SOFTWARE DEVELOPMENT AND REPRESENTATION OF CONSTRUCTION PROJECTS WITH AUGMENTED REALITY

Campollo Canduela, Alfonso [1]; Gómez-Jáuregui, Valentín [2, *];
Manchado del Val, Cristina [2]; Otero González, César [2]

[1] *School of Civil Engineering, Universidad de Cantabria, Avda. Los Castros s/n, Santander, Spain.*

[2] *EgiCAD Research Group, School of Civil Engineering, Universidad de Cantabria, Spain.*

[*] *Corresponding author. Email address:* valen.gomez.jauregui@unican.es

ABSTRACT:

Three-dimensional (3D) perception of construction design models is beneficial to the understanding of the projects developed in order to make optimal decisions. Augmented Reality (AR) permits enhancing the visualisation of construction models, created with CAD/BIM, superimposing the model information (graphical or alphanumeric) onto a real-world view.

This paper introduces the outlines of the research about the application of Mobile Augmented Reality (MAR) in construction projects. The objective is the improvement and further development of an existing MAR application, based on a mobile device, to generate a mixed view of the real world and a superimposed virtual simulation of 3D objects in an outdoor environment. The research focuses on the ability to achieve a realistic and accurate visualisation of construction as the user moves around the site.

An experimental program has been done to examine the parameters of projection and distortion of the AR platform and the mobile device camera. They affect directly on the 2D projection of real and virtual realities over a common plane, thus it is necessary to detect the potential deviations generated in the superimposition process.

KEYWORDS:

Augmented Reality; Mixed Reality; Mobile; Graphic Engineering; 2D Visualisation; 3D Models; AEC Architecture/Engineering/Construction.

1. INTRODUCTION

Three-dimensional (3D) perception of construction design models is beneficial to the understanding of the projects developed in order to make optimal decisions. The application of Mobile Augmented Reality (MAR) in architecture, engineering and construction (AEC) allows the visualisation of the different stages of a construction process on-site [1]. The visualisation of

computer-generated 3D models overlaying real-world views provides a valuable insight in the design, construction and operation phases of civil engineering projects. Monitoring construction phases also enables a promptly detection of discrepancies between planned and actual project performances [2].

Current research in AR shows a clear trend in the collection and process of time-lapsed photographs of construction sites to reconstruct 3D as-built models and represent them superimposed to as-planned information, based on computer techniques [3].

The investigation presented in this communication is part of *EgiCAD* (Universidad de Cantabria) research line in AR. The study of the application of MAR in the fields of construction, civil engineering and technical teaching has breakthrough potential in the future for *EgiCAD*. This research group has developed an innovative MAR application, created with the software *Unity 3D*, that enables the superimposition of computer-generated 3D models, created with a CAD/BIM software, onto a real-world view. The application allows the user to perceive two different realities by the superimposition of real and virtual elements with identical references over a common space (the display or screen in a mobile device). The overlay of both entities is achieved adjusting some projection parameters of the virtual model. The precision and realism in the superimposition of virtual elements over a real-world scene depends on the user capacity to set the appropriate viewing parameters of the virtual camera: bearing (horizontal angle), field of view (FoV) and pixels aspectratio.

Real use of the application on-site has shown the existence of discrepancies in the superimposition of real-world and virtual models on the device screen (Fig. 1). Perfect pixel correspondence of both entities has not been achieved in the visualisation of various scenes, for different viewing parameters (bearing, FoV and aspect ratio).

Figure 1. On-site use of *EgiCAD* MAR application and misalignments detected on the superimposition.

Misalignments in AR applications may be caused by technical issues in the capturing mode of the camera of the mobile device and/or errors in the projection of the virtual model [4].

2. APP ANALYSIS

A detailed user trial with the MAR application has been done to detect the origin of the discrepancies detected.

Virtual and real-world projections for a specific scene are correctly superimposed when the

virtual projection FoV adopts the value of the horizontal view angle of the device camera, approximately. Although the FoV could be set fixed in advance, the aspect ratio value must be adjusted manually to view entities “correctly” overlaid.

Virtual projection of a 3D scene onto a 2D plane on *Unity* is achieved through a perspective projection camera. Analysing the virtual model projection of cube elements on the MAR app, it has been detected that:

- For a specific view, the projection plane size is either wider or narrower depending only on the FOV value. With a low FOV, objects are projected bigger as the projection plane is narrow. The FOV allows us to zoom in and out the scene to project (Fig. 2).
- For a fixed pixel aspect ratio and any FOV value greater than zero, there is always distortion in the projection if objects are not at situated perpendicularly to the projection main direction. The larger the FOV, the more obvious this effect is.
- For a specific projection FOV value, when the pixel aspect ratio value is manually reduced, the entities projected are shown narrowed and distorted from reality.
- With independence of the projection axis and the FOV and aspect ratio values, *Unity* applies a pure perspective projection. As the projection main direction rotates around the vertical axis, and consequently the projection plane as well, the projection of objects in the distance appear to be smaller than objects close to the view-point (Fig. 3).

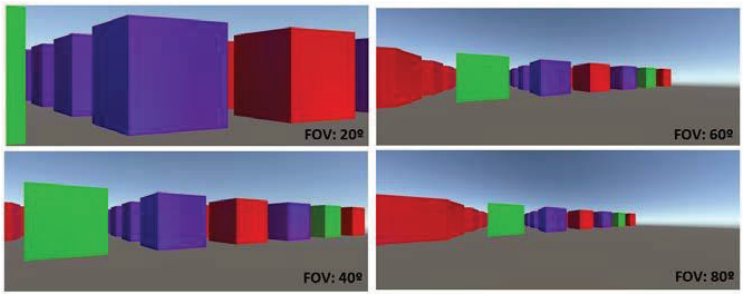

Figure 2. Large and small FoV effects on virtual 2D projection with *Unity 3D* software.

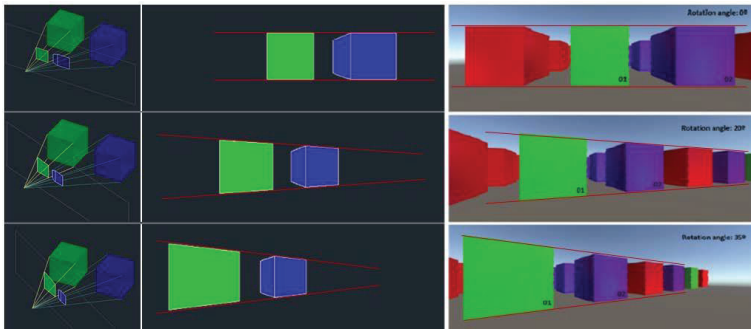

Figure 3. Geometric demonstration of Unity perspective projection using *AutoCAD 3D*.

Virtual projection parameters analysed here indicates that there is clear evidence that the default *Unity* camera projection matrix is suitable to render 3D virtual objects appropriately but not to be represented overlaid to a real-world photograph. Virtual projection matrix is not the same that the device camera uses to map a 3D world scene into the projection plane and therefore projections with different references and processing are being superimposed.

The deviations detected in the 2D projection of a CAD/BIM model developed can be corrected and visualised correctly by setting the device camera projection matrix parameters to the *Unity* projection camera used in the AR application.

3. CONCLUSIONS AND FUTURE WORK

Virtual and real-world entities superimposition in mobile AR applications can only be achieved by applying the same 2D projection configuration to both real and virtual cameras involved in the process. This is the starting point for developing source code to correct the problems of virtual entities overlaying real images captured by the camera of a mobile device.

4. BIBLIOGRAPHY

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5. RESEARCH TEAM

Name: Campollo Canduela, Alfonso.

Department, centre: *School of Civil Engineering*, Universidad de Cantabria.

Status: BEng Civil Engineering, Student of MEng Civil Engineering.

Name: Gómez-Jáuregui, Valentín. Manchado del Val, Cristina. Otero González, César.

Department, centre: *EgiCAD* Research Group, Universidad de Cantabria.

Status: PhD in Civil Engineering.

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NUEVOS MODELOS DE INVESTIGACIÓN Y COLABORACIÓN EN INGENIERÍA GRÁFICA

"Software development and representation of construction projects with Augmented Reality"

Introduction

***EgiCAD* Mobile Augmented Reality (MAR) App** = Real world physical environment + Computer generated 3D construction models

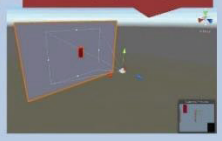
Projected by a "real camera" (mobile device camera)

Projected by a "virtual camera" (*Unity3D camera element*)

Virtual projection viewing parameters:

Field of view (FoV) | Pixels aspect ratio | Gyroscope attitude

2D Mixed view over a common projection plane



Detected misalignments in realities superimposition

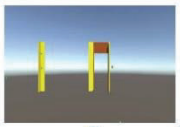
Methodology

Experimental use of MAR App
Creation of 3D scenes on a cross-platform engine: Unity3D

Analysis of realities superimposition in a built environment:
Calibration of viewing parameters and distortion models

Real camera projection analysis

Virtual camera projection analysis



$[x_{proyeted,real}] = [P] \cdot [X_{world}]$

$[x_{proyeted,virtual}] = [P'] \cdot [X_{world}]$

P: real camera projection matrix to link 3D real-world point coordinates to 2D projected points.

P': virtual camera projection matrix to link 3D real-world point coordinates to 2D projected points.

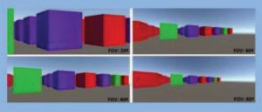
Analysis of the origin of projections misalignments

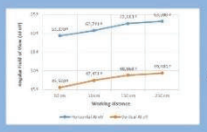
Impose: **P' = P**

Results

Images superposition

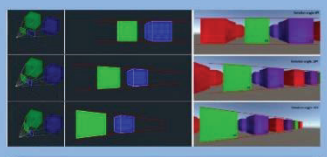
- Virtual projection angular Field of View (FoV) zooms in and out the virtual model projected on the projection plane.

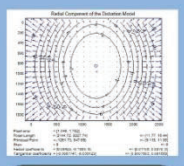




- Real camera FoV varies with the working distance.

- Adequate real and virtual pixels superposition is achieved with aspect ratio 1,33 (4:3).





Virtual camera applies a pure perspective projection. No radial or tangential distortion is applied on image processing

Real camera images have radial and tangential distortion induced.

Conclusions

Real and virtual entities perfect superimposition can only be achieved by applying **same projection and distortion parameters to virtual and real cameras.**

Solution: substitute default virtual projection matrix on *Unity3D* to real camera projection and distortion coefficients matrices.

Alfonso Campollo Canduela, Valentín Gómez-Jáuregui *, Cristina Manchado del Val, César Otero González.

valen.gomez.jauregui@unican.es

EgiCAD Research Team - Universidad de Cantabria (Santander, Spain)

UC UNIVERSIDAD DE CANTABRIA

GrupoEgiCAD I+D

Dpto. Ing. Geográfica y T. Exp. Gráfica