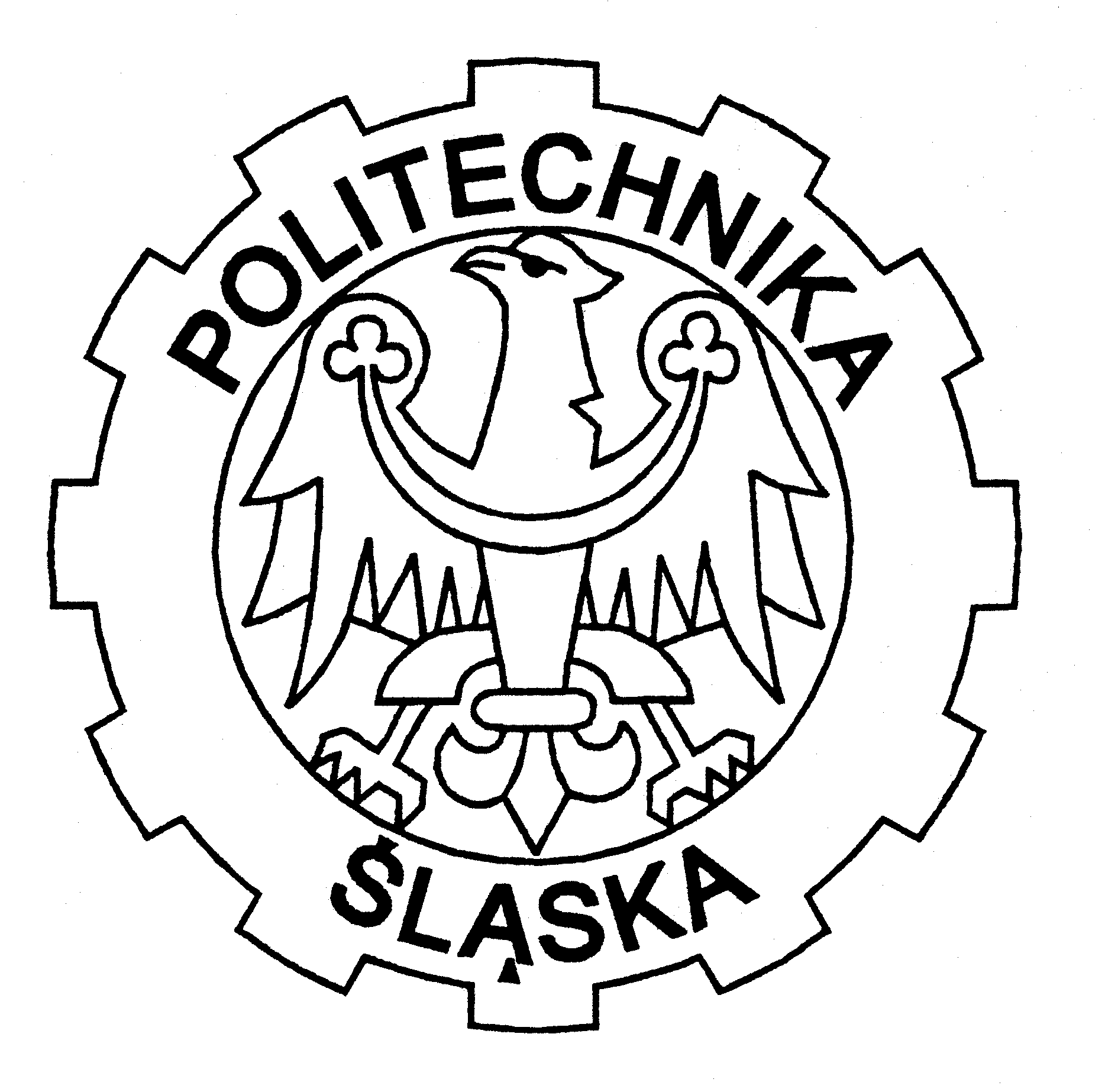
The Silesian University of Technology

– Faculty of Automatic Control, Electronics and Computer Science –



**Master Thesis**

Interactive business cards based  
 on Augmented Reality idea

**Author: Filip Sitko**

**Supervisor: dr inż. Michał Kawulok**

**Gliwice, September 2011**

Contents

1. [Introduction 3](#_Toc298453783)

[1.1. Problem Definition 3](#_Toc298453784)

[1.2. History 6](#_Toc298453785)

[1.3. Applications 9](#_Toc298453786)

[1.4. Requirements 12](#_Toc298453787)

1. [Augmented Reality problem analysis 13](#_Toc298453788)

[2.1. Display 13](#_Toc298453789)

[2.2. Video capture 16](#_Toc298453790)

[2.3. Marker detection 16](#_Toc298453791)

[2.4. Square detection 16](#_Toc298453792)

1. [Project Design 18](#_Toc298453793)

[3.1. Library choice 18](#_Toc298453794)

[3.2. Development Process 18](#_Toc298453795)

[3.3. Project Algorithm 18](#_Toc298453796)

[3.4. GUI 18](#_Toc298453797)

1. [Internal Specification 19](#_Toc298453798)

[4.1. Main program functions 19](#_Toc298453799)

[4.2. Graphical User Interface 19](#_Toc298453800)

1. [External Specification 20](#_Toc298453801)

[5.1. ‘How to’ instruction 20](#_Toc298453802)

[5.2. Errors handling 20](#_Toc298453803)

1. [Testing and results analysis 21](#_Toc298453804)

[6.1. Marker choice analysis 21](#_Toc298453805)

[6.2. Environment dependencies 21](#_Toc298453806)

[6.3. Threshold methods 21](#_Toc298453807)

[6.4. Displaying static image and video 21](#_Toc298453808)

[6.5. Camera parameters 21](#_Toc298453809)

1. [Summary 22](#_Toc298453810)
2. [Bibliography 23](#_Toc298453811)
3. [Contents of the CD 25](#_Toc298453812)

**Chapter 1**

# Introduction

Perception can be certainly considered as an essential factor of human life. Every information about the environment we are living in is received by our senses. Despite of human body imperfections people always tried to improve their perception skills and their inventions helped to find the new ways to explore and understand the surrounding world. Augmented Reality idea introduces a new dimension of perception and opens vast new possibilities that will aid nearly every area of human life.

## Problem Definition

In fundamental terms, the Augmented Reality, often abbreviated to **AR** is an area of Mixed Reality that refers to the real-time view of a physical world which is augmented by elements generated or triggered by a computer input and can be considered as the connection between the real world and the virtual one. Given real subject image captured by a camera is processed and combined with virtual layers (such as graphics, sounds, data and even smells which are triggered by computer input).

Most common definition was created by Ronald Azuma who described it as follows: “*Augmented Reality* (AR) is a variation of *Virtual Environments* (VE), or Virtual Reality as it is more commonly called.

VE technologies completely immerse a user inside a synthetic environment. While immersed, the user cannot see the real world around him. In contrast, AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it. (…) this survey defines AR as systems that have the following three characteristics:

* Combines real and virtual
* Interactive in real time
* Registered in 3-D” **[1]**



Figure 1.1.1. Real desk with virtual lamp and two virtual chairs. (Courtesy ECRC)

Augmented Reality is commonly mistaken with Virtual Reality, hence to provide better understanding of Augmented Reality the Paul Milgram’s Virtuality Coninuum**[2]** graph (Figure 1.1.2.) should be introduced to show the general classification of Mixed Reality areas and their unique features.

**MIXED REALITY(MR)**

**VIRTUAL  
ENVIRONMENT**

**AUGMENTED  
VIRTUALITY (VR)**

**AUGMENTED  
REALITY (AR)**

**REAL  
ENVIRONMENT**

Figure 1.1.2. Paul Milgram’s Virtuality Continuum graph.

Nowadays technology based on Mixed Reality is rapidly developed and distinct boundaries of each area are impossible to define.**[3]** However to remark the main differences between them each one can be described by a short definition and unique features:

* **Real environment:**

View of the real, physical world as it can be perceived directly.

* **Augmented Reality(AR):**

Real world view augmented by a computer- generated inputs which create a possibility of interaction.

* **Augmented Virtuality(AV):**

Virtual space view augmented by a real world inputs most commonly used for Human-Computer Interaction(HCI).

* **Virtual Reality(VR):**

Fully simulated world view which provides environment elements controlled by a real world input.

Reproduction Fidelity (FR) of the virtual image should be proportional to the quality of captured image of the real world.  
Basing on Reproduction Fidelity graph (Figure 1.1.3.) it can be noticed that to obtain the most realistic views combination the computer-generated models details should be real world image fidelity dependent (e.g. High fidelity 3D model with shadings and textures would look unnatural if projected on low-resolution monoscopic video).

**COLOUR VIDEO**

**STEREOSCOPIC VIDEO**

**3D HDTV**

**HIGH DEFINITION VIDEO**

**CONVENTIONAL  
(MONOSCOPIC)  
VIDEO**

**REAL-TIME  
 HIGH FIDELITY 3D ANIMATION**

**SHADING, TEXTURE, TRANSPARENCY**

**VISIBLE SURFACE IMAGING**

**RAY TRACING, RADIOSITY**

**SIMPLE WIREFRAMES**

Figure 1.1.3. Paul Milgram’s Reproduction Fidelity(FR) graph based on Naimark’s Taxonomy.

## History

Augmented Reality in form which is known nowadays was imagined as a technology of the future since the first computer was designed. People could observe multiple applications of AR in science-fiction movies but did not know that this concept was already researched. Rapid development of AR can be noticed within last 10 years and is commonly considered to be the one of the inventions of XXI century.

This belief is incorrect as the beginning of AR is dated for 1962 as Morton Heilig created a bicycle simulator called Sensorama (Figure 1.2.1.) based on multimodal (multi-sense) technology. The machine could provide stereoscopic 3D vision in wide-angle view, body tilt, stereo sound and even wind tracks and smells triggered as the film was displayed. As nearly all senses were involved during the simulation Sensorama gave the general idea of Augmented Reality which was developed further using the computer.

Ivan’s Sutherland invention of the first head-mounted display named Sword of Damocles (Figure 1.2.2.) in 1968 was the next m ile step in AR history. Allowing to see computer-generated wireframe rooms according to user head position it gave the background for user interaction with virtual world.

In 1975 Myron Krueger established artificial reality laboratory called Videoplace. Based on cameras, projectors and computer hardware it created an interactive artificial environment for the first time.

These inventions aroused interest of Augmented Reality and from this point it became a popular subject of studies and computer science research. In 1989 Jaron Lanier coined the ‘Virtual Reality’ phrase by leading the company that sold VR goggles and gloves. In 1990 Tom Caudell an aircraft manufacturer popularized ‘Augmented Reality’ phrase.

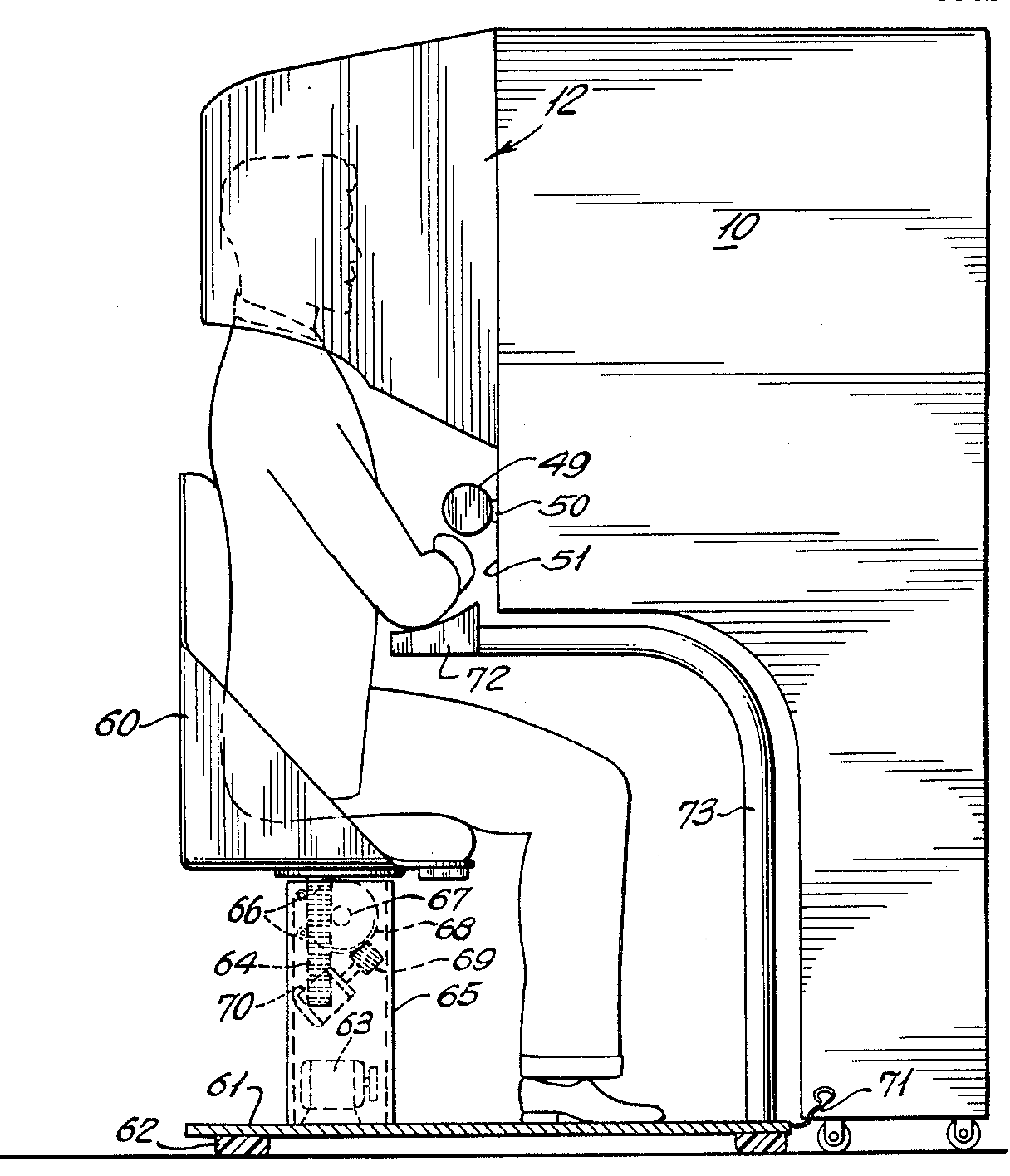


Figure 1.2.1. Morton Heilig's Sensorama. [Figure 5 of U.S. Patent #3050870]

Figure 1.2.2. Ivan’s Sutherland Sword of Damocles**[4]**

1994 introduced Paul Milgrim’s Vrtuality Continuum concept (Figure 1.1.1.) and classified Augmented Reality as an area of Mixed Reality specifying it’s boundaries and unique features.

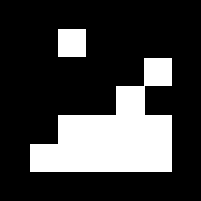
In 1996 Jun Rekimoto presents 2D matrix markers (Figure 1.2.3) - square-shaped barcodes, one of the first marker systems to allow simultaneously identify real world objects and estimate their coordinate systems.

Figure 1.2.3. Jun Rekimoto’s exemplary 2D matrix marker**Bibliography**

Commonly known definition of the Augmented Reality term and it’s field was defined by Ronald Azuma in “A Survey of Augmented Reality” in 1997. His paper survey described first AR systems from basis and it is popular material even for today’s research purposes.

The release of the ARToolkit- open source computer vision tracking library developed by Hirokazu Kato at the HITlab was the real milestone for the AR research. It began new wave of interest among developers and opened a new possibilities of AR programming.

The first game based on Augmented Reality concept “ARQuake” was developed in 2002 and started by it’s inventor Bruce H. Thomas. It provided outdoor first-person shooter based on virtual environment generated upon real world captured images.

ARToolkit was redesigned and ported to Adobe Flash (FLARToolkit) by Tomohiko Koyama (Saqoosha) in 2009 bringing Augmented Reality to web browsers and starting a new trend wave of web- based AR applications.



Figure 1.2.4. ARToolkit based 3D model projection **[4]**

Figure 1.2.5. ARQuake outdoor combined views image **[4]**

Augmented Reality technology is rapidly developed nowadays for variety of platforms starting with personal computers through mobile devices and ending with touch screens and technical aparatures.According to Rick’s Oller: “The future of augmented reality holds tremendous promise. With display technology getting better, smaller, lighter and requiring less power every year, it is only a matter of time before augmented reality displays can be fitted to an ordinary pair of glasses, or even contact lenses.” **[5]**

## Applications

Augmented Reality idea provides variety of new perception and interaction possibilities which are used in almost every field of human life. The applications of AR are practically limited only by imagination and technical development process. Although AR is rather new technology the rapid thrive in development brought it to daily life often staying unnoticed. Focusing only on common applications Augmented Reality can be used for:

* **Navigation:**AR can be used as a navigation tool which helps to define object positions in challenging environmental conditions. Combined with GPS functionality outdoor objects recognition and virtual routes can provide all the necessary data to enhance navigation process. Digital maps and object/human position indication aid the exploring and tracking tasks.
* **Sightseeing:**

Stored data with history and object descriptions, interactive animations and audio guides and even visual routes to places of interest are really attractive additions for sightseeing tours. AR technology can provide it almost everywhere, so usually head- mounted or mobile displays are designed for this purpose as their size and mobility are essential.

* **Military:**Detailed mission briefings, GPS-based navigation routes and location data, digital maps, enemy locations or even enhanced firing systems are introduced to the military with AR technology usage. Head- mounted display and goggles with addition of other devices (GPS receivers, orientation trackers, computers and handheld control devices) are the most suitable solutions for this propose as it requires to be mobile since it is used by troops.
* **Medicine:**

Medical students use the technology to practice surgery in a controlled environment. Visualizations aid in explaining complex medical conditions to patients. Surgery risk ratio is significantly reduced as surgeons get improved sensory perception during complicated operations. AR combined with MRI or X-ray systems can be an invaluable tool bringing all of them into one view.

* **Maintenance and task support:**

Using head worndisplay a mechanic can be aided by additional data, instructions and label for specified object’s parts. Repairing procedures can be provided in adverse environmental conditions and specialist training expenses are reduced by using simulations.

* **Advertising and promotion:**

Promotion through interactive animations, 3d models and games is becoming popular. New web services, company products and even movies are advertised with simple AR gadgets enticing to play and interact.

* **Entertainment:**AR technology influenced the gaming market starting new type of interactive entertainment applications and games to emerge. Bringing 3D virtual world into reality created fertile ground for developing new mobile and outdoor games and social such as sporting events and concerts.
* **Education:**Since beginnings AR technology stayed in association with educational institutions. Many AR research breakthroughs have been accomplished by college and universities teams, as prototypes and still developed devices were available as multipurpose educational tools. Providing possibility of real-time processing it can be used for presentations, training simulations and development research.
* **Industry:**Augmented reality can provide hands-free visual overlays of dynamic manufacturing information targeted to specific, highly controllable automated and semi-automated assembly environments. Computer generated virtual project prototypes can replace the real ones reducing the final product expenses.
* **Architecture:**Virtual models mockups and simulations could be projected on one platform aiding the design and planning process. As it provides possibility of collaboration on shared models it can be used as a powerful tool improving planning and communication process.
* **Translation:**Real-time dynamic subtitles display and text translation can really enhance communication process. Font and text recognition and even simple mathematical problems solution can be achieved using this unique feature.

These are only the main applications of Augmented Reality narrowed to the ones we are using nowadays.**[5][6]** Taking into account technical development progress we can expect more of them in near future as every unique area of life can be simplified, each object can be augmented to be more usable and each action can give extraordinary experience which cannot be obtained in real life.

Figure 1.3.1. Virtual fetus inside womb of pregnant patient. (Courtesy UNC Chapel Hill Dept. of Computer Science.)**[1]**

Figure 1.3.2. Head-up display for a fighter plane**[3]**

## Requirements

Final project’s design should provide simple AR elements to the final business cards labeled by 2D black and white markers. Created application should meet the following requirements:

* **Main detection algorithm written in C++:**

C++ usage should enhance the algorithm speed and influence on overall performance level.

* **High accuracy marker recognition:**

Business card markers must be detected and matched with selected template to display a virtual graphical element.  
High spectrum of marker angle and environment lightness level acceptance would improve the interaction process.

* **Real- time image processing (min 12 FPS):**

To provide high quality interaction acceptable Frames Per Second ratio has to be achieved. Lower FPS processing would create an illusion of delay.

* **Image and video display:**

Simple computer-generated graphical inputs should be combined with real, physical world image capture. Usage of AR technology in this case will project photos and videos that will aid the personal identification of the business card holder.

* **Graphical User Interface:**

Simple and intuitive GUI that would make the whole application more user- friendly and allow to use every program feature in a convenient way.

**Chapter 2**

# Augmented Reality problem analysis

There are several approaches to obtain the desired effect for Augmented Reality implementation. However each of them has the unique features designed for specific type of devices and environments in which they are used in. Some of them should not be used for this project purposes, hence strengths- weaknesses analysis of each approach property will reveal most suitable solution to achieve the project goals.

## Display

Augmented Reality based technology is classified in regard of displays used for combined computer- generated input and real physical world captured images visualization. According to Oliver Bimber and Ramesh Rascal:

“Augmented reality displays are image-forming systems that use a set of optical, electronic, and mechanical components to generate images somewhere on the optical pathin between the observer’s eyes and the physical object to be augmented” **[7]**.

There are 3 major display techniques**:**

**REAL OBJECT**

**SPATIAL OPTICAL  
SEE-THROUGH DISPLAY**

**HAND- HELD DISPLAY**

**RETINAL DISPLAY**

**HEAD- MOUNTED DISPLAY**

**PROJECTOR**

**PROJECTOR**

**PROJECTOR**

**SPATIAL**

**HANDHELD**

**HEAD-ATTACHED**

Figure 2.1.1. Image generation graph for augmented reality displays inspired by Oliver Bimber and Ramesh Raskar **[8]**

* **Head-Attached displays:**
* **Handheld displays:**
* **Spatial displays (SAR):**

## Video capture

-Uzywanie tylko jednej kamery i jej kalibracja.

-Uzywanie dwoch kamer do stworzenia wirtualnej rzeczywistosci 3d

## Marker detection

- Marker tracking na podstawie template’a

- Wykrywanie kwadratu i template’a

- Wykrywanie znakow szczegolnych- kolory

## Square detection

- 3 thresholding methods + contours + approxpoly

- Canny contour finding + Hough line finding + approxpoly

**Chapter 3**

# Project Design

## Library choice

Opis znanych mi bibliotek do tworzenia AR + historia ich powstawania + porownianie ich mozliwosci (plusy I minusy)- na koniec wybor OpenCV- dlaczego

## Development Process

Opis w jakis spoosb powstawal program – krotka notka o google code svn

## Project Algorithm

Pelny opisowy algorytm projektu + schemat blokowy

## GUI

Opis wyboru srodowiska do tworzenia GUI I krotki opis jego powstania

**Chapter 4**

# Internal Specification

## Main program functions

Dokladny opis funkcjio uzytych w programie oraz rozwieniecie teaoretyczne + wzory przy kluczowych funkcjach (thresholding, homograficzna transforacja, podkladanie obrazu itp)

## Graphical User Interface

Dokladniejszy opis GUI I podzial na poszczegolne elementy.

**Chapter 5**

# External Specification

## ‘How to’ instruction

Instrukcja w jaki sposob uzywac aplikacji

## Errors handling

Opis najczestrzych errorow (np brak zaladowanego markera lub obrazka czy wideo)

**Chapter 6**

# Testing and results analysis

## Marker choice analysis

Porownanie roznych markerow I dokladnosci ich wykrywania

## Environment dependencies

Porowanie wynikow wykrycia markera dla roznych srodowisk (jasno, normalnie, ciemno)

## Threshold methods

Rozne metody thresholdu

## Displaying static image and video

Porownanie wyswietlania obrazkow I wideo

## Camera parameters

Wyniki dla roznych kamer (w laptopie, statyczna Logitech, creative social hd z autofocusem)

**Chapter 7**

# Summary

Krotkie podsumowanie calosci

# Bibliography

[1] Ronald Azuma. “A Survey of Augmented Reality”, *Presence: Teleoperators and Virtual Environments* vol. 6, no. 4, pp. 355-385, August 1997.

[2] P. Milgram and A. F. Kishino, “Taxonomy of Mixed Reality Visual Displays” *IEICE Transactions on Information and Systems*, vol. E77-D no. 12, pp. 1321-1329, 1994.

[3] Joe Lamantia. “Inside Out: Interaction Design for Augmented Reality” *UXmatters*, August 17, 2009.

[4] Christian Doppler. “History of Mobile AR”, Laboratory for Handheld Augmented Reality,   
(accessed 12/07/2011)

[5] Rick Oller. “Augmented Reality”, Scribd.com, April 2010.  
http://www.scribd.com/doc/44664310/Augmented-Reality  
(accessed 14/07/2011)

[6] Tim Perdue. “Applications of Augmented Reality”, About.com Guide,  
http://newtech.about.com/od/softwaredevelopment/a/Applications-Of-Augmented-Reality.htm  
(accessed 14/07/2011)

[7] Gary Bradski, Adrian Kaehler. “Learning OpenCV Computer Vision with the OpenCV Library”, O’Reilly Media, 2008.

[8] Oliver Bimber, Ramesh Raskar. „Spatial Augmented Reality

Merging Real and Virtual Worlds”, A K Peters, Ltd., pp. 71-90, 2005.

[9]

[10] Gianpierre Villagomez. “Augmented Reality” University of Kansas, lectures materials, vol.3, December 2010.

[11]

[12]

[13]

[14]

# Contents of the CD

The content of attached CD directory structure is described by the following diagram:

**SRC**…………………………………………………………..………….**SOURCE CODE**

**EXC**………………………………………………………………...…….**EXECUTABLES**

**LIB**……………………………………………………..………………**USED LIBRARIES**

**OPECV**

**RSC**…………………………………………..……………………………..**RESOURCES**

**TEMPLATE.JPG**

**TEMPLATE.PSD**

**IMAGE.JPG**

**VIDEO.AVI**

**DOC**………………………………………………………………………**DOCUMENTATION**