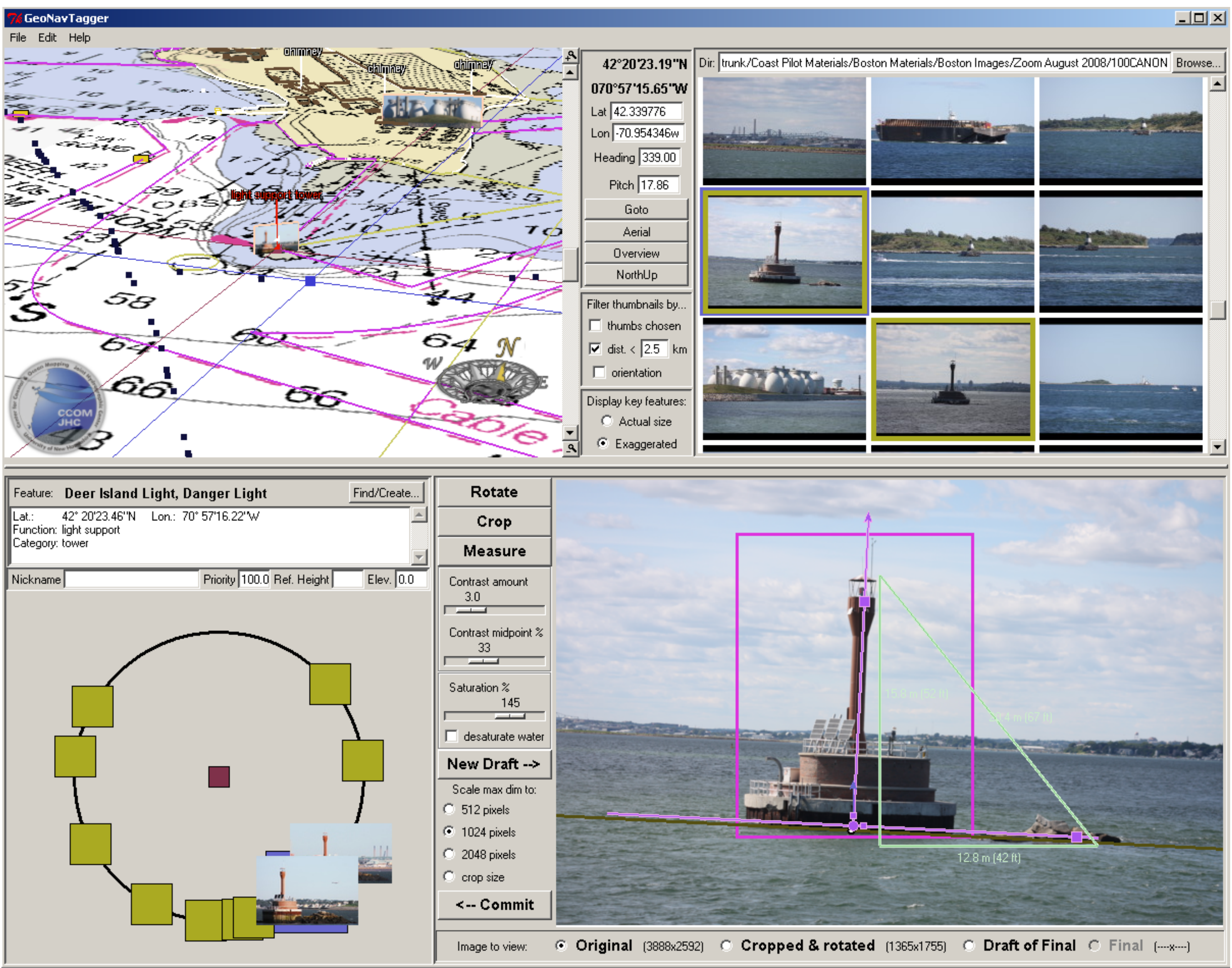

Figure 7.. The GeoNavTagger tool for converting geotagged imagery into feature-oriented multiramas. The tool has four main areas: ENC view (top-left), image collection view (top-right), image editor (bottom-right), and feature view (bottom-left).

box, and the corresponding thumbnail in the photo collection view is updated with a burgundy border. At this point, the ENC view can be updated by requesting the multirama for the current feature to be reloaded.

The effects of edits done in the image view are recorded in XML files, so that an image can be edited and regenerated again with minimal effort if changes are needed. During the "Commit" process several calculations are made based on the existing metadata including image height and direction of view for the multirama image, as well as an estimate for the total range of view for the original image. In a production setting, metadata could be used to track the history of changes, including who made them and when.

Finally, in the fourth stage, the feature view can be used to determine which other candidate images would be best to include for the multirama. Clicking on a thumbnail or yellow candidate placeholder brings up the associated image in the two views to the right. This area is where feature-level metadata can be entered or changed (such as elevation and exaggeration priority based on relevance to navigation). The process repeats until the user is satisfied with the images in the feature, or until the user decides to shift work to another feature.

IV. Conclusion

We see a number of potential benefits in the GeoCoastPilot approach.

A. *Operational Benefits of Multiramas and Microlinks*

Both multiramas and microlinks can provide benefits to mariners in terms of:

- decreased time in searching for relevant information;
- fewer errors in interpreting the information;
- increased awareness of important navigation aids, hazards, and regulations.

The reasoning behind these benefits is based three main points:

1) The computer takes care of cross-referencing data to make all information about a feature mentioned in the Coast Pilot readily available to the mariner within a couple of mouse-clicks. This eliminates both the time required for the mariner to manually do the cross-referencing, and the possibility of user-error in the same procedure.

2) All the information is tied together in a visual context that better resembles what the mariner will actually see when they actually reach the port. While the default behavior within GeoCoastPilot is to exaggerate image sizes, the relative position of features remains intact, and the oblique display angle provides a better sense of presence than the chart. Furthermore, the mariner can disable size exaggeration at the click of a button to get a much more realistic picture of what to expect. This leads to a better interpretation of the information and increased awareness of the layout of the port.

3) Features of highest importance to navigational safety are emphasized, while less-important features are deemphasized. This helps the mariner focus attention on the relevant navigation aids, hazards, and regulations without having to sort through information of lesser importance with regard to safety.

A corollary of this that different schemes of assigning feature emphasis can be implemented and made available to the mariner in a menu. This might be of particular interest to pleasure boaters. For example, features could be exaggerated based on their importance with respect to specific tasks such as finding fuel, finding alternatives for land transport, or planning a sightseeing trip. This could provide an added benefit of task-specific situational awareness.

B. *Operational Benefits of Data Integration Paradigms*

Besides the eventual benefits to mariners in terms of tools like GeoCoastPilot, the paradigms of consistent feature-level metadata and simple third-party mappings provide other benefits to collectors and maintainers of the base data, and to users of the data in the wider marine community. The benefits include:

- increased speed in tagging of additional metadata while making it easier to check for errors and inconsistencies;
- comprehensive coverage maps to help data collectors identify and prioritize where additional data should be collected next;
- increased reach and flexibility in presenting information in different media such as print, web pages, and cell phones;
- increased opportunity for participation by individuals in providing content and sharing their knowledge and priorities with the rest of the marine community; and
- better accuracy and timeliness of information due to more effective mariner participation in reporting errors and submitting field updates.

The reasoning behind these benefits rests on two main observations:

1) The presence of well-mapped, consistent metadata acts as a stable platform from which it is easier to identify, create, and cross-check additional metadata. This means it is not only easier for organizations such as NOAA and the Coast Guard to generate good metadata efficiently, but it also becomes feasible to consider allowing other parties to contribute both data and metadata, since infrastructure is in place for automatic flagging of inconsistent data. Furthermore, third parties can feasibly use the official data as a base for other value-added perspectives by combining it with other (potentially proprietary) data.

2) Well-mapped, consistent metadata is relatively easy to transform into a variety of presentation formats. This means the same base data could be used for a print version of the Coast Pilot as for something like the GeoCoastPilot, as for an application on someone's iPhone. It also means the same base data could be used for interactive media, allowing for users to propose additions, modifications, or new mappings of the data

and metadata. This has already been happening in other fields as evidenced by the examples highlighted on the *Mashup Dashboard* [12].

C. Project Status and Website

The first version of the GeoCoastPilot research application was released in May of 2008 and covers Portsmouth Harbor. Then second version covers Boston Harbor, and is expected to be released in September of 2009. GeoCoastPilot can be downloaded from http://ccom.unh.edu/GeoCoastPilot, where any additional updates will also be posted.

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