

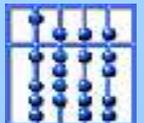
Master's Thesis

*Analysis of Conceptual Differences and Similarities
Concerning the Interaction with
Physical and Digital Objects in Augmented Reality*

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Supervisors

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Terms for different kind of objects:

real – physical – material
virtual – digital

Motivation:

- In AR: physical and digital objects
- What characterizes them?
- What do they have in common, how do they differ?
- How can digital and physical objects interact?



Overview

Introduction

- Terms ✓
- Motivation ✓

Identifying, measuring, and simulating characteristics of physical objects

- Overview of analyzed physical characteristics
- General proceeding
- One characteristic in detail: form of an object
- Some devices for measuring physical characteristics
- Devices for simulating physical characteristics of digital objects

Special characteristics of digital objects

Mixed physical and digital objects

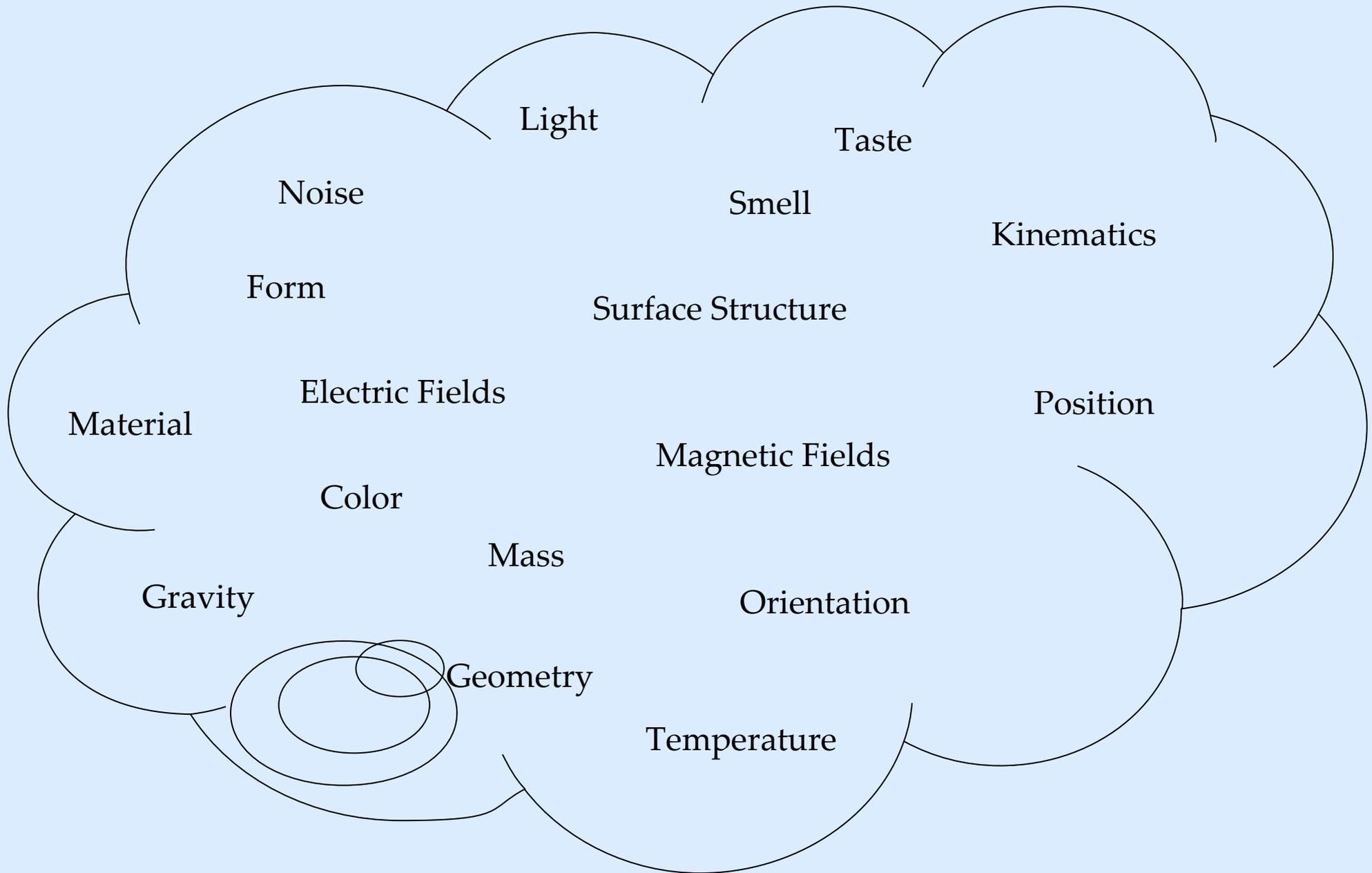
Collaborative work with physical, digital, and mixed objects

CRC cards application with physical, digital, and mixed objects

Summary



Overview of Analyzed Physical Characteristics



Approach for Characteristics of Physical Objects

Identifying a physical characteristic

Describing

- Informal description
- Physical model

Measuring

- Important for AR: application needs to know state of physical objects
- A priori measuring (e.g. object size and form)
- Real-time measuring and tracking (e.g. position)

Simulating physical characteristics for digital objects

- Using physical model
- Special devices (displays, force feedback systems, etc...)

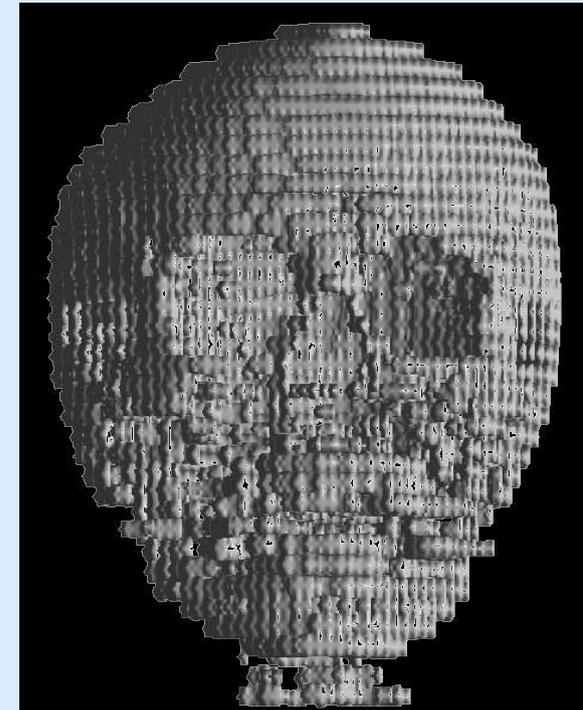


Description of a form → Computer graphics

– Polygon



– Volume model



– Mathematical description

- E.g. sphere

$$x^2 + y^2 + z^2 = 5$$

Measuring the form of a physical object:

- Using a ruler, tape measure...
- Image recognition of a camera picture

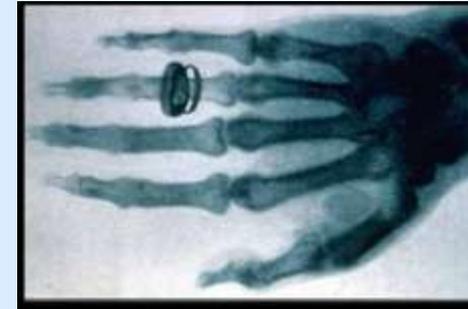
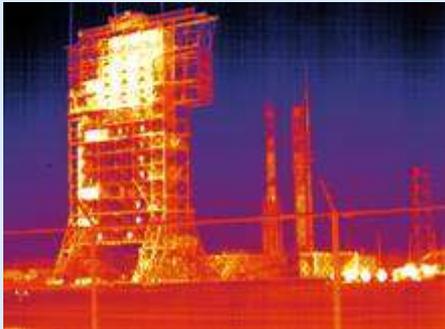
Simulation of the characteristic “form”

- Display
- Projector
- Image synthesis routines and software, e.g. OpenGL



Devices for Measuring Physical Characteristics

Camera, IR-camera, ultrasonic, x-ray equipment for determining position, orientation, form, temperature...



Electronic nose for measuring odor



Microphone for detecting noise, speech recognition systems for interpreting

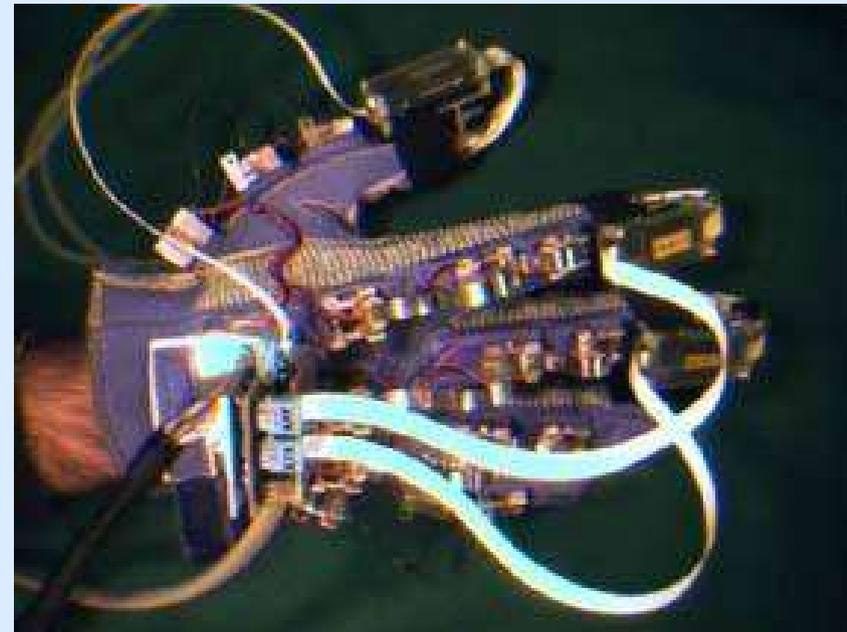


Devices for Simulating Physical Characteristics of Digital objects

Monitors, projectors for displaying form, position, material of digital objects

Speakers for generating noise, speech

Force feedback systems for simulating tactile sensation, gravity, forces of electric fields...



Temperature creation systems

Summary over Physical Characteristics

Physical characteristic	Quantitative description [unit, if applicable]	Example(s) for measuring	Examples for simulating characteristic on digital objects
Position	Three coordinates [mm]	Tracking with camera; magnetic tracking	Display object at the proposed position
Orientation	Three angles [°], rotation matrix	Tracking with camera; gyroscope	Display object with proposed orientation
Form/ geometry	Description with polygons, base volumes... [list of positions points, edges, surfaces and volumes]	Edge detection, other sorts of feature detection	Display geometries, for example using OpenGL
Material	Many different material constants	Chemical analysis, image recognition, recognizing sound of material	Textures
Color	Different color formats [RGB, YUV ...], transparency	Color from camera image	Display color
Light	Brightness, light distribution	From camera image	Lighting models like ray-tracing, radiosity
Temperature	One value [°C, °F], more sophisticated for temperature distributions	Using Thermometer; infrared camera	Thermal feedback
Tactile percept.	Mixture of feeling temperature and pressure		Force feedback systems
Mass	One value [kg]	Weighing	Force feedback systems
Electric fields	Electric field strength	Potentiometer	Force feedback systems
Smell	Amount of certain molecules in the air	Electronic nose	Create synthetic smell
Taste	Amount of certain molecules in substances	Electronic tongue?	Create from gustatory substance
Noise	Amplitudes for superimposition of basic sinus waves [decibel]	Recording with microphones	Sound synthesis; play recorded sounds over speakers



Findings Regarding Physical Characteristics

Physical world is complex and has lots of different physical characteristics

They can be explained and described using models

We can measure characteristics of physical objects, but not all of them and not permanently

Many physical characteristics can be simulated for digital objects with the help of specific devices



Overview

Introduction ✓

Identifying, measuring, and simulating characteristics of physical objects ✓

Special characteristics of digital objects

- Possibilities of object manipulation
- Pseudo-physical and unphysical behavior
- Uniqueness of digital objects
- Object creation and deletion
- Saving, logging, reconstructing digital objects
- Access rights, locking

Mixed physical and digital objects

Collaborative work with physical, digital, and mixed objects

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Possibilities of Visual Manipulation

Switch visibility

Use transparency

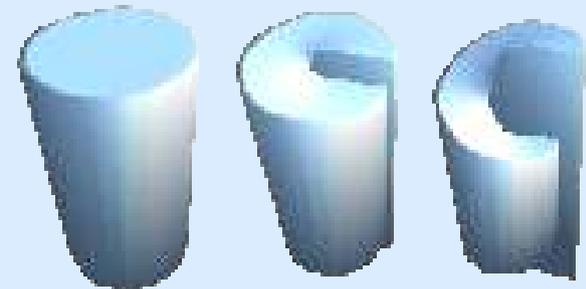
- To see covered objects
- To make internal structure of objects visible
- To indicate preview, helper objects



Switch view of one object, multiple views (MVC)

Geometric transformations

- Modify object size
- Deform arbitrarily

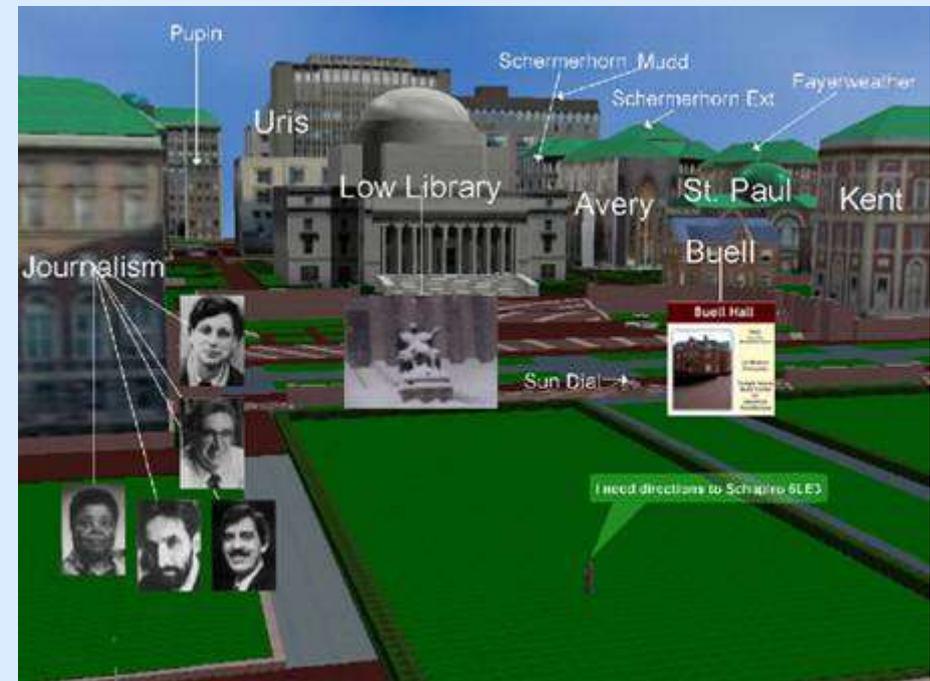


Pseudo-Physical and Unphysical Behavior

Simulate or ignore gravity

Pseudo-forces

- Snap-in forces
- Attracting and repulsing forces
- Avoid overlapping
- Self-organizing forces



Object permeation possible



Uniqueness of Digital Objects

In OO languages: pointer to object as ID

UUID: Universal Unique IDentifier

Physical objects not always identifiable uniquely →

- Confusion
- Ambiguities
- Errors



Object Creation and Deletion

Easier as for physical objects

Copy as special form of object creation

Things to give attention to

- Create space for new objects
- Violation of simulated physical laws (singularities)
- Collapse of the digital world
- Maybe restoring actions after object deletion



Saving parts or the whole digital world

- Needed for later reconstruction at restart
- Stored data can be transferred/copied to other systems
- Backup

Logging the state of all or certain objects

- Undo actions
- Possibility of restoring old states



Access Rights, Locking

Access rights

- Enables control over digital objects
- Concepts: read – write – execute
- Roles and groups

Locking of objects:

- Enable exclusive access for an object

Analogy for physical objects

read – write – execute	locking
see? – modify? – use?	reservation?

Only limited transfer of sophisticated access rights

Overview

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Identifying, measuring, and simulating characteristics of physical objects ✓

Special characteristics of digital objects ✓

Mixed physical and digital objects

- Definition of mixed objects
- Requirements for mixing digital and physical objects
- Examples for mixed objects
- Dissolution of mixed objects
- Replicating mixed objects
- Resume work within augmented worlds

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Definition of Mixed Objects

Idea for a mixed object:

- An object that consists of at least one physical and one digital part

What is “an object”?

- Do the locations of the digital and physical part(s) have to be attached?
- Can they be linked in another form?

Extended definition:

- Any function that connects at least one characteristic of a physical object with a characteristic of a digital object defines a mixed object



Requirements for Mixing Digital and Physical Objects

Requirements for digital objects

- Simulate desired physical characteristics
- Often only visual and acoustic simulation

Requirements for physical objects

- Create physical objects specifically for an application
- Use actuators like motors, enable remote control
- Integrate trackers

Requirements for tracking and visualization systems

- Realistic overlapping of digital and physical objects
- Consistent lighting and shadowing

→ physical-digital integration is limited,
but perfect integration is not always desired

Examples for Mixed Objects

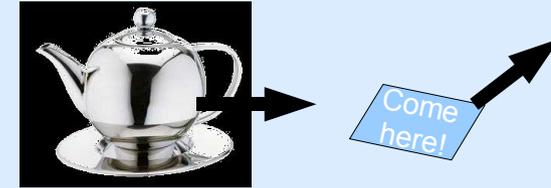
Connection of physical and digital position and orientation



digital label bound
to physical tea pot



physical tea pot bound
to digital hook



physical tea pot
follows digital label

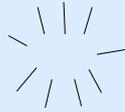
In general:

- connect any characteristic of one object to any characteristic of another one
- E.g.: digital temperature bar:
digital bar length – physical object temperature

Dissolution of Mixed Objects

Dissolution due to interrupted tracking

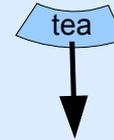
- Example: when the physical teapot disappears, the digital label will



b) disappear



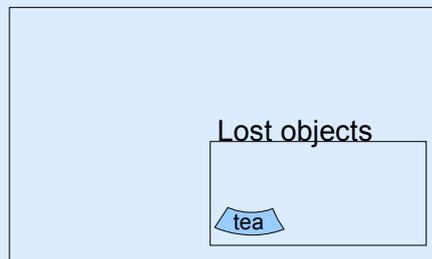
c) remain



d) fall down



e) blink



f) move to special position



g) extrapolate its position



h) search for a new object

Other forms: intentional dissolution, e.g. digital barrier

Replicating Mixed Objects

Replication often used in software (copy/paste, multiple views)

Various forms of replication for mixed objects

- A digital part can be replicated as digital or physical part
- The same goes for physical part
- Lots of combinations when mixed objects consists of several parts

Difficulties:

- Different behavior of digital and physical parts
- Limited control over physical replications

Examples: soon in topic “collaboration”

Resume Work within Augmented Worlds

Augmented reality scene at termination of session; at restart some physical objects have moved or disappeared



At restart attach augmentations to those objects they were at termination



At restart restore complete scene before continuing session



Restore single objects during work



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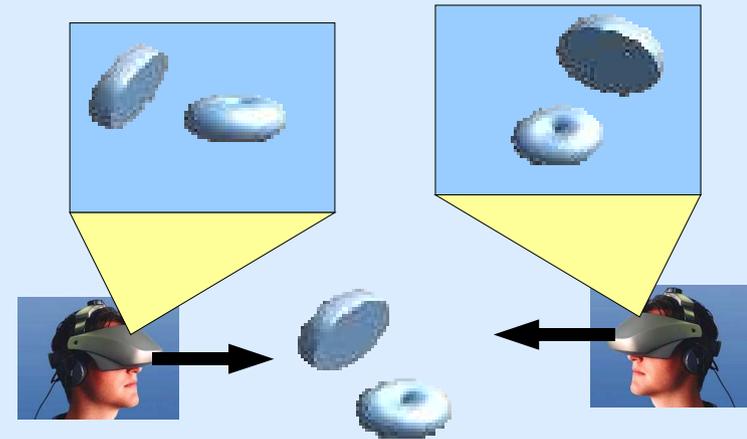
Summary



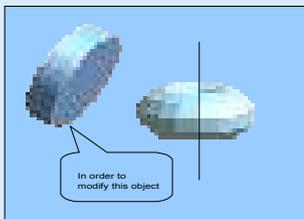
Collaborative work with physical, digital, and mixed objects



One common display
for all users



Different points of view
for every user



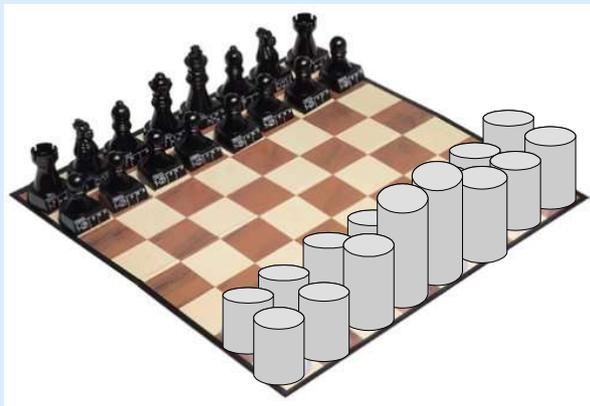
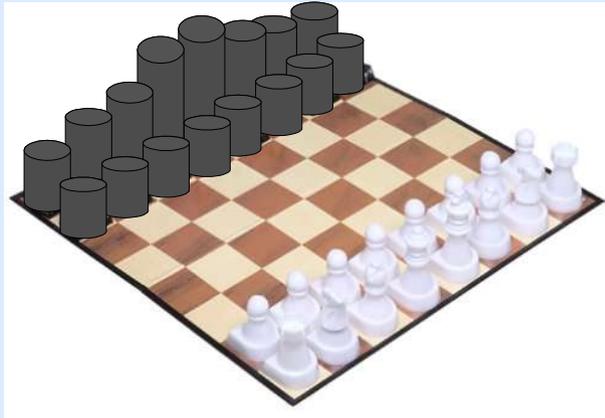
Different users see different aspects
from different points of view



Same object at different positions
for different users

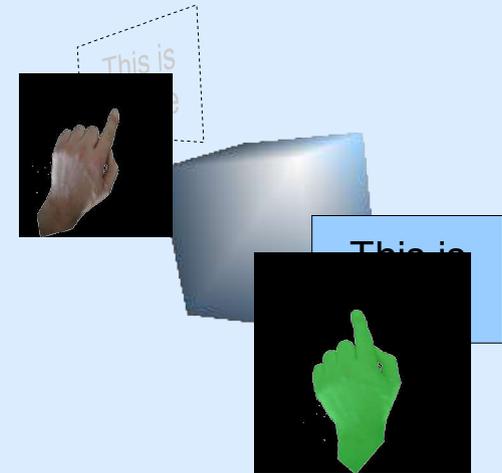
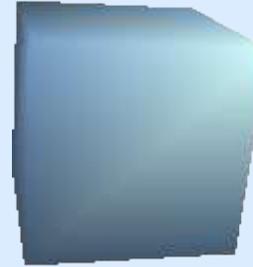


Collaborative work with physical, digital, and mixed objects (examples)



Augmented chess

This is
a cube



Pointing at a digital label



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CRC cards application with physical, digital, and mixed objects

- Work with CRC cards and components of a CRC card application
- An AR CRC cards application

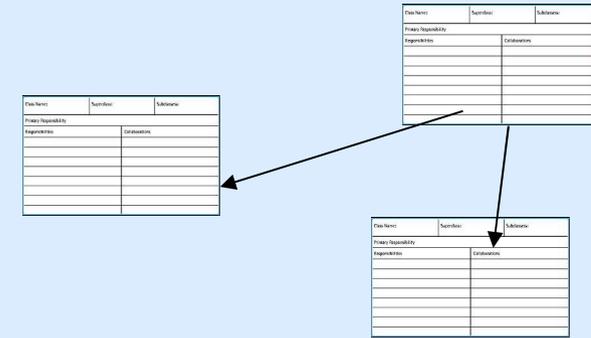
Summary



CRC cards application

Cards used in software engineering

- Object oriented development
- Collaborative working
- Physical cards and software implementations



Idea: Design AR application using gained insights

- Identify components
- Choose physicality, digitality of components and find ways to connect them



Table



Card base

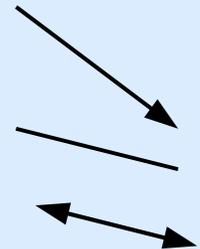
Class Name:	Superclass:	Subclasses:
Primary Responsibility		
Responsibilities		Collaborations

Structuring elements

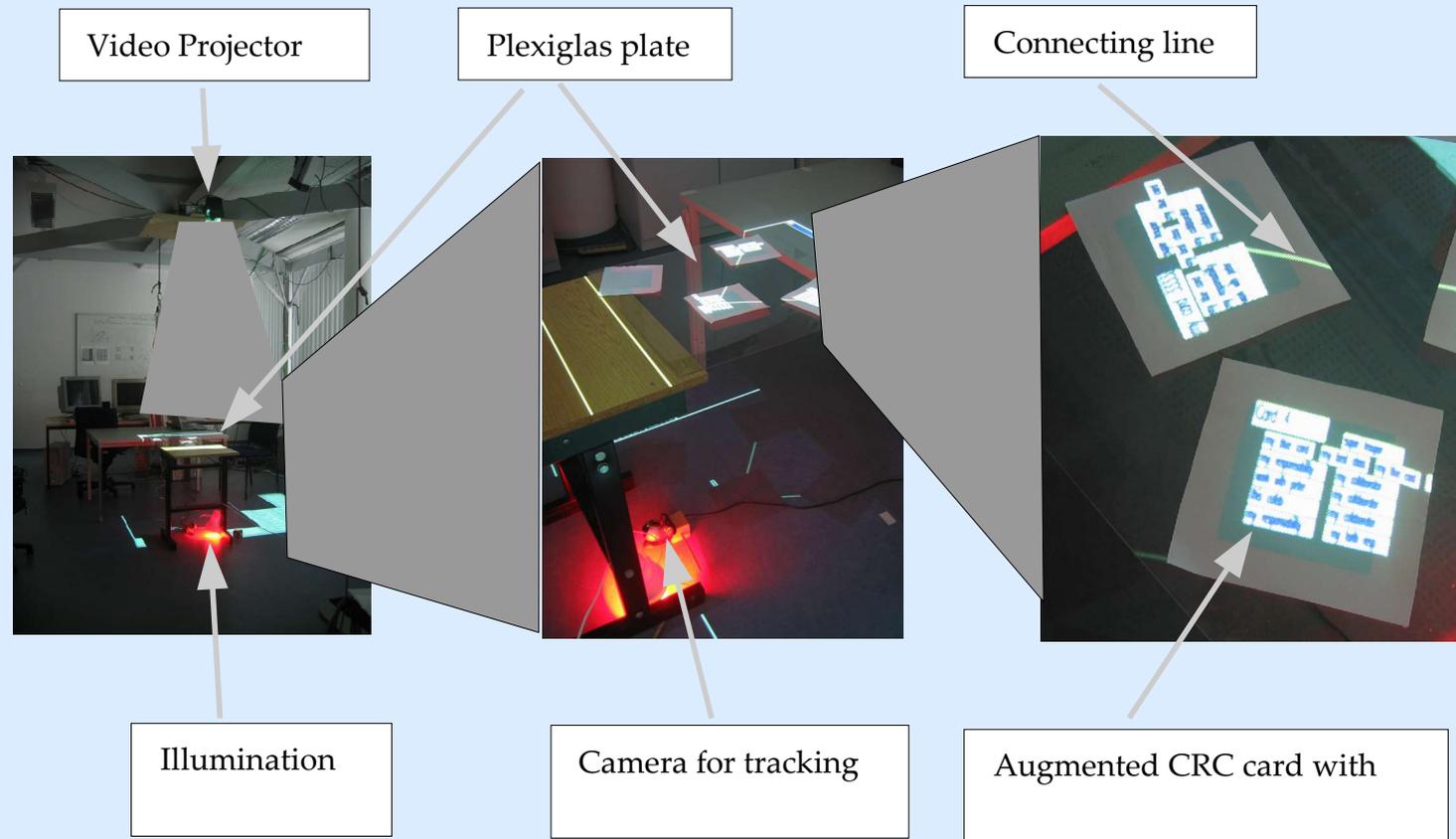
```

Concept: my Concept
Superclass: general
Subclasses: my sp..
Responsibilities:
    ....
    ....
Collaborators:
    ....
    ....
    
```

Content Connecting Lines



CRC cards application



Benefits:

- Integrating digital, physical, and mixed cards
- Collaborative work
- Align orientation of augmented and digital cards using special marker
- Digital connecting lines automatically drawn for augmented and digital cards
- Guidance in restoring previous state after restart

Result:

→ New application can take advantage of both the physical and the digital world



Summary

We identified physical characteristics

- Physical model describes them
- Can be measured to with limitations in order to use them in AR.
- For digital objects these characteristics can be simulated with restrictions and with sometimes considerable effort

Digital objects provide additional characteristics

- Derived from different fields of computer science
- Lots of new characteristics
- Difficult to transfer to physical objects
- Sometimes analogy to physical characteristics

Mixed objects can be build by connecting the characteristics of digital and physical objects

- Various ways of connecting objects via their characteristics
- Difficulties due to immanent differences
- Design new kind of objects with new characteristics

Design of (collaborative) applications in a new way by allowing and combining digital and physical objects



The End

**Thank You for
Your Attention!**



Summary of Digital Characteristics

Digital objects can have completely new characteristics

They are transferable only to limited degree to physical objects

Sometimes analogies can be found in the physical world



Establishing a Digital-Physical Connection

- Requirements for mixing digital and physical objects
- Examples for mixed objects
- Establishing a digital-physical connection
- Dissolution of mixed objects
- Replicating mixed objects
- Resume work within augmented worlds

