Panoramic Images for Situational Awareness in a 3D Chart-of-the-Future Display

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ABSTRACT

Many early charts featured sketches of the coastline, providing a good picture of what the shore looked like from the bridge of a ship. These helped the mariner to distinguish one port from another during an approach and establish their rough position within that approach. More recent experimental 3D chart interfaces have incorporated 3D models of land topography and man-made structures to perform the same function. However, topography is typically captured from the air, by means of stereophotogrammetry or lidar and fails to present a good representation of what is seen from a vessel's bridge.

We have been conducting an investigation of ways to present photographic imagery to the mariner to better capture the utility of the early coastline sketches. Our focus has been on navigation in restricted waters, using the Piscataqua River as a test area. This is part of our "Chart-of-the-Future" project being conducted by The Data Visualization Research Lab at the UNH Center for Coastal and Ocean Mapping. Through our investigation, we have developed a new method for presenting photographic imagery to the mariner, in the form of a series of panoramic images progressing down the channel. The panoramas consist of images stitched almost seamlessly together into circular arcs, whose centers are intended to be close to the position of a vessel's bridge during transit. When viewed from this center, there is no distortion, and distortion increases to a maximum between two panorama centers. Our preliminary trials suggest that panoramas can provide an excellent supplement to electronic navigation aids by making them visible in the context of what can be seen out the window. We believe panoramas will be especially useful both in familiarizing a mariner with an unfamiliar approach during planning, and in enhancing situational awareness at times of reduced visibility such as in fog, dusk, or nightfall.

INTRODUCTION

Most modern navigational charts provide only one perspective from which to gain visual information about an area, and it is not the perspective from which they guide their vessels: a downward-looking perspective (plan view) approximating a vantage point high above the surface. But this was not always the case. Many early charts featured sketches of the coastline, such as the one illustrated in Figure 1, providing a good picture of what the shore looked like from a vantage point resembling that of the bridge of a ship. While an overhead view is essential for longer-term tasks such as planning a route, these sketches helped mariners to double-check position and ensure they were where they intended to be.

More recent experimental 3D chart interfaces have incorporated 3D models of land topography and man-made structures to perform the same function as the coastline sketches [3]. However, topography is typically captured from the air, by means of stereophotogrammetry or lidar and fails to present a good representation of what is seen from a vessel's bridge: an idea of the overall height-profile can be given to the mariner, but lost are features on vertical faces or recessed features such as features on buildings, trees, and rock ledges. Such models can be improved by adding CAD models of structures and even vegetation.

However, such 3D models cannot be created automatically and would be prohibitively expensive to produce and keep up-to-date on a large scale.

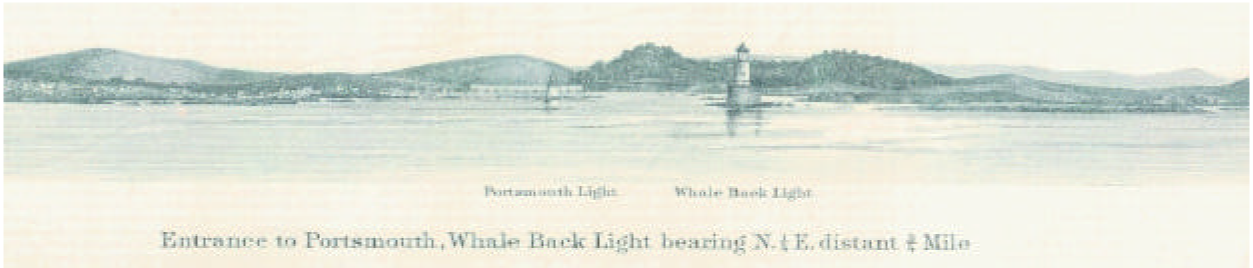


Figure 1: Coastline sketch from an 1876 edition of Chart 329 for Portsmouth Harbor.

As an alternative to 3D models, photographic imagery is relatively easy and cheap to obtain. An entire harbor can be photographed in less than a day from a launch. This imagery provides and extremely good representation of the bridge-level view, and although it also captures temporary features such as ships in transit, we believe that this can be used to provide excellent information about location relative to the shore—a kind of modern equivalent to the early coastline sketches.

We have been conducting an investigation of ways to present such photographic imagery to the mariner. Our focus has been on navigation in restricted waters, using the Piscataqua River as a test area. This is part of our larger "Chart-of-the-Future" project [1, 2], being conducted by The Data Visualization Research Lab at the Center for Coastal and Ocean Mapping. The goal of the Chart-of-the-Future Project is to develop a marine decision support system that takes full advantage of existing and emerging technologies in order to maximize safety and efficiency in routine marine responsibilities. We are developing a working research software prototype called GeoNav3D, and the ability to present photographic imagery is one area of active development.

APPROACH 1: VIDEO-STILL IMAGERY

The first method we investigated for presenting imagery was using video stills. Video-still imagery is a virtual ribbon image generated from individual video frames, with this video originating from a side-looking video camera that was mounted on a vessel at it transited through a channel.

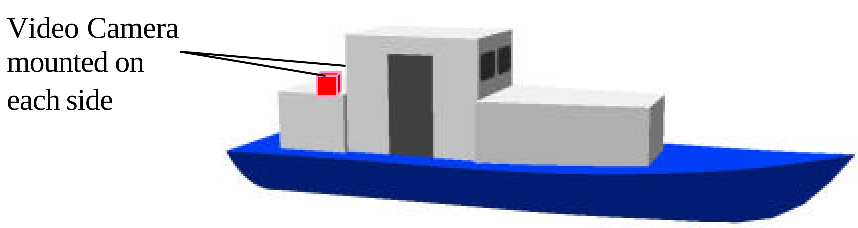


Figure 2: A model of the RV Coastal Surveyor illustrating the locations of the video cameras used to create the video-still imagery.

To determine how best to construct the video-still imagery, we constructed a ribbon of video stills along the shore of the Piscataqua River, and placed them in a 3D scene using our GeoNav3D display. The video we used was taken from video cameras mounted behind the bridge on each side of the RV Coastal Surveyor, as illustrated in Figure 2. We placed selected frames from the video into a 3D scene so that they provided a relatively accurate view of the coastline from a vantage point perpendicular to shore. One problem we encountered straight away in doing this was determining where the imagery should be placed, given that important features appeared at different distances from the shoreline. We decided that the best approximation in the typical case would be to place an image roughly at the distance of the most prominent landmark contained in the image, when possible. The result is illustrated in Figure 3.

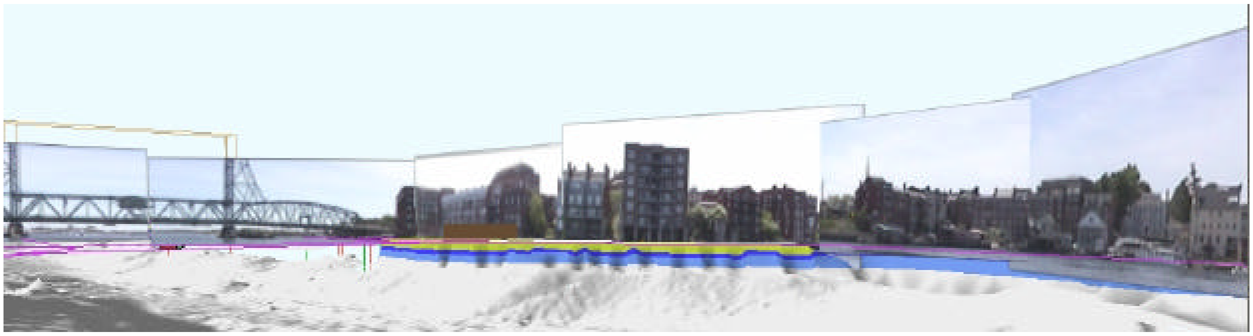


Figure 3: An example of our video-still imagery in the Piscataqua River just north of Portsmouth, NH. This image is taken from a screen shot of the bridge view from GeoNav3D, and includes some underlying bathymetry and selected S57 objects (such as the lift bridge).

Our preliminary field trials with the video-still imagery showed that the approach suffers from a number of drawbacks. First, the images were taken perpendicular to the direction of travel, so they often offered a very poor representation of shore features ahead of the vessel. When good images were available ahead of the vessel, they were often from a perspective too close to the shore—features near the shoreline look much larger and often obscure the overall profile seen from further away. Finally, because the video-still imagery was taken from consumer digital video cameras, their resolution was low enough that it was often difficult to identify even quite substantial buildings in certain situations.

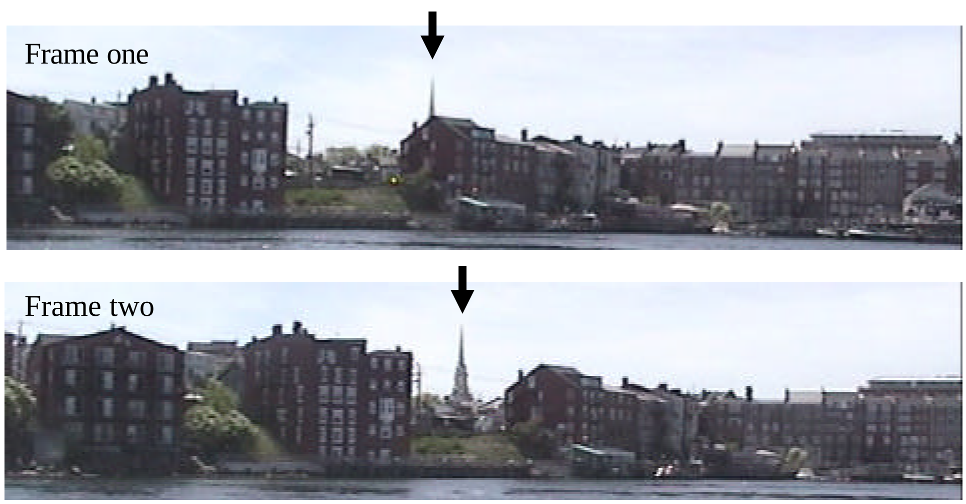


Figure 4: Two video frames taken from roughly 20 meters apart. These frames illustrate a geometric problem of parallax: there is no one location that a given image with prominent features at different depths can be properly placed in a scene. The church steeple appears in one place with respect to the other buildings on the coastline from one vantage point, but in another place from another vantage point not far away.

Other drawbacks of the video-still approach are technical. For instance, the video that generates the imagery requires both gigabytes of storage and a significant effort to choose appropriate video frames. Once the still imagery is created, there is the problem of properly geo-referencing it so that the image of a building appears situated over the shoreline in the proper location. Even if this can be done for the front-most buildings, however, there are still technical issues of geometry that cannot be solved with single-viewpoint imagery. Figure 4 illustrates the problem of parallax, with two video images taken roughly 20 meters apart. The church steeple is a prominent landmark that cannot be properly represented by images situated at the shoreline (unless the mariner happens to be looking at it from the location the camera was in when the image was taken). It appears behind a building in frame one, but appears between buildings in frame two. Other geometric issues are presented in comparison with the panoramic imagery we describe next.

APPROACH 2: PANORAMIC IMAGERY

Our second approach for creating coastline imagery involved constructing a series of "panorama" images progressing down the channel. The panoramas consisted of images stitched almost seamlessly together into circular arcs, with centers close to the intended position of a vessel's bridge during transit.

In order to produce a proof-of-concept prototype of the panoramic imagery, we used a standard Canon EOS Digital Rebel camera to collect the images we needed to construct the panoramas. The camera was mounted on a tripod with a pan/tilt head, and this tripod was secured on the back of the RV Coastal Surveyor as illustrated in Figure 5. We created a mission plan that indicated the locations at which we wanted the panoramas to be centered, as illustrated in Figure 6. Whenever we reached a point, one person inside the vessel would signal another person in back with the camera to take a series of photographs. Five photographs were taken as illustrated in Figure 7, starting at a starboard orientation, and continuing at 45° intervals through stern and finally to a port orientation. This was enough to complete half of a circular panorama. The other half was taken in the similar manner when we came back across the point in the opposite direction. These points were reached in lines rather than individually, so as to minimize turning around and maximize time efficiency. As this was simply a proof-of-concept run, we did not go through great pains to be extremely accurate in the proper timing of taking the photographs. Once the pictures were collected, they were processed with Canon's PhotoStich® software into panoramas, and touched up with Adobe PhotoShop® for overall brightness and color quality. Figure 9 illustrates panoramic imagery corresponding to the same area covered by video stills in Figure 3.

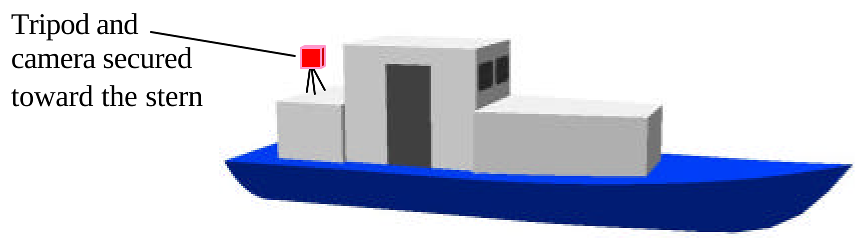


Figure 5: A model of the RV Coastal Surveyor illustrating the location of the still camera used to capture panoramic imagery.

During our preliminary development, we collected imagery under a variety of lighting conditions. We found that the panoramas came out best when the brightness was roughly the same in all directions, for instance on a clear day with sun high in sky, or on an overcast day. With areas of wide variation, it was difficult to generate panoramas in which there was sufficient contrast for all features to appear clearly.

The parallax problem we described earlier is inherently worse when images are collected near the shoreline. This can be remedied by increasing the density of panoramas with centers close to the shoreline. In general, the further the viewpoint is from the shore, the lower the required density of panoramas. Consequently, the technique is not likely to be useful less than 40 meters from prominent shore features. Mostly, panoramas can be laid out with centers along the main channel or corridor of approach, as this is where they are most likely to be used. Figure 8 illustrates our layout for a small section of the Piscataqua River, showing five of the near-shore panoramas on the southwest bank, and all of the panoramas down the center of the channel.

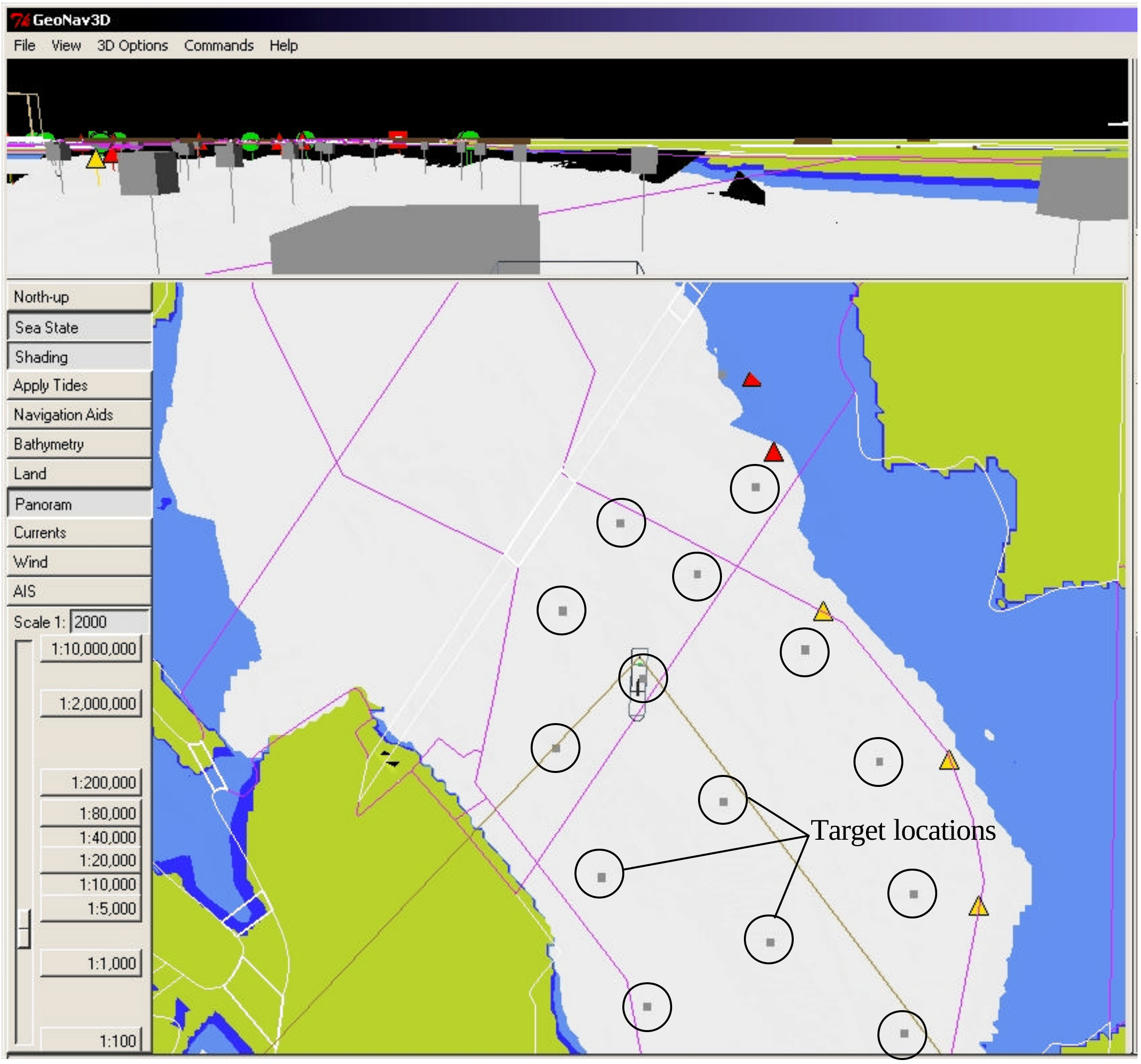
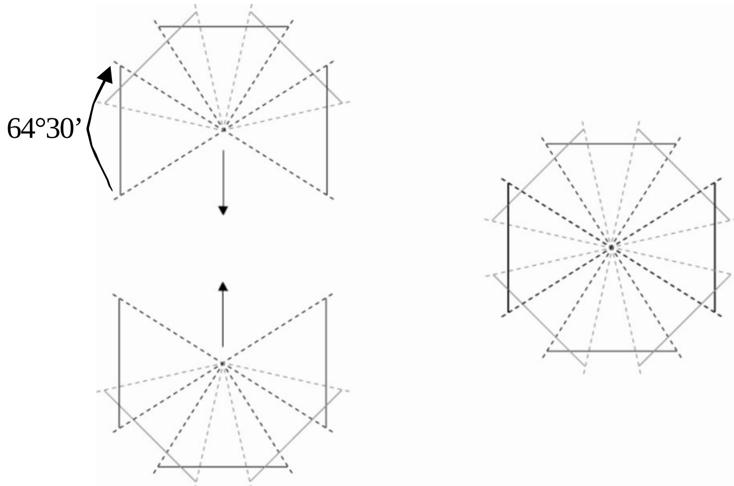


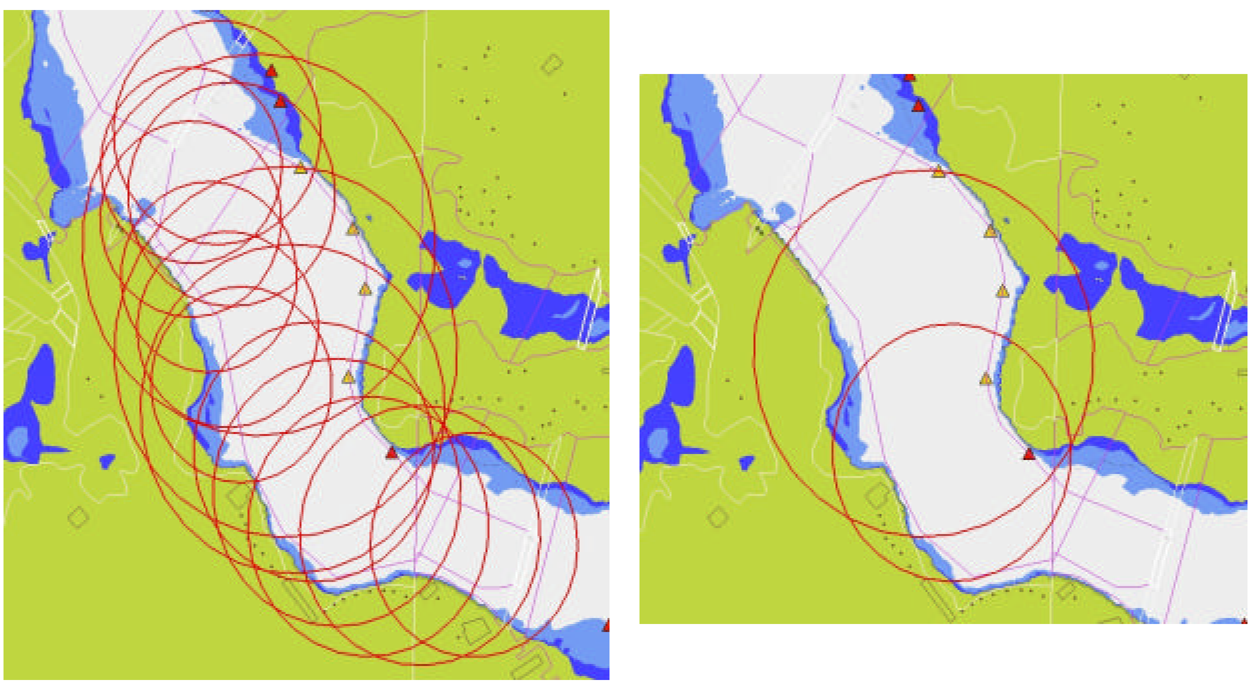
Figure 6: A partial screen-shot of GeoNav3D showing the type of interface used to aid in collecting images for the panoramas. The grey blocks indicate the target locations laid out for collecting images with the camera.

Our preliminary field trials with this panoramic imagery showed that the approach offers great promise. When viewed from the center of a panorama (the collection point), there is minimal distortion. The distortion that is present could be eliminated using a camera (or set of cameras) better suited to generating panoramas. Because of perspective geometry, distortion increases as one's perspective moves away from the panorama center. However, in GeoNav3D, panoramas are displayed and hidden according to the proximity of a vessel's bridge to the panorama center. When used in this way, the distortion reaches a maximum between two panorama centers, but even at these locations the distortion is much less than that obtained with the video-still approach. Comparisons of the right-hand sides of Figures 3 and 9, and of the edges of the images in Figure 10 provide illustrations of the distortion we mean—the closer a still image is to parallel with the direction of travel, the more distorted its contents appear. Furthermore, the resolution and quality of the imagery is consistently good, making it a more reliable way to identify shore features. The preliminary trials suggest that panoramas can provide an excellent supplement to other navigation aids in enhancing situational awareness. Panoramas can also aid in familiarizing oneself with a new port or approach, as suggested by initial feedback from mariners who suggested combining them with Coast Pilot reports. We believe panoramas may be especially useful at times of poor visibility such as in fog or at dusk, as it would enable the mariner to correlate barely seen objects out the window with the clear panorama imagery on the video display.



(a) (b)

Figure 7: (a) Five pictures were taken (represented by solid lines between two dotted lines) sweeping from starboard, through stern, to port going one way through each point, and the same process was later completed going the other way through the same point. (b) When combined together, these there are enough images to complete a circle, even if our approach angle was off by as much as 45°.



(a) (b)

Figure 8: (a) An illustration of the spacing and display size of successive panoramas (only a subset of collected imagery is shown). (b) The locations of the panoramas used in Figure 9 (smaller circle) and Figure 10 (larger circle). Spacing and display sizes were able to grow as the center of the panorama moved further away from key shore features.

Figure 9: Panoramic imagery in place of the video-still imagery shown in Figure 3.

There are some minor drawbacks to the concept of using panoramas as described, but the most severe drawbacks come only in the approach that we used. The biggest drawback to using the panorama concept as implemented in GeoNav3D is the abrupt transition between panoramas, which can cause features to appear to "jump" a bit left or right. A second drawback (and one that the video-still imagery suffers from as well) is that the panoramic views are somewhat height-dependent: what the captain of a small boat sees may be very different from what a helmsman in a large vessel sees, particularly if the features at the shoreline are no taller than a few stories. This may mean that two or three sets of panoramic imagery may be needed to get accurate images to all who might wish to use it.

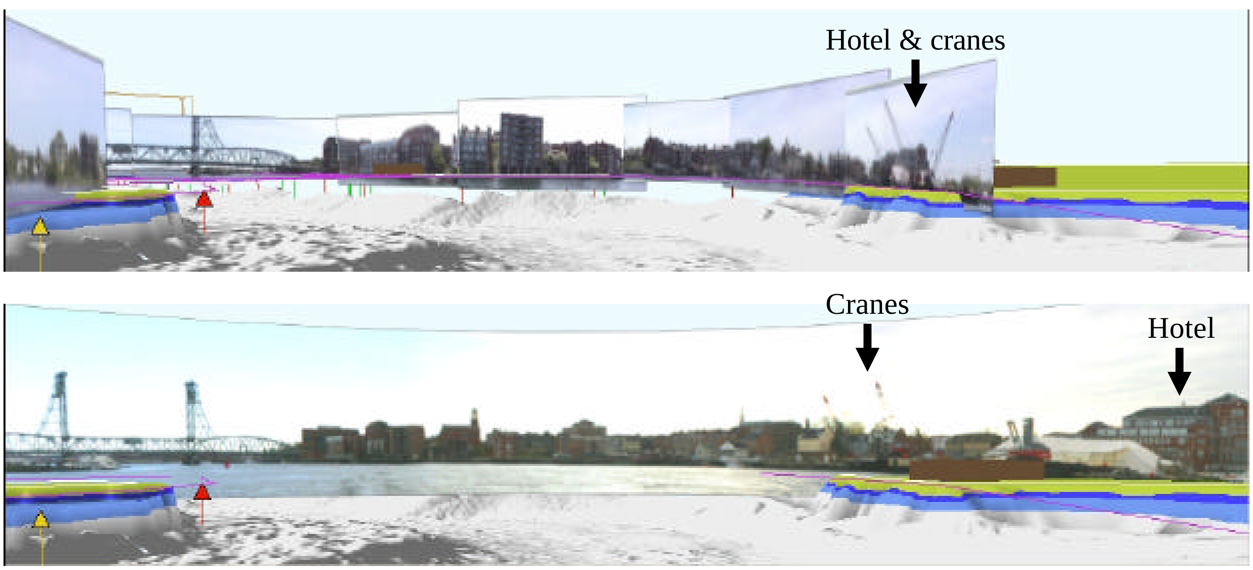


Figure 10: Video-still versus panoramic imagery at a location about 100 meters further upstream from Figures 3 and 9. Notice the distortion in the video-still images where the shoreline is not perpendicular to the viewing direction. Also note that while the cranes to the right of center are in roughly the same place, the hotel appears behind them in the video-still imagery.

Drawbacks to our collection approach are more easily remedied. In using a single camera on a constantly moving vessel compounded with having to make two passes to complete all 360°, we did not truly have a point-center for the panoramic images in each semi-circle. It would not be surprising if the viewpoint strayed by 10 or 20 meters within each panorama. The PhotoStitch® software fit the images together into a 360° view, but it could not eliminate long-period distortions—areas of the image that are somewhat magnified, with other areas somewhat shrunken. A solution to this would be to use a camera system specifically designed for taking panoramic shots and producing a truer 360° image.

CONCLUSION

We believe that panoramic imagery presented as a series of panoramic images progressing down a channel can be a cost-effective way to provide new, useful information to the mariner. We have shown how such imagery can be collected, and we have suggested low-cost improvements in that method for producing higher-quality panoramas. We have also shown how a series of progressive panoramas improves upon a scheme that represents shore features with only a single vantage point for each feature. Panoramic imagery could be improved further by including annotations identifying key landmarks, pier facilities, and navigation aids, with links to Coast Pilot information, and with an added ability for "zooming-in" on points of interest in a given image. We believe that such a mature form of panoramic imagery may be especially useful at times of poor visibility such as in fog or at dusk, as it would enable the mariner to correlate barely seen objects with the panorama imagery, as well as identify such objects even when they are being encountered for the first time.

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