PA198
Augmented Reality Interfaces

Lecture 2
Augmented Reality Software

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AR Solutions

- In the past only few tools
- Nowadays loads of solutions
  - Open Source
  - Proprietary
  - End-to-End Branded App Solutions

Open Source

- ARToolKit
  - Dual-license:
    - GPL, commercial
  - C-library
  - Ported to different languages and platforms
    - i.e. Android, Flash, Silverlight, etc
  - More later on...

Argon

- AR browser by Georgia Tech's GVU Center
- Uses a mix of KML and HTML/JavaScript/CSS for developing AR applications
- Any web content can be converted into AR content
  - With appropriate meta-data and properly formatted
- As of November 2011, available for iPhone only

http://argon.gatech.edu/

ArUco

- Minimal library for AR applications
  - Trivial integration with OpenGL and OGRE
- OpenCV implementation
  - Up to 1024 different markers
- Licenses:
  - BSD, Linux, Windows

http://www.uco.es/investiga/grupos/ava/node/26
JavaCV

- Java/Android interface to OpenCV
- Licenses
  - GPLv2

[Image of JavaCV]

ATOMIC Authoring Tool

- Created as a front end (Graphic Interface) for use ARToolKit without having to know programming
- Written in Processing
- Multi-platform authoring for creating AR applications
  - Microsoft Windows, Linux and Mac OS X operating systems

[Image of ATOMIC Authoring Tool]

Goblin XNA

- Platform for researching 3D user interfaces emphasizing games
  - Mobile augmented reality and virtual reality
- Implementation in C#
- Based on Microsoft XNA Game Studio 4.0
- BSD license

[Image of Goblin XNA]

GRATF

- GRAFT (Glyph Recognition And Tracking Framework)
- Does localization, recognition and pose estimation of optical glyphs in still images and video files

[Image of GRATF]

Mixare

- Mixare (mix Augmented Reality Engine) AR browser
  - Published under the GPLv3
  - Available for Android iPhone

[Image of Mixare]

PTAM

- PTAM (Parallel Tracking and Mapping) is a camera tracking system for AR
- Requires no markers, pre-made maps, known templates or inertial sensors
- Non-commercial use only

[Image of PTAM]
DroidAR

- AR framework for Android
- Features location based and marker based AR
- Open source (dual-license):
  - GPLv3 or commercial

[Image: https://github.com/bitstars/droidar]

GeoAR

- Open source (Apache 2.0 License) browser for Android
- Features location based AR and a flexible data source framework

[Image: https://wiki.52north.org/bin/view/Projects/GeoAR]

BeyondAR

- Open source (Apache 2.0 License)
- AR framework based on geo-localisation for Android

[Image: http://beyondar.com/]

Proprietary

Kudan AR Engine

- AR SDK for iOS and Android devices
- Powerful Rendering
  - Multi-million polygon 3D models
- Advanced Tracking
  - Markerless

[Image: http://www.kudan.eu/]

Vuforia Augmented Reality SDK

- The Vuforia SDK supports different types of targets
  - both 2D and 3D, including multi-target configurations, cylinder targets to track images on a cylindrical surface, marker less image targets, frame markers and cloud recognition targets to track 1 million targets simultaneously
- SDK supports both iOS and Android

[Image: http://www.qualcomm.com/products/vuforia]
Vuforia Features

- Provide faster local detection of targets with capacity of tracking 5 targets simultaneously
- Efficient tracking in low light conditions and even though target is covered partially
- Extended tracking capabilities, which enable app to keep tracking targets and helps maintain a consistent reference for augmentations of object even when the targets are no longer visible in real time camera view

Metaio SDK

- Modular framework which consists of different components
  - Rendering, capturing, tracking and the sensor interface
- Compatible with all major platforms:
  - Android, iOS, Unity3D and Windows
- SDK contains:
  - Marker or marker-less 2D and 3D tracking
  - POI’s tracking
  - Support for QR code and barcode reading
  - Built in 3D renderer
  - Optimizations for mobile chips
  - etc.

Metaio Features

- Provides high level of abstraction
- Provides powerful 3D rendering engine and highly advance tracking
- Support for obj, fbx and md2 model formats for 3D objects
- Direct loading of 3D models is supported with abstraction of OpenGL calls
- Includes AREL scripting language
  - AR experiences based on common web technologies
    - i.e. XML, HTML5 and JavaScript

End-to-End Branded App Solutions
Alive app

- Developed by Times Internet Ltd
- Recognise pre-trained images and overlay an image, video or 3D content
- Available on:
  - Android, iOS, Windows, Blackberry Symbian and Java

http://www.alive.com/

Aurasma

- HP Autonomy’s AR platform
- Available as SDK or free app for iOS and Android
- Recognize real world images and then overlay graphics
- Created in Cambridge

http://www.aurasma.com/

Blippar

- Visual browsing app using image-recognition and AR technologies
- Focused on smartphones, tablets or wearables

http://blippar.com/en/

Junaio

- AR browser designed for 3G and 4G mobile devices
- First AR browser that has overcome the accuracy limitations of GPS through LLA Markers
  - i.e. latitude, longitude, altitude marker, patent pending

http://www.junaio.com/

XARMEX

- XARMEX (eXtended Augmented Reality for Military EXercise)
- AR-aided Close quarters combat simulation system, combining motion detection hardware with image overlay/stabilization software to create realistic military simulation environments and computer games

http://en.wikipedia.org/wiki/XARMEX

Layar

- Mobile browser
- Can enhance—flyers, postcards, packaging or any other item with interactive content, including video messages, Web and social links, photo slideshows

http://www.layar.com/
Wikitude

- Mobile AR technology provider
  - Based in Salzburg, Austria
  - Founded in 2008
- Initially focused on providing location-based AR experiences through the Wikitude World Browser App
- In 2012, introduced Wikitude SDK
  - Uses image recognition and tracking
  - Geo-location technologies

Wikitude Video

http://www.youtube.com/watch?v=JnemoNQTa_w

D’Fusion

- Integrates real time interactive 3D graphics contents on a live video stream
- SDK available in different platforms
  - i.e. desktop, mobile and special Flash Plug-in

D’Fusion Features

- It is more UI based
  - D’Fusion Studio
  - D’Fusion CV
- Enables to build the whole scenario through the GUI
- One bundle scenario will work on both Android & iPhone
- Supports multi-tag and face-tracking

D’Fusion Video

https://www.youtube.com/watch?v=6NKT6eUGJDE
**ARmedia 3D**

- Uses a 3D model tracking approach
  - Recognizes planar images and complex 3D objects independently of their size and geometry
- SDK architecture consist of renderer to render 3D model, tracker to track the target, capture for capturing frames from the device camera and interface to native android and iOS
- Cross-platform and implemented in C/C++

**ARmedia Features**

- Provides 3D tracking of real world objects in real time in **changing lighting conditions**
- Provides modularity
  - Can integrate between different tracking algorithms and different 3D engines and interface
  - Different tracker parameters can be fixed to fine tune the results
  - Easily integrate with any other AR platform
  - 3D target creation and management services are available on cloud

**AR Media Video**

**ARToolKitPlus**

- Mobile version of ARToolKit
  - First approach
  - Development stopped June 2006
- Succeeded by Studierstube Tracker
  - It is a marker tracking library
    - [http://handheldar.icg.tugraz.at/stbtracker.php](http://handheldar.icg.tugraz.at/stbtracker.php)

**Comparison of AR SDK’s**

- Based on free and open-source SDK’s
- Popular SDK’s
  - Metaio
  - Vuforia
  - Wikitude
  - D’Fusion
  - Armedia
  - ARToolKit
### Based on License Type

<table>
<thead>
<tr>
<th>AR SDK Type</th>
<th>Vuforia</th>
<th>Metalo</th>
<th>Wikitude</th>
<th>ARToolKit</th>
<th>D'Fusion</th>
<th>ARmedia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open source</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Free</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Commercial</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tr>
</tbody>
</table>

### Based on Platform Supported

<table>
<thead>
<tr>
<th>AR SDK Type</th>
<th>Vuforia</th>
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<th>ARToolKit</th>
<th>D’Fusion</th>
<th>ARmedia</th>
</tr>
</thead>
<tbody>
<tr>
<td>iOS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Android</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Windows</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### Based on Marker Generation

<table>
<thead>
<tr>
<th>AR SDK Type</th>
<th>Vuforia</th>
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<th>ARToolKit</th>
<th>D’Fusion</th>
<th>ARmedia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online target marker.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Support generation of frame, image markers.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Online target manager.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Provide creation of target collection of multiple targets.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Provide set of predefined square markers in a PDF file.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Provide dataset of 300 images to use as marker.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### Based on Tracking

<table>
<thead>
<tr>
<th>AR SDK Type</th>
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<th>Wikitude</th>
<th>ARToolKit</th>
<th>D’Fusion</th>
<th>ARmedia</th>
</tr>
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<tbody>
<tr>
<td>GPS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>IMU</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Face</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Natural Frame</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Shadows</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Others</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### Based on Overlaying Capability

<table>
<thead>
<tr>
<th>AR SDK Type</th>
<th>Vuforia</th>
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<th>Wikitude</th>
<th>ARToolKit</th>
<th>D’Fusion</th>
<th>ARmedia</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D content</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3D content</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Others</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

### Benefits of Different AR SDK’s

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Vuforia</th>
<th>Metalo</th>
<th>Wikitude</th>
<th>ARToolKit</th>
<th>D’Fusion</th>
<th>ARmedia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enable to maintain tracking even when the target is out of view and view them from greater distance.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>CloudBased allows using thousands of image targets.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Powerful 3D rendering engine with capability load 3D model of Obj Format.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>No limit on number of interactive objects depends on device memory.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>All content can be programmed using native HTML5, JavaScript, and CSS.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Easy portability of AR apps from one platform to another.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Multiple platforms AR app development possibilities.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Only AR SDK which is available as open source, through which many new AR frameworks developed.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Depth camera calibration provided which creates more immersive experience</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Easy portability of AR apps from one platform to another.</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
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<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Limitation of Different AR SDK’s

<table>
<thead>
<tr>
<th>Limitation</th>
<th>Vuforia</th>
<th>Motevio</th>
<th>Wikitude</th>
<th>ARToolKit</th>
<th>D’Finion</th>
<th>ARmedia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vuforia SDK for Android does not expose any utility function to easily load a 3D model from any standard format.</td>
<td>Device database can only support 100 image targets.</td>
<td>Difficult to render complex 3D objects also limitation is associated with model size.</td>
<td>Doesn’t track 3D model which limits is use to only 2D tracking.</td>
<td>Less accuracy in tracking markers even when camera and marker are still. It itself doesn’t support location based augmented reality.</td>
<td>Video file supported but audio associated with video can’t be played.</td>
<td>Doesn’t support all type of textures for 3D objects.</td>
</tr>
</tbody>
</table>

How Does ARToolKit Work

- The camera captures video of the real world and sends it to the computer
- Software on the computer searches through each video frame for any square shapes
- If a square is found, the software uses some mathematics to calculate the position of the camera relative to the black square
- Once the position of the camera is known a computer graphics model is drawn from that same position
- This model is drawn on top of the video of the real world and so appears stuck on the square marker
- The final output is shown back in the handheld display, so when the user looks through the display they see graphics overlaid on the real world

Computer Vision Algorithm

- Based on a basic corner detection approach with a fast pose estimation algorithm

ARToolKit Basics

How Does ARToolKit Work

Computer Vision Algorithm
ARToolKit Coordinate Systems

• ARToolKit defines different coordinate systems mainly used by the computer vision algorithm and the rendering
• You need to precisely understand relations between them to prevent reverse image or bad position object display

Computer Vision Coordinate System

• arGetTransMat give the position of the marker in the camera coordinate system
  – Not the reverse
• Tip:
  – If you want the position of the camera in the marker coordinate system you need to inverse this transformation
    • arMatrixInverse()

Rendering Coordinate System

• When you use ARToolKit with OpenGL, remember that OpenGL is a right-handed coordinate system, with Z coming to you
  – i.e. the camera is facing in the direction of -Z

• ARToolKit uses a calibrated camera perspective that results in an off-axis projection matrix for OpenGL
  – Can not be created by calling gluPerspective, but requires the extra parameters of glFrustum
• Rather than decomposing ARToolKit’s projection into parameters to pass to glFrustum, directly load the OpenGL projection matrix by:
  – Setting glMatrixMode(GL_PROJECTION_MATRIX)
  – Calling glLoadMatrix

Rendering Coordinate System ..
ARToolKit Framework

Introduction to Framework

• ARToolKit is a software ToolKit like GLUT
• It furnishes predefined functions that need to call in a specific order for developing an AR application
  – Can also use different parts of the ToolKit separately
• ARToolKit supports multiple platforms
  – While attempting to minimise library dependencies without sacrificing efficiency

Introduction to Framework.

• ARToolKit uses
  – OpenGL for the rendering part
  – GLUT for the windows/event handler aspect
  – Hardware-dependent video library
  – Standard API on each platform
• The API is in C and a lot of samples provide good starting points for creating new applications
  – Skeleton framework

ARToolKit Architecture

• The ARToolKit library consists of four modules:
  – AR module: core module with marker tracking routines, calibration and parameter collection
  – Video module: a collection of video routines for capturing the video input frames
  – Gsub module: a collection of graphic routines based on the OpenGL and GLUT libraries
  – Gsub Lite module: replaces GSub with a more efficient collection of graphics routines, independent of any particular windowing toolkit

Hierarchical Structure of ARToolKit

• Hierarchical structure of ARToolKit using Gsub Module
Hierarchical Structure of ARToolKit

- Hierarchical structure of ARToolKit using Gsub_Lite Module

ARToolKit Pipeline

- The modules respect a global pipeline metaphor — i.e. video -> tracking -> display
- User can easily replace any module with another — i.e. gsub with Open Inventor renderer

Data Types

- ARToolKit manipulates a lot of different kinds of variable
- Internally, it uses global variables, that restrict re-entrant part of the code
- Otherwise, standard multi-argument interface are used based on a data-flow approach
- ARToolKit uses different image formats between different modules

ARToolKit Data-Flow

- Information about the detected markers is contained in the ARMarkerInfo structure defined in ar.h in the include directory

ARToolKit Documentation

- All ARToolKit functions generally begin with the prefix ar, and a specific prefix for each module
  - arVideo for video
  - arg for graphics
  - ar for main core
- More information:

ARToolKit Hardware
ARToolKit Camera

- The choice of a camera is the most important
  - Resolution, frame-rate, optics distortion, are some of the main parameters for selected your camera
- But supported platforms, parameters of the driver (like auto-contrast) can also influence your choice
- Some cameras enable by default auto-contrast that decrease your performance, or offers 25Hz frame-rate with a lost of image quality
  - i.e. distortion, latency lag

http://www.hitl.washington.edu/artoolkit/documentation/hardware.htm

ARToolKit Camera

- The most efficient solution keep a video capture card with a PAL or NTSC camera that offers a large choice and a really good quality camera
  - But a PAL camera can be really expensive according its characteristics
- The signal deliver is RGB image (color palette) that reduce hardware or software palette conversion cost

http://www.hitl.washington.edu/artoolkit/documentation/hardware.htm

ARToolKit Camera

- The traditional choice is USB or Firewire camera
- Can notice that frame-rate or color palette (RGB, YUV, YUV compressed) depend mainly on the bandwidth of the technology
- USB Camera used generally compressed format transmission like YUV:4:2:2 YUV:4:1:1
  - i.e. lossy compression
- Firewire Cameras offers better solution, but camera with full RGB color palette are generally expensive
  - A compressed format in VGA remains a good choice

http://www.hitl.washington.edu/artoolkit/documentation/hardware.htm

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<table>
<thead>
<tr>
<th>ArtoolKit Camera Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
</tr>
<tr>
<td>USB1.1</td>
</tr>
<tr>
<td>IEEE1394a</td>
</tr>
<tr>
<td>PCI32bit1.0 (33Mhz)</td>
</tr>
<tr>
<td>PCI64bit2.0 (33Mhz)</td>
</tr>
<tr>
<td>USB2.0</td>
</tr>
<tr>
<td>IEEE1394b</td>
</tr>
<tr>
<td>PCI32bit2.1 (66Mhz)</td>
</tr>
<tr>
<td>PCI64bit2.1 (66Mhz)</td>
</tr>
</tbody>
</table>

http://www.hitl.washington.edu/artoolkit/documentation/hardware.htm

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<table>
<thead>
<tr>
<th>ArtoolKit Camera Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Format</td>
</tr>
<tr>
<td>SIF RGB 15 fps</td>
</tr>
<tr>
<td>SIF RGB 30 fps</td>
</tr>
<tr>
<td>SIF YUV 4:1:1 15 fps</td>
</tr>
<tr>
<td>SIF YUV 4:1:1 30 fps</td>
</tr>
<tr>
<td>VGA RGB 15 fps</td>
</tr>
<tr>
<td>VGA RGB 30 fps</td>
</tr>
<tr>
<td>VGA YUV 4:1:1 15 fps</td>
</tr>
<tr>
<td>VGA YUV 4:1:1 30 fps</td>
</tr>
</tbody>
</table>

http://www.hitl.washington.edu/artoolkit/documentation/hardware.htm

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HMDs and ARToolKit

- ARToolKit uses computer vision techniques for image-based recognition and tracking
- Since it uses only a single camera, a self-contained head tracking system can be developed if this camera is fixed to an HMD
- In this way AR applications can be developed which use HMDs

http://www.hitl.washington.edu/artoolkit/documentation/hardware.htm
Non-HMD and ARToolKit

- It is not necessary to have a head mounted display to use the ARToolKit
  - A camera connected to a computer is the only requirement
- Without an HMD ARToolKit applications can be viewed on a computer monitor
  - With an HMD a more immersive experience can be created

ARToolKit Limitations and Benchmarks

General Limitations

- There are some limitations to purely computer vision based AR systems
- Naturally the virtual objects will only appear when the tracking marks are in view
- This may limit the size or movement of the virtual objects
- It also means that if users cover up part of the pattern with their hands or other objects the virtual object will disappear

Limitations Range

- The larger the physical pattern the further away the pattern can be detected and so the great volume the user can be tracked in

<table>
<thead>
<tr>
<th>Pattern Size (inches)</th>
<th>Usable Range (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.75</td>
<td>16</td>
</tr>
<tr>
<td>3.50</td>
<td>25</td>
</tr>
<tr>
<td>4.25</td>
<td>34</td>
</tr>
<tr>
<td>7.37</td>
<td>50</td>
</tr>
</tbody>
</table>

Limitations Pattern Complexity

- The simpler the pattern the better. Patterns with large black and white regions are the most effective
  - i.e. low frequency patterns
- Replacing a 4.25 inch square pattern with a pattern of the same size but much more complexity will reduce the tracking range from 34 to 15 inches

Limitations Marker Orientation

- Tracking is also affected by the marker orientation relative to the camera
- As the markers become more tilted and horizontal, less and less of the center patterns are visible and so the recognition becomes more unreliable

http://www.hitl.washington.edu/artoolkit/documentation/hardware.htm
http://www.hitl.washington.edu/artoolkit/documentation/cs.htm
http://www.hitl.washington.edu/artoolkit/documentation/limits.htm
Limitations Lighting

- Overhead lights may create reflections and glare spots on a paper marker and so make it more difficult to find the marker square
- To reduce the glare patterns can be made from more non-reflective material
- For example, by gluing black velvet fabric to a white base
- The 'fuzzy' velvet paper available at craft shops also works very well

Pattern Size Parameter

- Tracking Error with Pattern Size

Range Parameter

- Tracking Error with Range

Angle Parameter

- Tracking Error with Angle

First ARToolKit Example

First Step

- Once ARToolKit has been installed there is a sample program, simpleTest or simple according your ARToolKit version, in the bin directory that can be run to show the capabilities of ARToolKit
- In order to run the code you need to print out the hiroPatt.pdf paper fiducial marker that is contained in the directory patterns
- Best performance is achieved if this is glued to a piece of cardboard to keep it flat
Running ARToolKit

- In each platform you have generally two choices: click on the program from your OS explorer or starting from the command line
  - the last choice is better since it give you the error and standard output stream (and ARToolKit used it a lot)
- Each platform offer a dialog box to setup the video before starting the main AR loop.

Windows

- On a Windows PC double click on the simple.exe icon in the bin directory from your windows explorer
- A dos console window will open and when the camera is detected the follow dialog will open

Linux

- On a Linux double click on the simple icon in the bin directory from your gnome or kde explorer
  - Notice than you will not have error or output stream display
- Otherwise start a terminal, go the bin directory and run simple
  - If you have V4L this dialog will appear

MacOS

- On MacOS X double click on the simple icon in the bin directory from your mac explorer
- A console window will open and when the camera is detected the follow dialog will open
- Otherwise start the Terminal program, go the bin directory and run simple

simpleTest Output

- In order for the virtual object to appear the entire black square border of the marker must be in view and also the pattern contained within the square border must be visible at all times
- If the virtual image does not appear, or it flickers in and out of view it may be because of lighting conditions
- This can often be fixed by changing the lighting threshold value used by the image processing routines

- If you hit the ‘t’ key on the keyboard you will be prompted to enter a new threshold value
- This should be a value between 0 and 255; the default is 100
- Hitting the ‘d’ key will show the thresholded video image below the main video window
- Possible tracking patterns found in the input image are marked by a red square in the thresholded image
- This will help you check the effect of lighting and threshold values on the video input
ARToolKit Tutorials

Camera and Marker Relationships

• ARToolKit gives the position of the marker in the camera coordinate system, and uses OpenGL matrix system for the position of the virtual object
• These different elements and their relationship is explained in the next slides

ARToolKit’s Coordinate System

‘exview’ Example

• The example demonstrates:
  – The camera position in the marker (in 3D and text)
  – A 3D model of the camera and the marker

‘relationTest’ Example

• Computes the relative transformation between two markers
  – Important for having different scenarios

Multi-Marker Tracking

• ARToolKit can give you the position of multiple markers as a function of the camera coordinate system
• Can also have a set of markers that define only one position
  – i.e. Glue to a cardboard plane
• ARToolKit can do that with a specific set of functions based on the multiMarker module
Using Multiple Markers

• Print the pattMulti.pdf

• Run multiTest example

‘multiMarker’ Configuration File

```markdown
# the number of patterns to be recognized
6

# marker 1
Data/multi/patt.a
40.0
0.0 0.0
1.0000 0.0000 0.0000 -100.0000
0.0000 1.0000 0.0000 50.0000
0.0000 0.0000 1.0000 0.0000
```

ARToolKit Code

Video Initialization

• Configure the video input
  – vconf = <video configuration string>
• Start video capture
  – arVideoCapStart();
• In init(), open the video
  – arVideoOpen( vconf );
  – arVideoInqSize(&xsize, &ysize);
• When finished, close the video path
  – arVideoCapStop();
  – arVideoClose();

Changing Image Size

• For input capture
  – vconf = “videoWidth=320,videoHeight=240”;
    • Note – the camera must support this image size
• For display
  – argInit( &cparam, 1.5, 0, 0, 0, 0 );
    • The second parameter means zoom ratio for display image size related to input image

Graphics Handling: libARgsub

• Set up and clean up the graphics window
  ```c
  void argInit( ARParam *cparam, double zoom, int fullFlag, int xwin, int ywin, int hmd_flag );
  void argCleanup( void );
  ```
  • cparam: camera parameter
  • zoom: zoom ratio
  • fullFlag: 0: normal, 1: full screen mode
  • Xwin, ywin: create small window for debug
  • hmd_flag: 0: normal, 1: optical see-through mode
Main Function

main()
{
    init();
    argMainLoop(mouseEvent, keyEvent, mainLoop);
}

Graphics handling: libARgsub

• Go into the iterative cycle
  
  void argMainLoop(
      void (*mouseFunc)(int btn, int state, int x, int y),
      void (*keyFunc)(unsigned char key, int x, int y),
      void (*mainFunc)(void)
  );

• Swap buffers
  - void argSwapBuffers(void);

mainLoop Function

if( dataPtr = (ARUint8 *) arVideoGetImage() == NULL ) {
    arUtilSleep(2);
    return;
}
argDrawMode2D();
argDispImage(dataPtr, 0, 0);
arVideoCapNext();
argSwapBuffers();

Image capture: libARvideo

• Return the pointer for captured image
  - ARUint8 *arVideoGetImage(void);

• Pixel format and byte size are defined in config.h
  - #define AR_PIX_FORMAT_BGR
  - #define AR_PIX_SIZE 3

Graphics handling: libARgsub

• Set the window for 2D drawing
  - void argDrawMode2D(void);

• Set the window for 3D drawing
  - void argDrawMode3D(void);
  - void argDraw3dCamera(int xwin, int ywin);

• Display image
  - void argDispImage(ARUint8 *image, int xwin, int ywin);

Detecting a Marker

• Key points:
  - Threshold value
  - Important external variables
    - arDebug – keep thresholded image
    - arImage – pointer for thresholded image
    - arImageProcMode – use 50% image for image processing
      - AR_IMAGE_PROC_IN_FULL
      - AR_IMAGE_PROC_IN_HALF
Marker Detection

/* detect the markers in the video frame */
if(arDetectMarker(dataPtr, thresh, &marker_info, &marker_num) < 0) {
    cleanup();
    exit(0);
}

for( i = 0; i < marker_num; i++ ) {
    argDrawSquare(marker_info[i].vertex,0,0);
}

Marker Structure

typedef struct {
    int area;
    int id;
    int dir;
    double cf;
    double pos[2];
    double line[4][3];
    double vertex[4][2];
} ARMarkerInfo;

Using a Pattern

• Key points
  — Pattern files loading
  — Structure of marker information
    • Region features
    • Pattern Id, direction
    • Certainty factor
  — Marker identification

Making a Pattern Template

• Use of utility program:
  — mk_patt.exe
• Show the pattern
• Put the corner of red line segments on the left-top vertex of the marker
• Pattern stored as a template in a file
• 1:2:1 ratio determines the pattern region used

Pattern File Loading

int patt_id;
char *patt_name = "Data/kanjiPatt"

/* load pattern file */
if(patt_id=arLoadPatt (patt_name) < 0)
{
    printf ("Pattern file load error !! \n");
    exit(0);
}

Checking for Known Patterns

/* check for known patterns */
k = -1;

for( i = 0; i < marker_num; i++ ) {
    if( marker_info[i].id == patt_id ) {
        /* you've found a pattern */
        printf("Found pattern: %d \n",patt_id);
        if( k == -1 ) k = i;
        else /* make sure you have the best pattern (highest confidence factor) */
            if( marker_info[k].cf < marker_info[i].cf )
                k = i;
    }
}
Getting 3D Information

- Key points
  - Definition of a real marker
  - Transformation matrix
    - Rotation component
    - Translation component

Transformation Matrix

double marker_center[2] = {0.0, 0.0};
double marker_width = 80.0;
double marker_trans[3][4];

arGetTransMat(&marker_info[i], marker_center, marker_width, marker_trans);

Finding the Camera Position

- This function sets transformation matrix from marker to camera into marker_trans[3][4]
  - arGetTransMat(&marker_info[k], marker_center, marker_width, marker_trans);

- You can see the position information in the values of marker_trans[3][4]
  - Xpos = marker_trans[0][3];
  - Ypos = marker_trans[1][3];
  - Zpos = marker_trans[2][3];

ARToolKit Coordinate Frame

Virtual Object Display

- Key points
  - OpenGL parameter setting
  - Setup of projection matrix
  - Setup of modelview matrix

Appending your Own OpenGL Code

- Set the camera parameters to OpenGL Projection matrix
  - argDrawMode3D();
  - argDraw3dCamera(0, 0);

- Set the transformation matrix from the marker to the camera to the OpenGL ModelView matrix
  - argConvGlpara(marker_trans, gl_para);
  - glMatrixMode(GL_MODELVIEW);
  - glLoadIdentity(gl_para);

- After calling these functions, your OpenGL objects are drawn in the real marker coordinates
3D Model Loading

- ARToolKit does not have a function to handle 3D CG models
- 3rd party rendering software should be employed
  - OpenVRML
  - OpenSceneGraph
  - 3D parsers
  - Unity
  - etc

Loading Multiple Patterns

- Object Structure
typedef struct {
  char name[256];
  int id;
  int visible;
  double marker_coord[4][2];
  double trans[3][4];
  double marker_width;
  double marker_center[2];
} ObjectData_T;

Finding Multiple Transforms

- Create object list
  - ObjectData_T *object;
- Read in objects - in init()
  - read_ObjData(char *name, int *objectnum);
- Find Transform – in mainLoop()

  for (i = 0; i < objectnum; i++) {
    // Check patterns
    // Find transforms for each marker
  }

Drawing Multiple Objects

- Send the object list to the draw function
  - draw(object, objectnum);
- Draw each object individually

  for (i = 0; i < objectnum; i++) {
    if (object[i].visible == 0) continue;
    argConvGlpara(object[i].trans, gl_para);
    draw_object(object[i].id, gl_para);
  }

ARToolKit Examples

iNVENtor 2014 AR Showcase

https://www.youtube.com/watch?v=pVyFxdJ5lcI
Conclusions

- Although a lot of solutions exist, there is no complete solution for all types of AR
- Depending on the app, specific SDK/solution should be used
- Expect in the future more ‘complete’ tools

Questions

Acknowledgements

- Special Thanks to Prof. Mark Billinghurst