A Method on Using Video in Architectural Design Process: Matchmoving

Özgür Dağlar¹, Togan Tong²
¹A2 Tasarım - Turkey, ²Yıldız Technical University Department of Architecture - Turkey
¹ozgurdaglar@gmail.com, ²togantong@yahoo.com

Abstract. Computer technologies are used frequently and effectively in film-making. It is almost inevitable to exclude computer aid in different phases of the process such as video editing, compositing and generation of visual effects. Therefore, techniques and software used in this field are improving every day. In this paper, potentials of a technique known in film making industry as matchmoving will be elaborated to be used in architectural design process. The types of software available for matchmoving purposes excel at generating 3D environment data from video shots, making them very useful tools for architects.

Keywords. Architectural analysis; digital environment generation; matchmoving; motion-tracking

INTRODUCTION

The main aim of this research is to connect architecture and film-making field. The technique known as matchmoving is proposed for use in architectural design process.

One of the current techniques used in film-making’s post-productional stage is a process known as matchmoving or motion tracking. The specialized software that deals with motion-tracking reproduces camera movement of an actual footage in digital environments. While the software calculates camera path using photogrammetry techniques, it also creates a 3D data of the environment that the shooting took place.

The context of this study is to research, both possibilities and benefits of using matchmove data in the field of architecture. As a method, some matchmoving software products were examined and several shots processed. Then the software performance and resulting solve data were analyzed. Following the reference studies mentioned, new techniques involving matchmove technology in different phases of architectural design were proposed.

MATCHMOVING

Matchmoving is the process of creating a virtual camera or recreating its path in order to match computer generated imagery such as visual effects with the actual footage allowing a smooth transition (Hornung, 2010).

It is mainly used by graphic artists in fields such as film-making, entertainment and advertising and has a major role in this line of work.

In cases where there is camera motion in footage, the added artificial imagery has to be positioned properly in the scene or should follow the
camera path in a consistent manner. In order to provide this visually realistic scene and accurate animations, properties of the actual camera have to be defined and its movement path has to be re-created in a 3D space.

This is where matchmoving software comes in. After the footage is imported into this specialized software, several calculation processes take place and the camera path is created. As the final step, computer generated imagery is imported into the scene and merged within a video compositing software.

There are several matchmoving software available for graphic artists. Mainly the entire matchmoving process is identical on each software. However they vary in price, usage, functionality and user interface. Some of them have minimal functionality being able to process only image sequences whereas others have extra features such as support for stereographic imagery and post processing. The software available is listed below [1]:

- 2d3 Vicon Boujou
- 3DEqualizer
- Andersson Technologies SynthEyes
- Autodesk MatchMover
- The Foundry Nuke
- PFTrack
- VooCat
- Voodoo Camera Tracker

MATCH-MOVING PROCESS
Tim Dobbert (2005) explains the basic principle of matchmoving process as conversion of 2D-data on camera and the scene into 3D information. He also defines the process steps as follows:

- Identifying distinctive 2D features in the image sequence.
- Tracking the 2D features throughout the footage and defining their positions in every frame.
- Calculating 3D positions of the tracked features with the help of the 2D tracking data.
- Camera position and path that matches the actual movement is calculated.
- Finally the 3D positions, virtual camera and its path are imported to an animation or 3D modelling software package for further processing.

Matchmoving software uses photogrammetry techniques for the calculations and analyzes the data called parallax, which is simply a change of perspective depending on perceiver’s position. (Dobbert, 2005)

PROPOSALS FOR USING MATCHMOVING SOFTWARE IN ARCHITECTURAL DESIGN PROCESS
The main goal of this research is to involve matchmoving software in different phases of architectural design with its advanced video based 3D environment forming capabilities and to develop new computer aided design methods especially for the use of architectural students. All of the proposed methods within the context of this paper are essentially based on gathering 3D spatial data from 2D information and consequently using this 3D data as design reference. Raw 2D information may be a video shot made in an empty building lot, a district with historical buildings or an untouched natural terrain. It may also be an artificial scene made up with a scale model or a 2D sketch on paper. In every case possible, it is much easier and cheaper for students who are studying architecture to gather spatial information by taking a video shot with a hand held camera and processing it within a matchmoving software than setting up a 3D laser scanner and using it on site. After the 2D information is processed and converted to 3D data, it can be used in different phases of architectural studies such as: architectural environment analysis, preliminary sketching and presentation.

In this paper, an example of digitalizing a scale model by matchmoving technique will be explained and three different matchmoving usage proposals for architectural analysis will be mentioned briefly. For the sketching phase, a case study will be examined. The software, “Andersson Technologies - SynthEyes 2008” will be used in every case study for matchmoving.
**3D SURFACE GENERATION FROM A SCALE MODEL WITH MATCHMOVING**

An imperative benefit of using matchmoving software is its digitalization of a scale-model created in the initial phases of the design process.

In this case study, an amorphous surface made of clay was used to sample the whole process. The steps that take place in this example cover the basics of matchmoving (Figure 1).

Firstly, the scale model was marked by a pen for the software to identify points on the surface and then a 360 degree video shot was made to provide the visual data with enough parallax to the software. The video file was imported to the matchmoving software and automatic tracking was started. As a result of the solving process the software successfully identified the majority of the marked points and recreated the camera path. The unidentified points were selected manually and a manual solve was started to define these points and increase the accuracy of the surface to be generated.

In order to have a smoother mesh, the number of vertices were increased by an interpolation method which defined possible locations of extra nodes. Finally, all the vertices created by the software were selected and a surface generation command was executed.

A typical resulting scene such as the one in this case study includes a coordinate system, a point cloud, generated mesh and the recreated camera path. The scene can be exported to many supported 3D modelling software. There, the scene can be modified and be rendered with scene lights and mapping.

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**Figure 1**
3D surface generation process by matchmoving software

**Figure 2**
1- Marked scale-model made of clay  
2- Identified points on scale model  
3- Generated point cloud in top, left, front and perspective view  
4- Generated surface by the matchmoving software
USING MATCHMOVING IN ARCHITECTURAL ENVIRONMENT ANALYSIS

Video shots can be considered as the transition phase between still-images and 3D computer generated models. Even though they do not provide complete freedom when analyzing a product, gathering data can be much more efficient than still images depending on the type of footage. For that reason in particular, performing the environmental analysis process with video footage may increase visual perception.

Three different usage proposals for the architectural environment analysis were made within this study. They are as follows:

- Facade and ratio expressions for buildings

  Figure 3 shows several frames from a video shot. After the shot was processed, the matchmove software identified features. Following that, some key points such as window frame corners were marked manually and processed again. Resulting scene has 3D locations of these identified points which enables user to create and align simple geometries with facade elements. Representation of facade ratios by a diagonal image was then created within the 3D modelling software.

- Creation of basic 3D representations of elements such as buildings, roads, etc in a design area

  Frames from a video shot of a building can be seen on Figure 4. After the solve process, a point cloud was generated by the matchmove software. Using the 3D points in the scene, basic representations of the buildings were created and the final video was composited with the added 3D solids.

- 3D terrain generation

  Figure 5 shows a terrain generation example

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<th>Figure 3</th>
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<td>Features identified by the matchmove software and visual representation of facade ratios by a diagonal image created within 3D modelling software.</td>
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<th>Figure 4</th>
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<td>Image shows original video shot, basic representations of the buildings created with the help of the matchmove software and composited final video with the added 3D geometry.</td>
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from a video shot [2]. After the solve process, identified points were connected within the matchmoving software to create a mesh of the terrain. The software is also able capture images from the video and project these onto the mesh to create a more visually realistic 3D representation.

**USING MATCHMOVING IN PRELIMINARY SKETCHING PHASE**

The main purpose of using matchmoving in this phase of design process is to use, the most important examples of visual data, video footages, efficiently. Via the specified software’s efficiency of gathering 3D data from video footage:

- 3D environment data can be generated in the design area
- Preliminary sketches can be imported digitally and thus further design studies can be carried on
- Visual design data for the design area will be ready for architects’ use as a reference for the entire design process.

The proposed method is based on digitalizing a preliminary design product in order to enable the architect to do further modifications and digital sketching. Using the data gathered from a 2D sketch, planning and layout decisions can be made and also relations to the surrounding area, terrain and buildings can be observed efficiently (Figure 6). Also with a digitally converted facade sketch, façade elements can be defined on 3D plane and modified within 3D modelling software to finalize their position or relations to each other. The same conversion principle can be applied on a 3D design input - a scale model - without the need of a 3D laser scanner. The model including surrounding

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**Figure 5**
Image shows identified features on the video shot, 3D points and mesh generated by the matchmoving software [2]

**Figure 6**
Layout design study steps
structures and the design area can be used to make further design decisions after the model is digitally converted by matchmoving software to provide necessary 3D reference data.

**FACADE STUDIES WITH MATCHMOVING**

In this case study, using matchmoving software during facade studies in the design process is explained.

Essentially the whole process consists of shooting of a video, gathering the matchmoving solve data and transferring the data between the animation software and the matchmoving software.

As a first step, the scale model of the design area was made and physical tracking markers were inserted to some key points on the model in order to define the location of the digital model to be created and increase the accuracy of the whole matchmoving process. A video shot of the design area was made on the selected model, moving the hand held camera to different positions thus creating parallax in order to provide maximum geometrical data. This video was then imported to matchmoving software and thereby the solving process started.

After the automatic tracking process, the software was able to capture all the tracking markers successfully therefore a manual tracking was not needed at this step. With the calibration step, 3D positions of points were defined, a point cloud was formed and the camera path was recreated. By selecting three points defining the horizontal plane, a coordinate system was set up. Within matchmoving software's modelling interface a rectangular prism representing the building was created and positioned in the scene with the aid of the identified tracking marker points.

Solve data from the matchmoving software including identified 3D nodes, primitive geometry representing the design proposal and the camera path, were then imported to the 3D modelling software. A preliminary facade sketch prepared earlier was also imported and mapped on the rectangular prism. The whole sequence was rendered inside the 3D modelling software. The resulting video shot with the facade sketch and the rectangular prism serves as
Figure 8
Facade study process by using matchmoving technique

Figure 9
Solve result showing identified points in 3D and camera path
a transition step where it will be used in the match-moving software once again to track the elements on the sketch.

After this second solve process, the software identified most of the new points on the facade and calculated their positions in 3D space. Some unidentified points after the automatic tracking were marked by the user and a manual track process was executed to define their 3D positions. Within match-moving software’s modelling interface, the identified points defining the structural elements were converted into polygons.

As a final step, all 3D reference geometry formed in the previous step, identified vertices and camera path, were exported. In the 3D modelling software the newly formed geometries were edited and modified as a part of further design study.

CONCLUSION
In this study several design method proposals were made that aim to use matchmoving techniques’ 3D point generation capabilities. It is anticipated that students of architectural studies may use these proposed techniques in the early stages of their projects to create alternatives or express their ideas, especially when digitalising complex scales models to do further sketching and modifying geometries on polygon level. Exporting the vertex data to supported software to apply parametric design techniques is also possible.

In order to use matchmoving techniques more efficiently in architectural design process, it is necessary to specialise these software products for architectural use. The anticipated software should be utilised in parallel research such as augmented reality, “Video Tracing” (Hengel, et al., 2007) and “Probabilistic Feature Based Model Acquisition” (Pan, Reitmayr and Drummond, 2009) and integrated with these techniques. The predicted specialization steps would be:

- Creating a wizard interface within the matchmoving software that explains the method and directs user the on intervention and input step-by-step.
- Developing a plug-in for 3D modelling or animation software packages.
- Developing fully specialised software that serves as an independent design tool, based on feedback from architects such as expectations and usage.

Figure 10
Facade sketch applied on the solid and identified features on elements
REFERENCES