MYINTERIOR: AR SUPPORTING INTERIOR DESIGN

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ABSTRACT

Interior design is the study of designing and arranging living space in an aesthetically pleasing way. Sometimes interior design may involve furnishing a brand new, empty home; but in most cases, interior design implies adding new components to an already furnished living space, such as adding a new sofa in the living room, or changing the wallpaper of the kitchen. Interior design includes the choice and arrangement of furniture, color schemes, lighting, etc.; but our interest is in the choice of furniture.

People have traditionally used tools such as color wheels and furniture catalogues to help them develop their interior design. Recently, developments in technology, and a demand for more intuitive and visual tools, have seen the rise of 3D interior design tools. However, such tools do not give users a better idea of how the new interior design will look in relation to their current living space.

Augmented Reality (AR) is a technology that maps a real environment and allows placement of virtual objects within this environment. It creates a cognitive and perceptual overlap of senses between a virtual and real environment. This quality of AR is perfectly suited for interior design tools; using AR could allow people to create interior designs that are truly related to their own environment; it is also a highly visual and intuitive form of interaction, providing a "what-you-see-is-what-you-get" interface.

This project explored the use of AR technology to improve upon the limitations of existing interior design tools, by accurately mapping a given interior space and allowing accurate placement and arrangement of virtual furniture within this interior space, resulting in an interior design tool that is truly in relation to the real environment.

Keywords: augmented reality, interior design, room dimensioning

1. INTRODUCTION

In order to achieve a seamless blend of reality and a virtual selection of furnishings for a space requires solutions to a surprisingly large number of significant research issues. A device needs to be able to accurately locate its user within a space and to accurately identify the boundaries of the space in order to ensure that virtual furnishings are accurately placed. In this paper we introduce *myInterior*, an AR interior design application. The aim of the application is to improve upon the limitations of existing interior design tools, by mapping a given interior space and allowing placement and arrangement of furniture within this interior space, resulting in an interior design tool that is truly in relation to the real environment.

A number of researchers have explored issues in this area previously. Omar et al. (2008) is one of the earliest developers to implement an interior design tool using 3D. The user is able to manipulate and interact with furniture in a virtual showroom. Yet this approach limited in that interior design is carried out within the virtual space, which is not related to the user's real environment.

There has also been an increase in the use of AR in interior design tools. A notable example of this is IKEA (Butcher 2009), a major furniture retail company that develops and supplies an AR-based furniture catalogue application for their prospective customers. Users are able to select a piece of furniture and place it on the picture of a particular surrounding environment using a smart device. However, furniture objects are not aligned with the room and do not need to follow the perspective of the room; the user instead must manually control the furniture's size and placement, creating an illusion of aligned perspectives.

Sayduck Ltd. released a AR augmented reality application in 2012 which uses marker detection in order to align virtual furniture with real-world environment perspective (Thurab 2012). In this application, users arrange furniture around the room by placing and moving around corresponding fiducial markers (see Figure 1).

Research by Feuerstack et al. (2011) is an attempt to improve upon the traditional marker-based AR. In this browser-based system, virtual objects can be freely placed and moved around even when the marker is fixed, giving the user more freedom. Yet this approach still suffers from the limitations of a marker-based approach to AR; if the marker is not within camera range, augmented reality will cease to function, limiting the user's ability to envisage the space.

Figure 1: Sayduck's Augmented Reality interior design application in action (Thurab 2012)

2. REQUIREMENTS FOR AN AR-BASED FURNITURE LAYOUT SYSTEM

Through reviewing existing interior design tools and AR applications, the study derived the major requirements that the user expects in prospective interior design tools, and improvements the user wants to see from existing applications, with special emphasis in providing interior design experience that is related to the real environment. It is important for an interior design tool to be intuitive and accessible. Due to the nature of our application, prospective users are expected to be span all levels of age, architectural knowledge and computer proficiency; therefore, the application should be easy to learn and use, and must not demand extensive knowledge in architecture, interior design or IT.

Prospective customers will most likely use the application for casual reasons, seldom for professional or commercial use. Therefore, users are not expected to own high-level devices such as an AR headset or AR table, and would not be interested in spending a large amount of money to use the application. It is also unlikely they

will wish to undertake a significant set-up process to map out dimensions of the space being visualized or to place markers across all strategic points in a space in order for the application to work.

As an interior design tool, users should be free to add furniture of different types or several pieces of one type of furniture, and perform actions such as spatial arrangement, rotation, and changing the color and fabrics of the furniture. It is important that furniture pieces are visualised in their correct physical perspective – aligned with the perspectives of real environment and obeying laws of physics. If this is not managed, the cognitive and perceptive overlap of virtual objects and the real environment will be broken, and the believability of the application will diminish. The literature review showed systems that rendered the walls of a space, but they were only for visual effect and physically impossible interactions, such as furniture passing through walls, were possible. Furniture should not be passing through the walls, overlapping each other, or floating in the air.

Even though augmented reality provides a more intuitive 3D view of a room, making the 2D birds-eye view available is also of benefit to the user. The 2D architectural blueprint is the traditional method for displaying and communicating interior designs, which people are familiar with. Also, people may want access to 2D blueprints for later reference, such as commission for builders.

2.1 Measurement approaches

An initial analysis in the project focused on advantages and disadvantages of two major AR approaches – marker-based AR and depth-measuring device AR - was made, in order to see which approach would be most applicable for an interior design application.

In marker-based AR, printed fiducial markers are used to augmented objects. The pattern of a marker is detected, the perspective and distance of the camera in relation to a marker is calculated, and the object is rendered using this information. Marker-based AR carries several advantages; it is simple to implement, has low calculation overhead, and well-documented libraries such as ARToolKit are already available. In most marker-based approaches a virtual object is assigned to a single printed marker; for every new virtual objected, another marker would have to be added to the environment, and every time the user wants to arrange furniture in the augmented view the corresponding marker is moved accordingly. Having to print out and control so many markers is a deterrent for an interior design application.

An alternative to marker-based AR is employing a depth-measuring device, relying upon specialized device such as Kinect to perform perspective measurement required for augmentation. However, such devices are often expensive, and are not as commercially available or distributed as personal computers or smart devices, also making this approach unsuitable for our interior design tool.

Since these existing AR methods appear to be unsuitable for our specifications, the project examined gyroscopic measurement as an alternative to standard AR approaches. This measurement uses the gyroscope and compass in a smart device to perform measurements, thus eliminating the restrictions posed by the use of printed markers. Also, as a gyroscope and compass are installed in most commercial-level smart devices, there is no need to buy expensive or specialized equipment.

2.2 Overview of gyroscopic measurement

All AR methods, in some way or another, calculate the perspective and 3D coordinates of a target point in relation to the device, which is used to render the augmented virtual objects. In the case of gyroscopic measurement, this information is calculated by taking in three parameters; the height of the device, the horizontal tilt of the device, and the angle of the device in relation to the North point.

To measure a ground-level target, the user stands and looks through the camera to place the target at the center of the camera. The relative angle of the device is derived from compass, while the horizontal tilt of the device is derived from the gyroscope. The horizontal distance towards the target can be calculated using Pythagoras theorem, as is illustrated in Figure 2. This results in the 2D polar coordinate of the target, with the position of the device as the origin point.
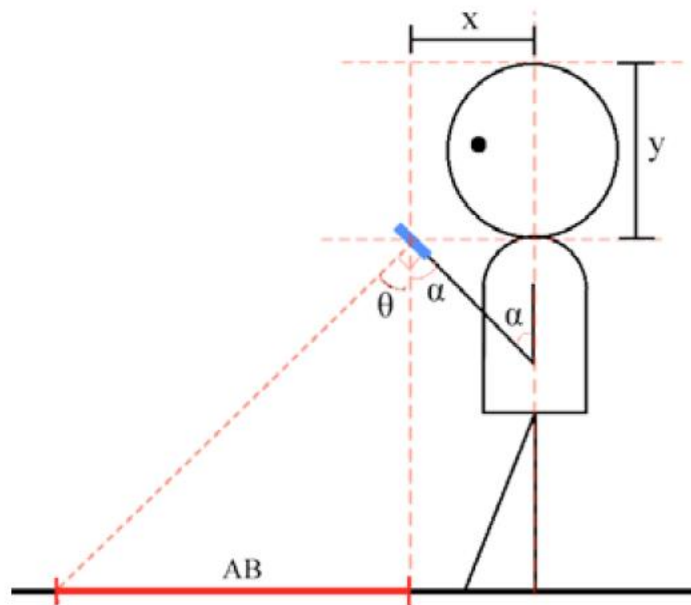
Figure 2: Measuring horizontal distance based on user height and device tilt

2.3 Mapping of the interior space

One of our major requirements was to ensure that the virtual furniture matched the perspectives of the real environment. Having argued that preventing the furniture from making out-of-perspective or physically impossible translations would ensure the perception of mixed reality. However, in order for this specification to be achieved the application must have the knowledge of relative positions of walls and floor of the room. The project investigated a mapping stage prior to the actual augmentation, for the application to chart the dimensions of the room.

Our requirements state that the virtual objects must be prevented from going through physically impossible translations, such as vertical displacement from the floor of the room or passing through walls and floors. This limits the possible interactions the furniture can go through to horizontal translations and rotations. In addition to this, we make an assumption that all furniture slides on the surface of the floor. To achieve this there is a mapping stage, where the application creates a model of the room's floor plan (a virtual blueprint). This floor plan consists of a 2D plane, representing the floor of the space, upon which the furniture must sit; and a series of lines which represent the boundary walls of the space. For this project we also assume that the corners of the walls that enclose the room are all 90 degrees, be they convex or concave. Finally, to map out the space the user is expected to stand in one spot during the mapping and augmentation of objects, as the device is considered as the origin of the coordinate system and when the user moves, the origin moves and perspective is broken.

2.4 Virtual furniture

Once the virtual blueprint has been computed, it may now be used as a coordinate system with boundaries, which can contain an arbitrary number of pieces of furniture. Furniture placement, translation, rotation, furniture-furniture collision detection, and furniture-wall collisions can be handled accordingly. Also, the virtual furniture provides a solution for the final specification, which asks for a system architecture that allows the user to freely transition between 2D and 3D views of the room and furniture any time during the augmentation. This just requires that all furniture representations in the system have both 2D and 3D representations that can be rendered dependent upon the view being utilized.

3. IMPLEMENTATION APPROACH FOR THE FURNITURE LAYOUT SYSTEM

3.1 Implementation platform

MyInterior was implemented on Android, which is the OS for many commercial smart phones and tablet computers including Galaxy series, Nexus series and ASUS Eee series. Android 2.3.3 Gingerbread, in contrast to the newest Android 4.0.3 Ice Cream Sandwich, was the Android version chosen for this particular implementation; even though 4.0.3 is faster and provides a more versatile library, 2.3.3 is better documented and is supported by more devices. For the project we have used an ASUS Eee Pad Transformer TF101. The technical specifications of the ASUS Transformer include: a built-in gyroscope, accelerometer and compass and 10.1" LED multi-touch screen (ASUSTeK Computer Inc 2011).

We have utilised a series of libraries to support our implementation. For dynamic rendering of 2D images, Android Canvas was used over ImageView due to the greater freedom it offered when rendering complex graphics. For 3D transformations and rendering of 3D images during augmentation, OpenGL-ES was employed due to its low resource overhead and optimization with embedded system.

3.2 Implementation architecture

As an Android application, *myInterior* was implemented as an interaction between three main activities. These are; MeasureCornerActivity, which performs the initial mapping before the augmentation begins, and 2DViewActivity and 3DViewActivity, which present the augmented environment in 2D and 3D viewpoint respectively and which the user may translate to and from.

In the system the user is first prompted to enter his/her height, before being asked to take measurements of each corner. For each corner of the room the user focuses the device camera on the ground-level cross-section of the corner and then takes the measurement by pressing a button. Once the user has taken all the measurements, the user presses the *Confirm* button, after which the application generates a virtual blueprint.

3.3 Calculating the device height

Gyroscopic measurement, as described in section 2.2, was used to calculate the 3D coordinate of a given corner every time the user presses the measure button. However, the implementation of the theory saw several design decisions and modification to the original method.

In order to calculate the height of the device from ground level, an assumption that the device will always be in fixed proportion with the height of the person was made; the higher the user's height is, the higher the height of the device will be. We attempted to find the ratio by referring to a person's body ratio.

However, pilot tests revealed that our initial assumption was flawed. Depending on which angle the subject was holding the device, the position of the arms and therefore the height of the device would be altered (as seen in Figure 2). Therefore, ur initial algorithm was modified in order to reflect the influence of device tilt in device height.

$$h = H - [H * s\text{Ratio}] + [H * fa\text{Ratio} * \cos(90 - \theta)] \qquad (1)$$

h –	height of the device
H –	height of the user
$s\text{Ratio}$ –	head-to-shoulder ratio (<0)
$fa\text{Ratio}$ –	forearm length ratio (<0)
θ –	device horizontal tilt

3.4 Calculating corner placement

After creating an algorithm for calculation of horizontal distance, the next stage was implementing the algorithm in such a way that the horizontal distance can be measured with the highest precision; ensuring high accuracy

would also ensure the room dimensions are mapped accurately, therefore resulting in more precise synchronization of perspectives between real and virtual objects.

An issue to consider was that the device was held by a human hand, and therefore the measured height will be susceptible to noise, produced by ambient movements of the human body. To minimize this noise, a sample averaging method was used. The device would take a sample of the calculated distance at regular intervals. Once the user presses the button to take the corner measurement, an average of the last few samples is used to calculate the horizontal distance, thus mitigating the effect of ambient noise. A sampling interval of 0.1 second and a sample number of 5 were chosen for the implementation.

Also, the "jolt" effect when the user measures the corner must be taken into account. When the user presses the button to get a corner measurement, the motion will cause the device to "jolt" for a fraction of a second, influencing the measurement taken and corrupting the result. In order to resolve this, the sample-averaging method was extended so that the device took in 10 tilt measurements instead of 5, and the average is taken out of only the earliest 5 measurements. This discards the 5 most recent measurements, taken in period of 0.5 seconds, which is considered to be corrupted by the jolt effect (see Figure 3 for a view of corner measurement). An evaluation of this approach with a number of users indicated an accuracy of approximately ±20cm after training of users.
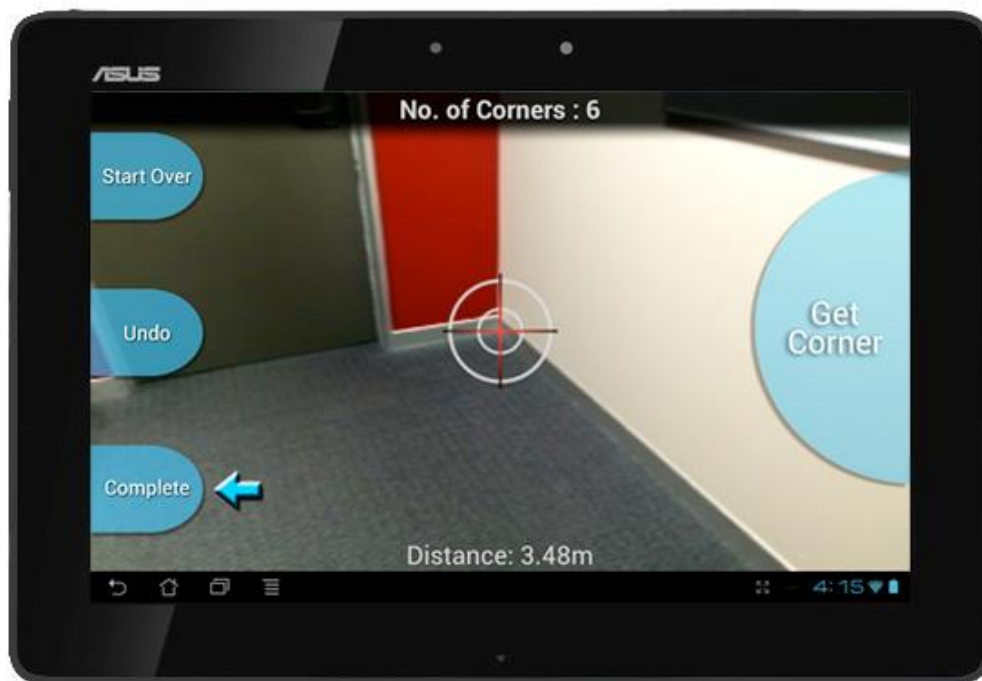

Figure 3: Screenshot of *MeasureCornerActivity*

After the corners are measured and the virtual blueprint representation of the room has been generated, the application switches into the next activity, *2DViewActivity*, where the actual interior design may be carried out. As seen in Figure 4, the view shows the birds-eye view of the floor plan. The user may add new furniture, remove existing furniture, perform linear and angular displacements on furniture and change the color of furniture, and any changes would be directly made to the underlying virtual blueprint layer. The user may also switch to the *3DViewActivity* at any given time (see Figure 5). Currently, furniture in the 3D view is pre-rendered with a default light source and no attempts are made to cast shadows which are consistent with the actual lighting of the scene, or to determine occlusions with existing furniture in the scene. It is also assumed that the user remains standing at the point that measurements were made for all further visualization within the space, though they may rotate on the spot to view the furniture layout across the whole space.
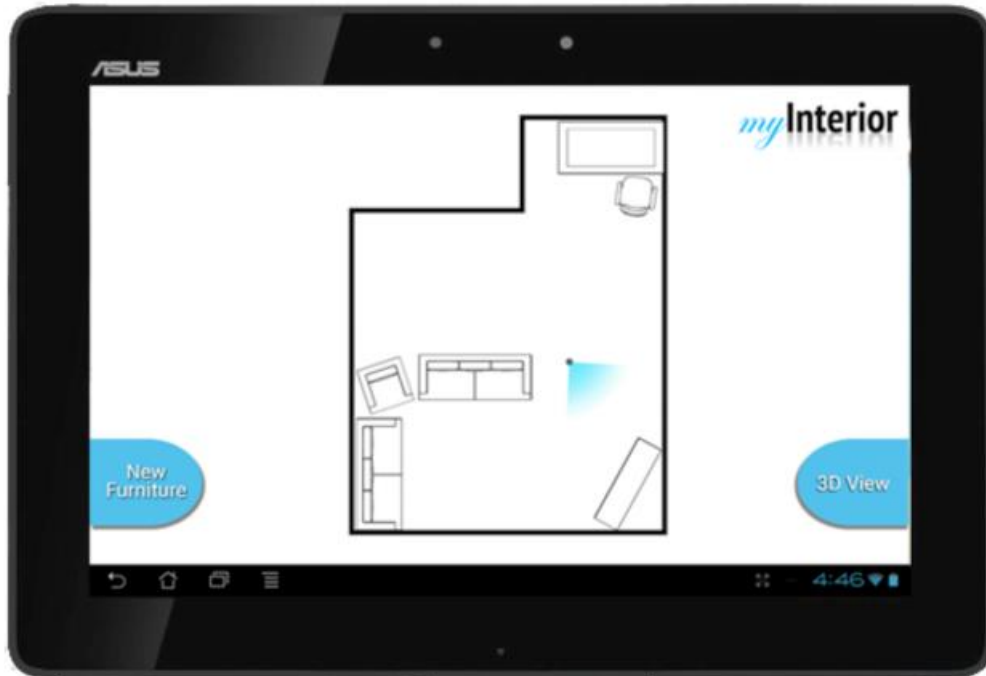
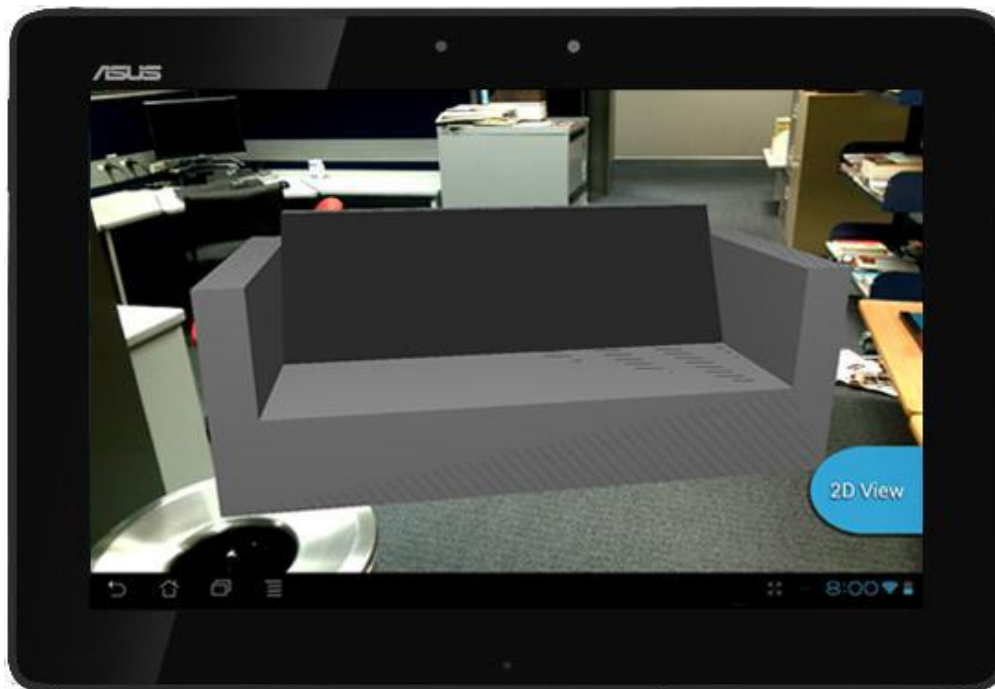Figure 4: Screenshot of *2DViewActivity* in operation

Figure 5: Screenshot of *3DViewActivity* in operation

Once room coordinates have been calculated, however, the axes of the resulting coordinates of the subject space may not be aligned with axes of absolute coordinates, neither the corners completely perpendicular to each other. This is due to the fact that the absolute axes are aligned to the absolute North direction, while the axes of the virtual blueprint are aligned to whichever direction the room was in. Therefore, after derivation of corners, the virtual blueprint aligns the axes with absolute coordinates. First, the angular displacement of each wall in relation

to the absolute axes is calculated. Then, an average value of all of these angles is calculated. Finally, the entire virtual blueprint is rotated by this average angular displacement, effectively aligning the axis of the virtual blueprint and now allowing the virtual blueprint to be effectively considered as a coordinate system.

3.5 Viewing 2D and 3D scenes

Once the arrangement of interior design has been created in *2DViewActivity*, the user may switch to *3DViewActivity*, which shows the surrounding environment using the camera of the device, upon which furniture are rendered using OpenGL (see Figure 5). The perspective of the camera view is calculated in real-time using the gyroscope and compass data. Meanwhile, the necessary information to render furniture, including 3D position of the furniture, mesh and texture, is updated from the Virtual Blueprint level.

4. EVALUATION OF THE SYSTEM

Following the completion of the implementation of *myInterior*, two usability tests were carried out. This process helped to increase the usability, functionality and accuracy of our design and implementation decisions and validate the usability of the application.

12 people tested the application, all of them members of the Engineering department of University of Auckland. Participants varied in height from 155cm to 190cm. All of the participants reported that they had average or above average computer proficiency, but only one of the participants answered that they had average or above average knowledge in architecture or interior design.

The tests were carried out in two locations; the first environment was set up in a study area of the Engineering building at the University of Auckland, while the second environment was set up in a study area of the main student building. A mock room of approximately 4x4m was created by denoting a space with physical walls and tape measures (see Figure 6).

Figure 6: The environment for usability testing

Before the beginning of the test, information such as the height of the participant, computer proficiency and architectural knowledge of the participant were collected. The participants were given a series of instructions, beginning with the measurement of the room, followed by adding and arranging at least five pieces of furniture,

before finally switching to the 3D view in order to view the augmented furniture. Participants were not asked to follow a rigorous guideline, but were encouraged to explore different aspects of the application. Participants were also encouraged to "talk out loud" throughout the duration of the usability test, and any comments that the user made during the test was recorded for later reference.

After completing the test, the user was asked to complete a questionnaire which consisted of five 5-point Likert scale questions and two open-end questions.

Overall, the usability tests were completed with relatively little problem. All usability tests were completed within 8 minutes, and 11 out of 12 participants were able to successfully complete all of the given tasks without supervision. One participant required supervision to progress from the corner measurement stage to the 2D view, but was able to complete the rest of the test without supervision. Also in the questionnaire, 9 out of 12 participants Agreed or Strongly Agreed when asked whether they found the application to be easy to use.

A notable reaction from some of the participants was that of confusion as did not understand the concept behind the application. Many people commented that they were puzzled by how the application measured the distance accurately without any markers or special device. One of the participants even commented that he believed we had modified the hardware of the device. This was upheld by the post questionnaire, where only 33% of the users answered Agree or Strongly Agree when asked whether they understood the concept of the implemented system.

User feedback from questionnaire was highly positive in general. 11 out of 12 participants answered that they would like to use the application again in the future, and all of the participants answered to have found the application novel and promising.

5. FUTURE WORK

A major future goal will be improving the accuracy of the distance measurement algorithm. The current accuracy rate makes the application suitable for general design use, but less suited for architectural use, where higher precision is required. There are two major reasons for this; inaccuracy due to the miscalculation of device height, and inaccuracy produced by the gyroscope. However, removing the error produced by the inaccuracy inherent in the gyroscope itself is expected to be very difficult, and implementing some other means of distance measurement in addition with gyroscope must be considered.

The application places several restrictions on the movement of the user during the augmentation. One way of resolving this problem would be adding in functionality that allows the user to "re-measure" the room whenever the user moves to another spot, effectively returning the coordinate origin to the device and this would be possible to implement using the current distance measuring algorithm; however, asking the user repeat the measuring process every time the user moves to another position still puts a high restriction on its use. Another way of removing the restriction is finding a means to track device displacement. If we know the exact distance the device has translated from the origin, we may translate the view accordingly. However, this cannot be achieved by using only the gyroscope. Again, other methods of distance measuring, such as utilizing inertial sensors, must be considered.

The current stage of implementation only allows the interior design to be modified at 2D view, and 3D view only allows inspection of the arrangement of furniture. 3D furniture interaction could be implemented by calculating furniture projection on the plane of the floor of the space. The visualization of 3D furniture is currently fairly unnatural and future work would look to automatically determine the light sources in the physical space (e.g., by determining shadow positions in the scene) and match this lighting to the rendered furniture. Providing realistic rendering of the virtual furniture around furniture actually in the scene (e.g., providing realistic occlusion between real and virtual furniture) is becoming possible and could be explored in future versions of the system.

In the current implementation, furniture is assumed to slide on the floor; this eliminates smaller objects that can be placed upon one another, or lights and other objects that are aligned to the ceiling rather than the floor. In order to resolve this the virtual furniture may be expanded to provide a 3D check across the whole geometry of the space.

6. CONCLUSIONS

In this study, we have investigated an interior design application which takes advantage of intuitive and visual qualities of augmented reality. As a result we have successfully implemented *myInterior*, an intuitive and visual interior design application which uses augmented reality alongside an accurate location placement algorithm to enable calibration of the space layout and its virtual furniture placement. Usability tests validated the intuitiveness of the system and provided positive user feedback on the novel approach decribed.

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