Creating real-time holograms using the Pepper's Ghost Pyramid technique

Report Name	Outline Project Specification
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1 Project Description

My project is to create a system to produce real time holograms from a camera feed, using the Pepper's ghost pyramid technique. The system is intended for use at the Aberystwyth Science Week next year, however, a prototype could potentially be displayed at this year's event held in mid-March. This project is intended to show case a technique, originally used in stage and theatre productions, and how it can be adapted with the aid of computer science to make an impactful visual display.

The system will take real-time data captured from one, or multiple, cameras from a staging area which will consist of a black background and appropriate lighting to illuminate the subject t. The video feed will then be processed to ensure that the background is black, as due to lighting it is likely to be grey, and the feed will then be displayed on a large monitor to work with a ghost pyramid of appropriate size. The pyramid is square based, made of Perspex, clear acrylic or similar, and open ended at both top and bottom. The pyramid is placed on the monitor and the videos reflect through each side of the pyramid creating an illusion of a hologram in the centre.

To make the final demonstration more interactive, the display will have an accompanying system that allows users to play a charades style game. This would display a topic for the user to act out in the stage area and then others viewing the hologram would be able to guess the activity being performed. This would require a system capable of taking multiple different string inputs (guesses) from users simultaneously, and feeding back to the user if their guess is successful.

Additionally, as a further extension of the project I would like to investigate the use of multiple cameras to build a 3D object as opposed to several 2D images viewable from each side of the pyramid. This would be carried out at the end of the project and would be preceded by a feasibility study and an assessment of suitability for the specific application. The main reason for assessing the suitability is to ensure that value will be added by using a 3D object given the rules of the game.

2 Proposed Tasks

2.1 Research and spike solutions

I have already begun research into how to create video feeds that work with the Pepper's ghost pyramid, however, additional research will be required to implement the more complex features. For the core system, research will be carried out into the best ways to separate the background and foreground of the video, to enable background subtraction.

I plan to use OpenCV and python to implement the corrections required for the video feed. Whilst I have a working proficiency in python, I have not used the OpenCV module in detail. I plan to begin working on a spike solution to test how I can obtain and load a video feed to process it. Some examples, such as a script for edge detection, were provided in the CS34110 Computer Vision module and these could be studied to improve my understanding of OpenCV. Furthermore, research is required into how to gain real-time images from an external camera and for this, knowledge of the camera being used should be obtained.

2.2 Main tasks

2.2.1 Scene and hardware

A staging area will be needed for users to stand in. This will require thought regarding lighting, background, and camera position to enable the system to work correctly. Furthermore, the hardware such as the camera, the computing machine to perform the processing, and the display medium must be considered. Discussion will be required to establish resources currently available within the department. The hardware choices, and their justification, will be detailed in the design documentation.

2.2.2 Image processing and display

I propose to handle the image processing in OpenCV. I would like to take an adapted Feature Driven Development (FDD) methodology where the system is built iteratively by feature using continuous integration (CI). As this project has the possibility of displaying a prototype at the Aberystwyth Science week, a CI strategy would suit it well. Furthermore, FDD offers an appropriate up front design for the system. It is my intention to use Test Driven Development (TDD), as it greatly complements CI and will pair well with FDD. Due to the development scenario of the project, certain implications must be considered to adapt FDD. These include, reduced contact with the on-site customer as well as not having development teams when coding.

2.2.3 The charades game

Finally, the charades game, will require the use of several technologies such as an android or simple web application for the interface, and a way to handle software communication between the actor in the staging area and the users play the game. I intend to continue using FDD, TDD and CI for this stage of the project.

3 Project Deliverables

Design: I plan to produce an overall model of the system and a full feature list as part of the adaptive FDD methodology I wish to use. This will be comprised of various UML diagrams to build up a view of the components of the system architecture. Due to the various parts of the system, initially I will produce use case and component diagrams for the highest levels of abstraction. Activity diagrams and class/object diagrams will be used where appropriate for internal parts of the system.
Produced by: 20.02.2017

Staging area: A technical design for the staging area set up will be provided. During the project the staging area will also be constructed for use in the final presentation.
Produced by: 20.02.2017(Design) – 13.03.2017(basic implementation) – 08.05.2017 (full implementation)

Software and prototype: As mentioned, a prototype (not including the charades game) will be produced earlier in the project and this will form the base of the final full system. The full software system, containing functionality to perform video feed processing and a charades style game, will be included. The system will also come with a full test suite to ensure correct program functionality.
Produced by: 13.03.2017 (Prototype) – 08.05.2017 (Full system)

Documentation: Software documentation, as well as the final technical report, will be produced. The software documentation will be created alongside the code and will aid the understanding of developers reading the code. The technical report will be delivered at the end of the project and will include a technical study to summarise the research undertaken to explain the Pepper's ghost effect.
Produced by: 08.05.2017

4 Initial annotated bibliography

[1] Y. Benezeth, P.-M. Jodoin, B. Emile, et al., "Comparative study of background subtraction algorithms," *Journal of Electronic Imaging,* vol. 10.1117/1.3456695, no. inria-00545479, p. 19, 2010.

A summary of multiple background subtraction techniques and their effectiveness given different types of data. The Article includes a variety of techniques ranging from the simple to the complex and many of the techniques are already implemented in the OpenCV module.

[2] B. Costa, "Explaining the Pepper's Ghost Illusion with Ray Optics," Comsol, 11 January 2016. [Online]. Available: https://www.comsol.nl/blogs/explaining-the-peppers-ghost-illusion-with-ray-optics/. [Accessed 07 02 2017].

Comsol blog that describes the Pepper's Ghost Pyramid implementation used for this project. The blog details in brief how the technique works and explains this with ray tracing. Furthermore, the blog mentions the history of the technique.

[3] OpenCV development team, "Getting started with Videos", OpenCV, 10 November 2014. [Online]. Available: http://docs.opencv.org/3.0-beta/doc/py_tutorials/py_gui/py_video_display/py_video_display.html#display-video/. [Accessed 09 02 2017]

The tutorial pages provided by the OpenCV development team on video manipulation using the OpenCV module. The tutorial details how to handle obtaining a camera feed and this will prove useful for obtaining the feed to be processed from the external camera.

[4] S. Khramthchenko, "A Project Management Application for Feature Driven Development (FDDPMA)", A.L.M thesis, Harvard University, Cambridge, MA, June 2005. [Online]. Available: http://fddpma.sourceforge.net/help/fddpma_thesis.pdf

S. Khramthchenko details his adapted FDD methodology he used when creating a project management application for FDD for his thesis at Harvard university. Not only does his discussion of the methodology he followed (Chapter 2) raise good points for consideration in my own methodology, the project management software he created as a deliverable is freely available and may be worth investigating further.