MOBILIAR : Augmented Reality for Virtual Furnishing

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ABSTRACT

We present a novel vision based augmented reality system that facilitates the measurement, 3D modeling and visualization of furniture or other objects using a mobile device. Using minimal user interaction, the proposed system uses a single image to measure object dimensions and acquire a 3-D primitive based textured model. The textures are automatically extracted from multiple images of the object thereby allowing the user to capture textured 3-D models and virtually place them elsewhere in the room.

Two user interaction frameworks are presented; both designed for different device types.. The first is better suited for smaller screens while being simple enough to reliably measure objects. The second approach exploits larger screen sizes and also provides greater flexibility of use and robustness in measurement.

Author Keywords

Augmented reality, image based rendering, visual metrology

ACM Classification Keywords

Algorithms Measurement

General Terms

Algorithms, **Measurement**, **Theory**.

INTRODUCTION

Increasing power of mobile devices and smartphones have significantly contributed to the progress of augmented reality (AR) applications becoming mobile. While early mobile AR application truly focused on the mobile user, addressing location based applications (see [3]), the current trend is to move traditional AR to the mobile device. Such AR applications mainly address themes in entertainment, education/training or interaction (see [2,5,6]) with virtual objects. None allows the user to capture and manipulate real world objects around them.

AR based virtual furnishing

We present a novel system that allows the user to photograph furniture or other objects using their mobile camera and directly measure their sizes from the image alone. Furthermore, the system allows the user to walk around the object and take more photographs and automatically compute image based textures for the 3D models. Finally, using a marker (similar to [3]) to determine the user's perspective, the furniture is rendered in real-time in a new position/environment. While the idea of displaying intricate *authored* 3-D models is not novel (see [5]), none of the systems allow for capture and augmentation with user generated 3D content of real-world objects.

We begin with an overview of the entire system and the steps towards interactive measuring or visual metrology, modeling and visualizing the captured 3D models on mobile devices.

We present our interaction metaphors for visual metrology chosen for their suitability for small screen displays. Unlike single view metrology [1], we do not depend on user provided relative sizes of structures in the image. We directly determine object size in a manner similar to [7]. We describe the mathematical models behind visual metrology as well as their constraints. For larger displays we are able to provide a more intuitive and direct interaction metaphor while at the same time allowing more flexibility and robustness to measurement.

We show initial results of our complete augmented reality mobile virtual furnishing system and explore possible avenues to further develop our system.

MOBILIAR – AN OVERVIEW

While manually measuring furniture and objects would provide very accurate results, it does not always provide the sense of space occupied by an object. The look and sheer size of an object cannot be captured by a few numbers denoting the dimensions alone. Moreover the problem is further complicated if the object in question is heavy and cannot be moved around easily or worse still not at hand (for example at a shop). It is with these circumstances in mind that the virtual furnishing application was developed.

The AR system we present, as illustrated in Figure 1, allows the user to measure an object reliably (within acceptable margins of error) and capture images from which a texture mapped 3D model is computed as well as use the textured models to virtually place and manipulate the object in a new location. Thus, not only do we determine its size but can in real-time view it in another location and virtually walk around it and get a better sense of size and space occupied.

Figure 1: The marker based AR Furnishing system allows the user to interactively define the bounding box of an object and thereby determine its size. The system uses multiple images to determine a textured 3D model also utilized for AR based virtual furnishing.

Visual Metrology

In general, to make any metric and geometric analysis of the image we must determine the camera's *pose* (rotation **R** and translation **t**) with respect to the scene. We also require knowledge of scale[1] of objects in the image. For this, we use the standard approach of 2D markers similar to [4].

In order to measure objects in the scene from an image we need to know exactly where the object of interest lies within the image. Since automatic segmentation of the object of interest is relatively challenging, especially for the purpose of robust measurement, we require user interaction to define the extent of the object being measured. As shown in Figure 1, the user visually marks out the bounding box as would be visible in the image. We present two interaction metaphors designed for small and large display devices respectively. The constraints imposed by each metaphor and their effect on robust estimation shall also be explored.

INTERACTIVE VISUAL METROLOGY

The size of the object can be defined in terms of its bounding box in 3D as show in Figure 1. The user however has to indicate from a single image the visual extents of the bounding box in order to compute the object's size.

We now present two key interaction paradigms developed specifically with the display size in mind. On small smartphone displays fine manipulations as required for geometric analysis are cumbersome. In contrast, larger displays allow greater freedom for such interactions. We now explore these two contrasting approaches.

Model Manipulation with Feedback

In general it is sufficient to indicate the object corners that define the bounding box of the object. However, this requires fine motor control for point selection which can be tedious on small screens. We therefore developed a coarser movement (swipe to resize) paradigm that is less tedious while achieving the required accuracy.

The user places the marker on or next to the object so that it is aligned with the edges of the object. Furthermore discarding the rotation interaction reduces the number of interactions needed and therefore reduces complexity to the measuring task.

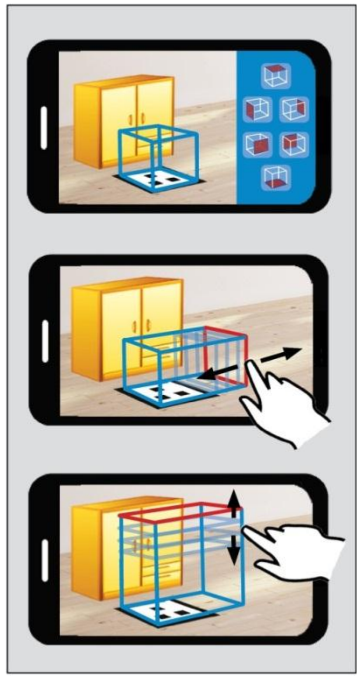

Figure 2: Model manipulation with feedback interaction: Here we allow the user to choose the specific face of the bounding box to moved. Then a simple swipe of the finger either left/right extrudes the box along that face. Since the actual size of the 3D model is internally maintained, the visual overlay provides feedback in the image as to its fit to the object. When satisfied, this directly provides the size and position of the object/furniture with respect to the marker.

As shown in Figure 2, the system displays a control-cube of known size on the marker along with a control-pane allowing the user to select specific faces of the box to move and extrude the box thereby moving and resizing it. The user can select one face at a time, and swipe left or right to extrude that face of the box inwards (making the box smaller) or outwards (making it bigger). These operations allow the user to resize as well as translate the box in the plane of the marker as shown in the real measurement example in Figure 3. Note that although the object is not truly rectangular, it can still be measured accurately. In most cases our experiments revealed measurements to be within a couple of centimeters of their true sizes.

It should be noted that the interaction forces either the top or the bottom of the control-cube to lie in the plane of the marker. This ensures avoiding any scale-depth ambiguities i.e. ambiguities between a close by small object and a faraway large one in the image.

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[1] Perspective images have no notion of depth and scale and from an image alone it is in fact impossible to make Euclidean measurements without some knowledge of scale and geometry.

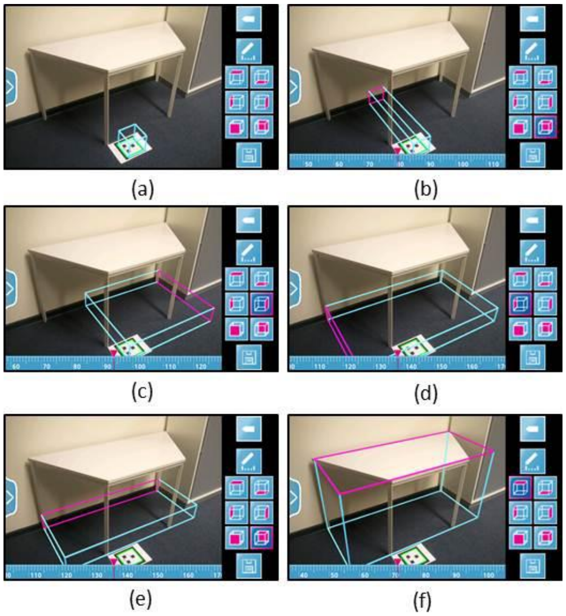

Figure 3: Android smartphone with model manipulation based interface for visual metrology. The user selects faces (b—f): rear, right, left, front and top, in order to directly manipulate a virtual bounding box to fit its view in the image. The control-cube provides the object size and position.

Open Issues

Rotation control was omitted in order to avoid it's complexities under perspective projection. As a consequence, the marker must be precisely aligned with the edge of objects. Failure to align the marker results in errors in measurement and texture computation.

Direct Interaction

The model manipulation approach in the previous section required considerable number of interaction steps to align the control-cube with the extent of the object. Typically the user would need to iterate over the faces by adjusting and readjusting the faces (depending on the perspective) to eventually obtain the 3D size of the object.

However, since the size of an object is determined by purely its length, width and height, all we need are three corner points along the corresponding edges to compute its size. This indicates that the user should ideally be able to provide all necessary data by simply indicating the three points – three "touch/clicks" on the screen.

Five point Interaction

The new direct interaction approach we present does not require the marker to be aligned with the furniture edges thereby proving greater flexibility and robustness.

As shown in

Figure 4, the user again takes a snap-shot of the object with the marker. The user then *drags-and-drops* five corners of the cube onto the corresponding five corners of the objects. The system then computes the exact rotation, size and position of the object automatically (see Figure 5.).

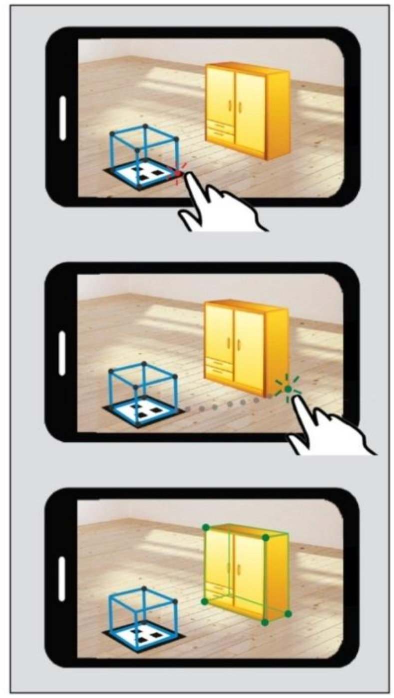

Figure 4: Direct Interaction - Point out to our system the correspondences between the unit box corners to those of the object. The system computes the object size automatically.

TEXTURE COMPUTATION FOR IBR

As mentioned before, accurate measurement alone does not provide a full sense of the space occupied and appearance of furniture. For this purpose our system is also capable of automatically extracting textures from the object's images.

AR VIRTUALL FURNISHING RESULTS

We now present results of employing the various measuring approaches presented together with the automatic texture extraction. The measured and extracted textures were then used to virtually place the furniture in new locations and visualize their appearance and space that they occupied.

Figure 5: The direct interaction process: bottom right- shows the computed (reshaped) control-cube, after the system automatically computed the size of the object.

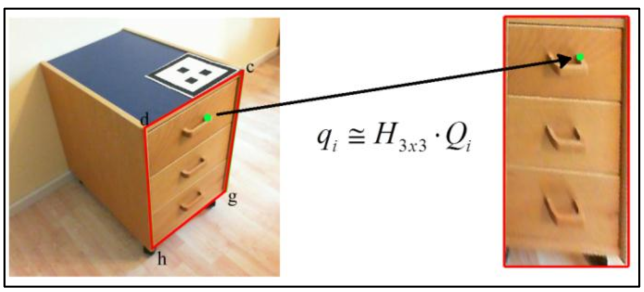

Figure 6: A homography is used to find the corresponding pixel q_i on the source image and map it to the texture Q_i.

Figure 7: The real aquarium (top left) was measured using the "model manipulation" method and then textures were automatically extracted by the mobile app in real time. The remaining images show the same aquarium virtually placed in different environments and viewed from various perspectives.

CONCLUSION

We have presented a novel use of vision based augmented reality towards measuring, modeling and virtually furnishing environments using the developed mobile AR application.

Moreover, we presented two methods of visual metrology (measuring of 3D objects) that lead to two very different interaction metaphors. While one was suited for small display devices, the other (direct interaction based) approach achieved minimal user interaction while providing very robust results. Further, we showed that this second approach using reshaping transformations also allows greater flexibility in using the marker in the scene while also providing robustness by allowing the marker to be misaligned.

Finally the image based rendering aspect of automatically computing texture models for the measured furniture leads to a very useful and realistic AR exploration of real world objects virtually placed in new environments.

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