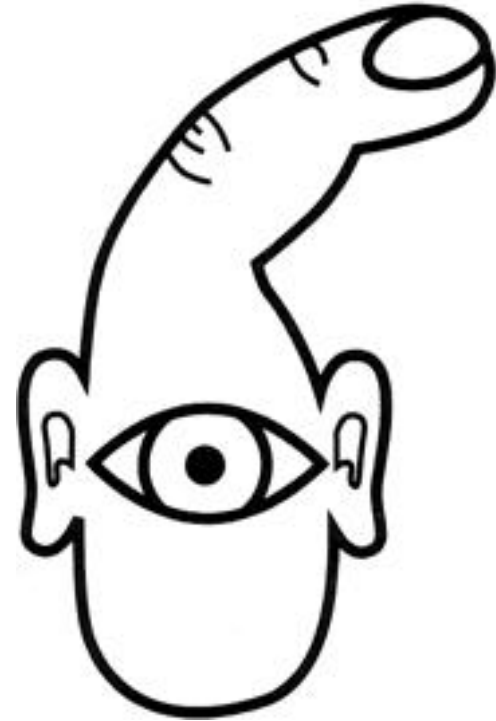


# tangible user interfaces

## lecture 04: frameworks & protocols



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# **++ computer vision requirements**

## **+ objects**

identification, tracking of position and orientation  
speed, direction & acceleration can be calculated

## **+ hand and finger gestures**

recognition of one or more finger-tips  
tracking of the finger path until removal  
-> gesture recognition in a different layer

## **+ unknown objects**

shape recognition and tracking of untagged objects  
mapping of shapes to predefined prototypes

## **+ performance**

has to be fast, accurate and robust

# **++ computer vision issues**

## **+ image quality**

being an optical sensor computer vision systems highly depend on acquired image quality. Important factors are:

- \* camera resolution
- \* illumination
- \* exposure (motion blur)

## **+ performance**

image analysis consumes significant computing resources. In an optimal system we want to process and recognize in real-time

- \* high frame rates
- \* with low latencies

## **+ problems**

- \* dirt & scratches on tags and surfaces
- \* reflections

# **++ d-touch**

## **+ Enrico Costanza, Liminal Devices, MLE**

developed the d-touch system as part of his master's thesis while studying at the University of York, UK

collaborator: Simon Shelley

## **+ audio d-touch**

a set of three audio applications with a TUI

- \* Augmented Stave
- \* Tangible Drum Machine
- \* Physical Sequencer

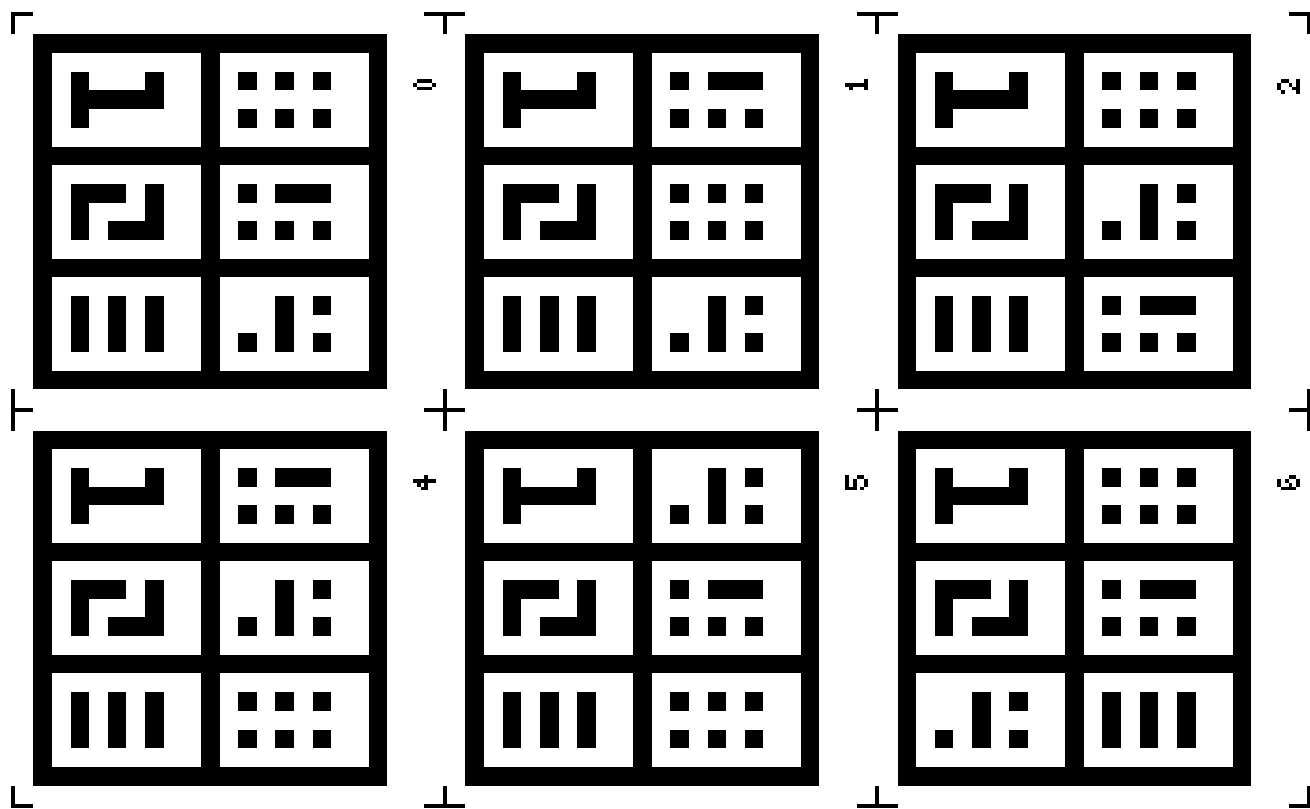
## **+ TUI & augmented reality**

d-touch is suitable for design of 2D table-top TUIs as well as 3D augmented reality applications

# ++ d-touch

## + fiducial symbols

d-touch is using a set of symbols which have been developed especially for its recognition algorithm.



# **++ d-touch**

## **+ topological approach, region adjacency**

each symbol is constructed out of a series of white areas within a black frame. Each of these areas can contain a small number of black regions which are counted to define their id.

permutations of these sub-regions (usually 4-6) allow the calculation of higher-level ID numbers for the complete symbol (factor of n).

The top left box carries allow the same number to allow the detection of the orientation. Hence a symbol with 6 boxes can carry 120 IDs.

after pre-processing the source image with an advanced thresholding algorithm a region adjacency tree of subsequent black and white areas is built and then searched to retrieve the possible fiducial symbols.

## **+ performance**

d-touch is very robust and accurate and fiducial symbols can be still recognized even if they are bent or distorted.

# **++ reactIVision**

fast and robust fiducial marker tracking, multi-touch finger tracking, tracks ID, location and rotation angle of any object on 2D surface, optimized for speed and accuracy in real-time interaction

developed and maintained by Martin Kaltenbrunner & Ross Bencina, engine developed by Ross Bencina inspired by E. Costanza's d-touch

## **+ free software**

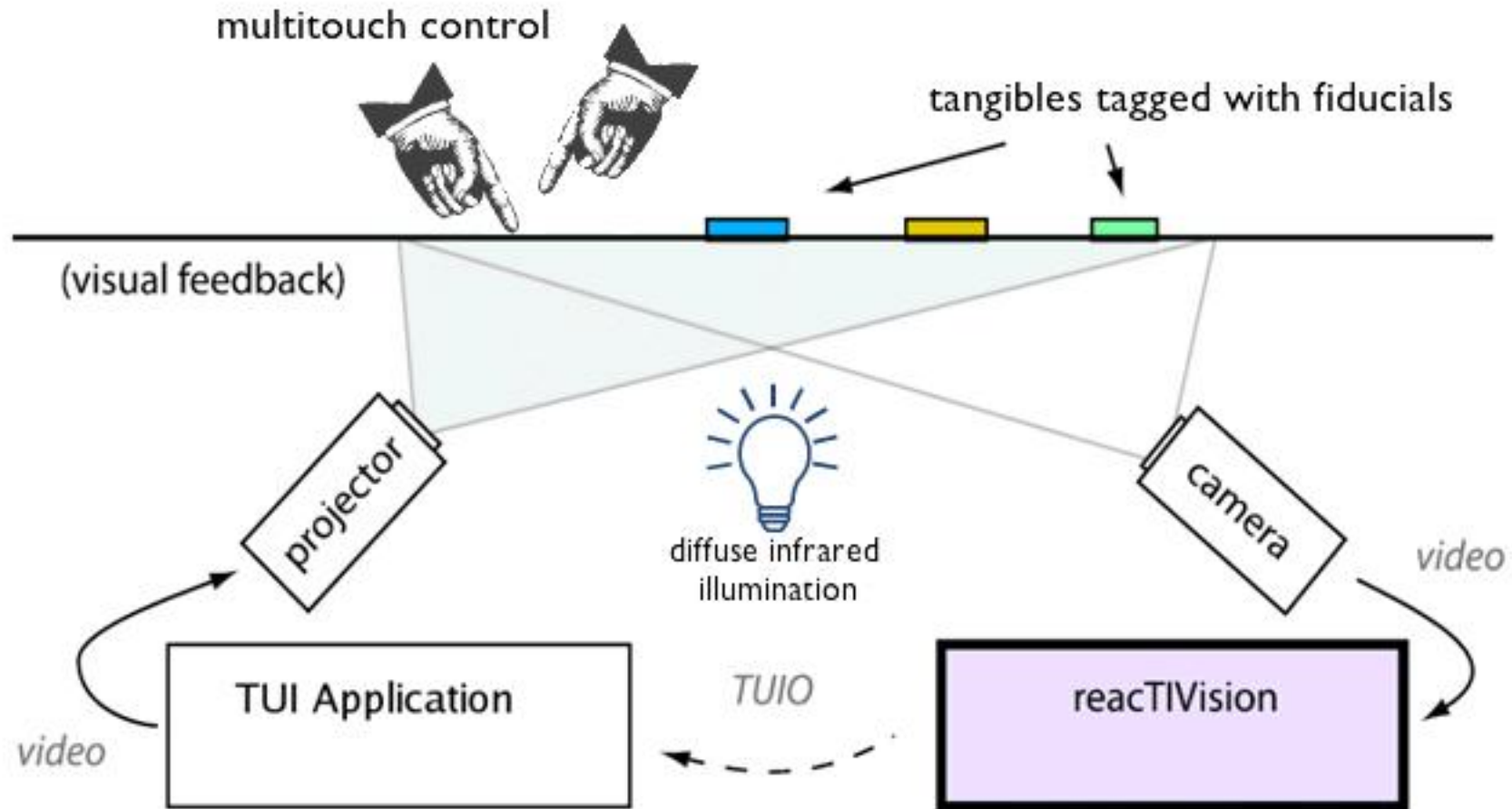
source released under a GPL licence, binaries available as well  
multi-platform: Windows, Mac OS X, Linux

## **+ distributed system**

reactIVision is a stand-alone application that communicates with the actual client application via an Open Sound Control (OSC) based protocol, TUIO.

The application developer can choose the suitable environment, such as C++, C#, Java, Processing, Pure Data, Max/MSP, Flash etc.

# ++ distributed framework



# **++ TUIO protocol**

## **+ interactive surfaces**

a protocol designed to describe events on interactive surfaces  
multi-touch and tangible interaction (tracking multiple finger-tips and object type, position and rotation)

## **+ open sound control**

a protocol which was designed to overcome the limitations of MIDI for the control of current musical instruments  
improved data types, resolution and bandwidth  
usually using Ethernet based UDP communication

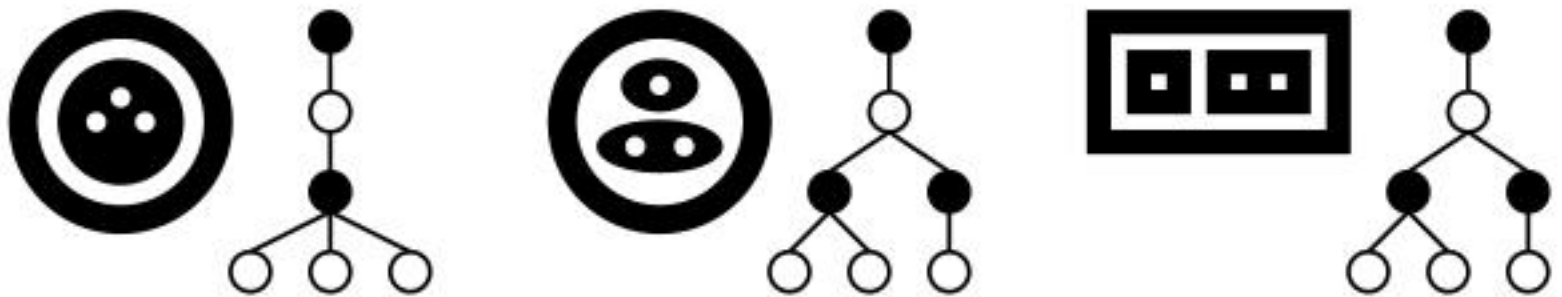
## **+ community acceptance**

TUIO has been adopted by various open source projects as the common interchange protocol for interactive surface applications  
NUI group, touchlib, iPhone, ...

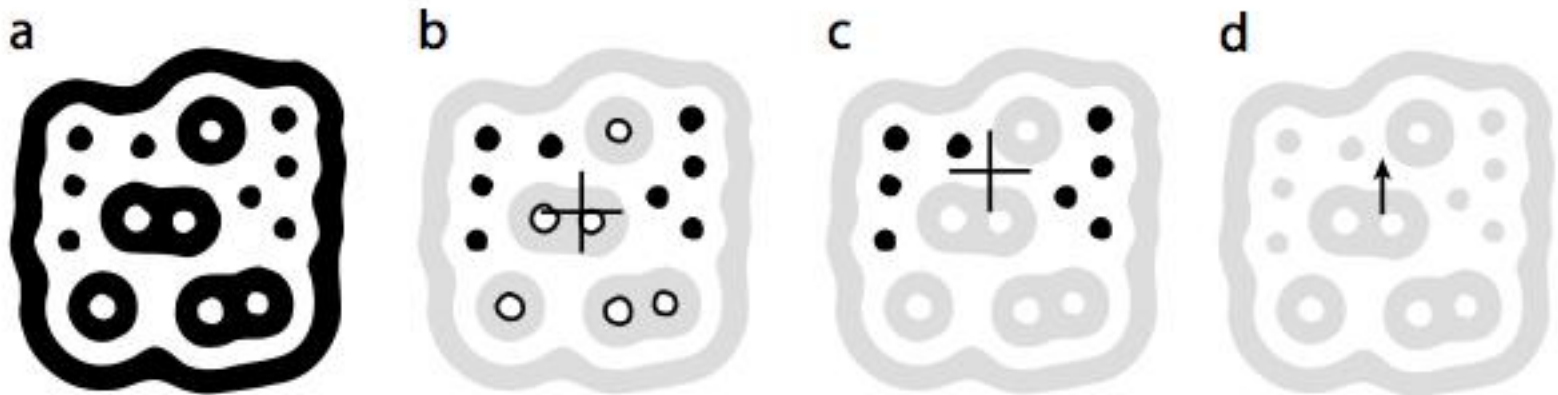
# ++ fiducial markers



# ++ region adjacency graphs

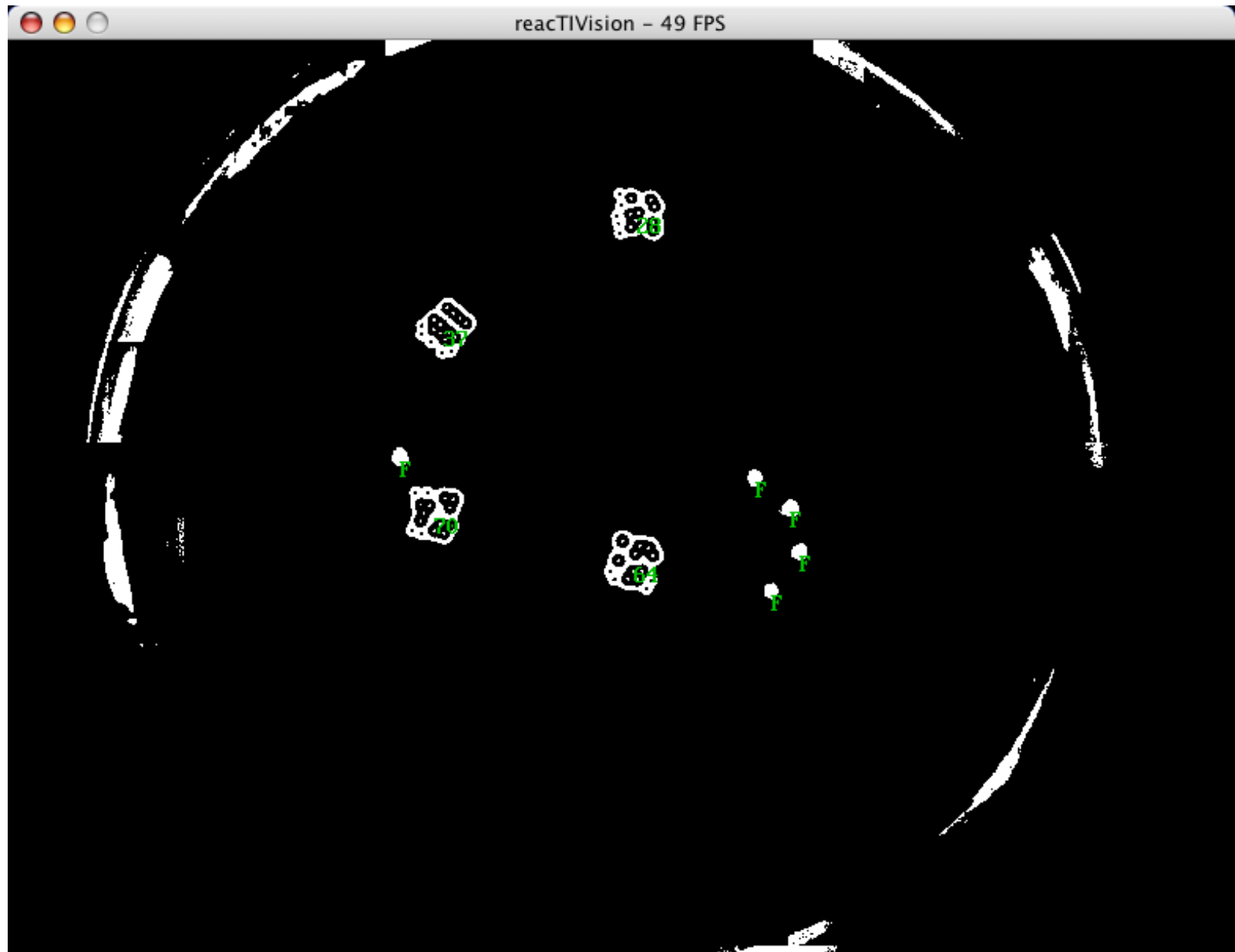


Some simple topologies and their corresponding region adjacency graphs.



- (a) a reactIVision fiducial (b) black and white leafs and their average centroid  
(c) black leafs and their average centroid, and  
(d) the vector used to compute the orientation of the fiducial.

# ++ finger tracking



# **++ OpenSound control**

## **+ features**

- \* Open-ended, dynamic, URL-style symbolic naming scheme
- \* Numeric and symbolic arguments to messages
- \* Pattern matching language to specify multiple targets of a single message
- \* High resolution time tags
- \* Bundles of messages whose effects must occur simultaneously
- \* Query system to dynamically find out the capabilities of an OSC server and get documentation

## **+ implementations**

Java, C++, Flash, Perl, PHP, Max/MSP, Pure Data, Supercollider, ...

## **+ transport**

generally OpenSound control is transmitted with UDP packets on local or wide area networks (Ethernet, ...). UDP is very fast but unreliable on distant connections. TCP can be used as a reliable but slightly slower alternative. Additionally OpenSound controls could be transmitted over serial connections or wireless networks such as Bluetooth as well.

# **++ OpenSound control**

## **+ data types**

32bit integer, 32bit float  
OSC-string, OSC-timetag  
OSCblob

## **+ message format**

address pattern + type tag string + arguments

## **+ explanatory simplified example**

/message/path,iff,10 0.1 0.5

## **+ pros & cons**

- + in deed overcomes the restrictions of MIDI
- + is becoming popular in computer music research & industry
- almost too general to allow easy interoperability

# **++ OpenSound control**

## **+ what is it?**

OpenSound Control ("OSC") is a protocol for communication among computers, sound synthesizers, and other multimedia devices that is optimized for modern networking technology and has been used in many application areas.

## **+ motivation**

although MIDI is still the standard and very popular protocol for the connection of musical devices it has significant limitations:

- \* bandwidth (32150 bits/second)
- \* data resolution (7bits -> 0-127)

OpenSound control was designed to overcome these limitations

## **+ origin**

Matt Wright, CNMAT, Univ. of Berkeley

first presented in 1997

<http://www.cnmat.berkeley.edu/OpenSoundControl/>

# **++ TUIO protocol**

## **+ motivation**

creation of a common communication protocol between the reacTIVision computer vision sensor component and the application mostly focusing on table-style TUI environments.

The advantage of a communication protocol over a library solution is its modularity and the possibility to execute the components on different platforms. An additional option is the complete implementation of the sensor component in hardware.

## **+ requirements**

tracking of physical objects in 2D planes, and 3D space

tracking of a pointer (such as a finger) in 2D and 3D

consistency of the object states, even if messages are lost

## **+ implementation**

based on OpenSound control, sending messages to port 3333

# ++ TUIO protocol

## + profiles

2D object: sessionID, classID, x,y,rot,xSpeed,ySpeed,rotSpeed, motionAccel, rotAccel

2D cursor: sessionID, classID, x,y,xSpeed,ySpeed, motionAccel

additional profiles: 2.5Dobj, 2.5Dcur, 3Dobj, 3Dcur

raw profiles: transmit raw sensor data

## + messages

set: transmit the current parameters of any changed object

alive: transmit a list of all currently visible objects

## + example

```
/tuio/2Dobj/set 10 10 0.35 0.75 3.14 0.1 0.2 0.05 -0.3 0.2
```

```
/tuio/2Dobj/alive 7 10 14 32
```

## + bundles

each SET message comes with an ALIVE message in a bundle to assure constantly consistent set of objects

# **++ TUIO client API**

## **+ TuioClient**

create and start a TuioClient instance  
listening to TUIO on default UDP port 3333

## **+ object and cursor events**

addObject, updateObject, removeObject  
addCursor, updateCursor, removeCursor

## **+ object and cursor parameters**

session\_id, object\_id, x\_pos, y\_pos, (angle)  
additional speed and acceleration values

## **+ event callbacks or polling**

\* implement a TuioListener with callback functions

OR

\* retrieve list of current objects and cursors from TuioClient

# **++ how to build a table**

## **+ camera & projector**

firewire camera and projector with wide-angle lenses

## **+ table surface**

transparent glass or perspex board, or special projection surface  
semi-transparent plastic or copy-paper for projection  
(fiducial symbols become visible on contact)

## **+ illumination**

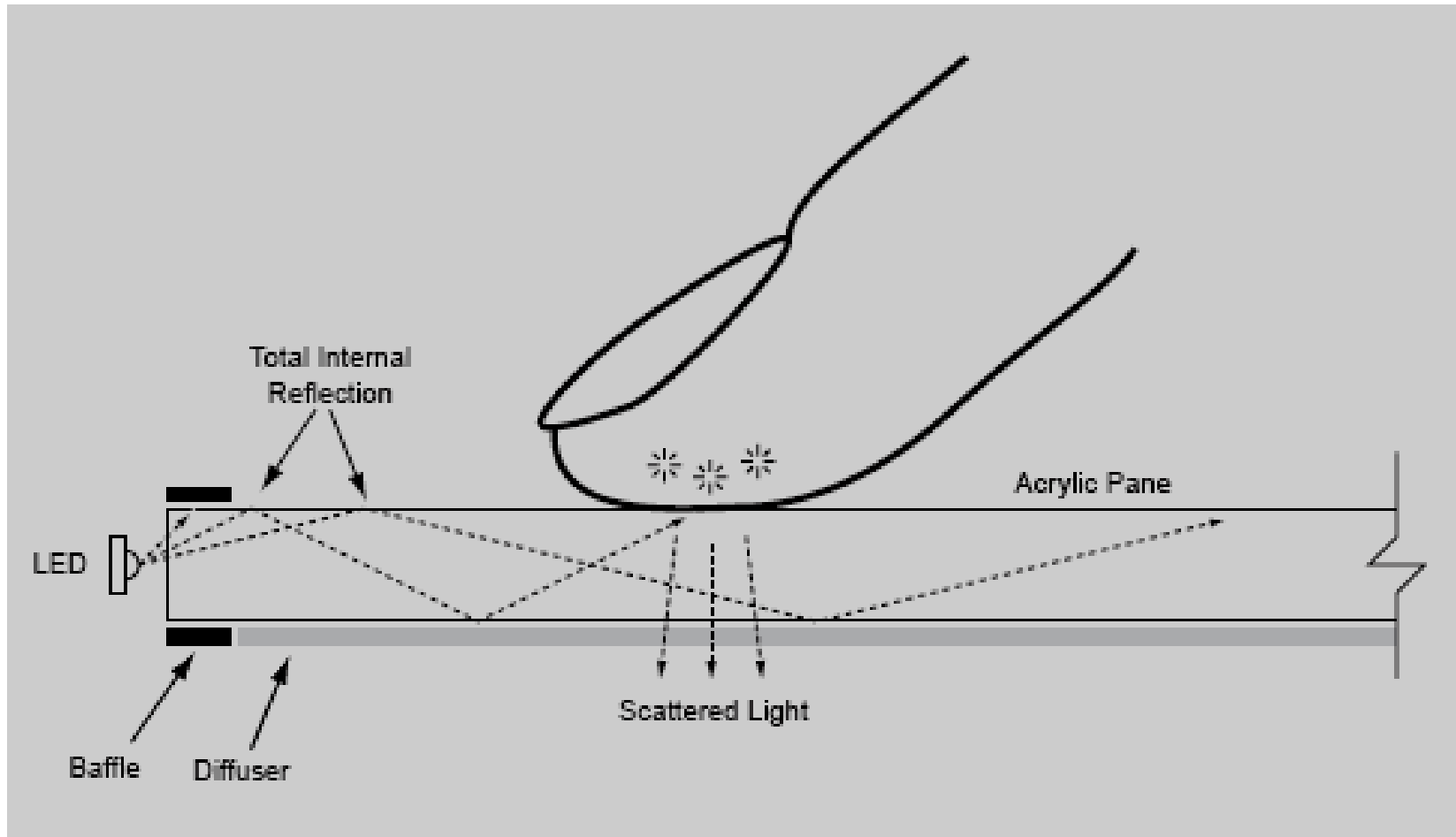
separate vision from projection:

infrared LED illumination: remove IR filter in camera of present  
add IR pass filter to eliminate visible light (projection, environment)  
projection in the visible spectrum - add IR filter

## **+ lenses & mirrors**

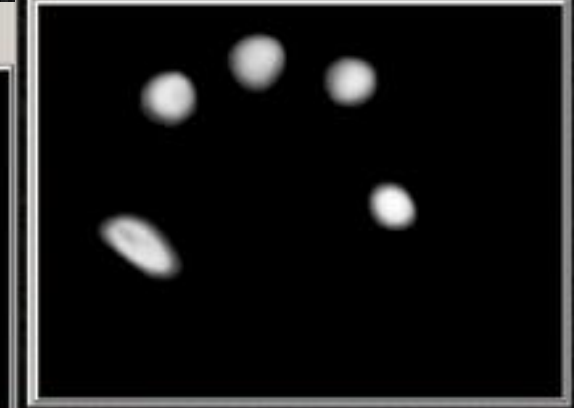
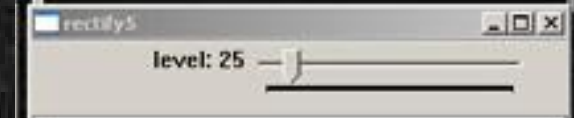
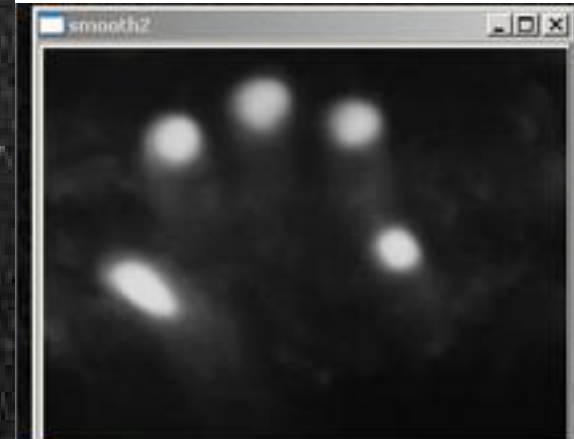
achieves larger surface at shorter distance (and table size)  
results in a distorted image, which needs to be corrected  
reactIVision includes fully configurable distortion correction

# ++ FTIR – Frustrated Total Internal Reflection



Jeff Han: FTIR diagram 2005

# ++ FTIR – Frustrated Total Internal Reflection



# ++ NUI group – multitouch community

## + online community

Web community dedicated to the discussion, development and reverse engineering of Jefferson Han's FTIT multi-touch technology. They provide a forum, IRC channel and WIKI for online discussion.

<http://www.nuigroup.com/>

## + multi-touch tutorial

Very useful PDF documentation on the topic of FTIR hardware issues. Provides a detailed step-by-step guide for the construction of a FTIR multi-touch panel (LEDs, silicon layer, projection surface)

## + multi-touch software

Starting point for multi-touch finger tracking software and libraries such as the original **touchlib** and it's more recent derivatives such as **tbeta** and **tisch** libraries. Most of these libraries adopted and support the TUIO protocol.

<http://tbeta.nuigroup.com/>

<http://tisch.sourceforge.net/>

# ++ commercial platforms

## + microsoft surface

Among many large industry players who are currently developing their multi-touch tangible surface interfaces, Microsoft was the first to announce its Surface platform in June 2007. While the platform is available to selected partners, common availability is expected in 2010

<http://www.microsoft.com/surface/>

## + nui-group commercial spin-off

Parts of the NUI community created a commercial spin-off which offers multi-touch solutions such as the NUI horizon platform



# ++ ARtoolkit

## + HIT-Lab, Univ. of Washington

primarily developed by Dr. Hirokazu Kato

<http://artoolkit.sourceforge.net/>

## + augmented reality toolkit

detects the relative position and orientation of marked objects tracked by a camera and provides an OpenGL framework to attach virtual objects to their position in real-time.

The marker symbols can be freely designed black&white graphics within a black frame

open source and multi-platform:

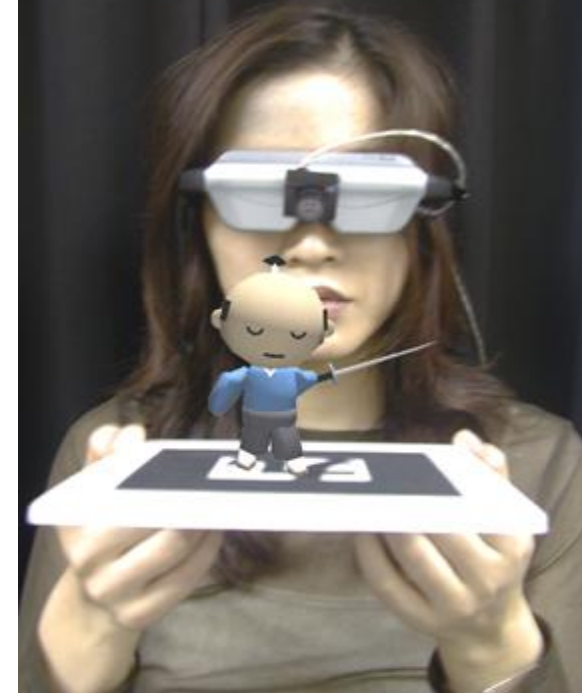
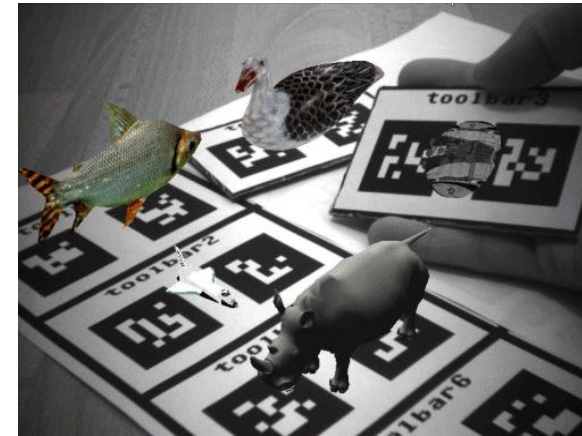
Windows, Linux, MacOSX, IRIX

## + improved/forked derivatives

ARtag improves image processing and marker robustness <http://www.artag.net/>

ARtoolkit+ adopts some of the Artag improvements as an open source branch

[http://studierstube.icg.tu-graz.ac.at/handheld\\_ar/artoolkitplus.php](http://studierstube.icg.tu-graz.ac.at/handheld_ar/artoolkitplus.php)



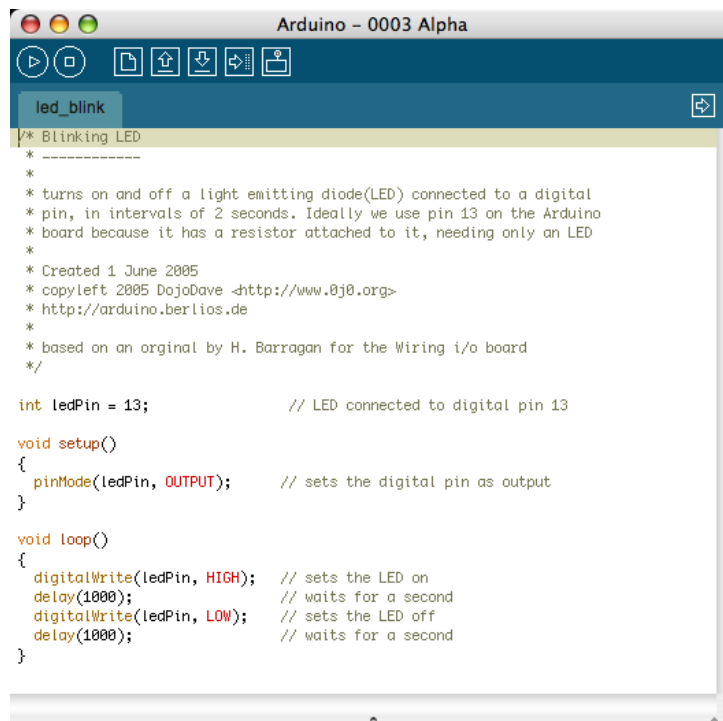
# ++ arduino

## + open hardware project

tiny micro controller hardware with analog and digital inputs/outputs  
serial, USB or Bluetooth interface. Allows the rapid development of  
hardware interfaces, sensor input, robotics, etc.

Processing (Java) style development environment

<http://arduino.berlios.de/>

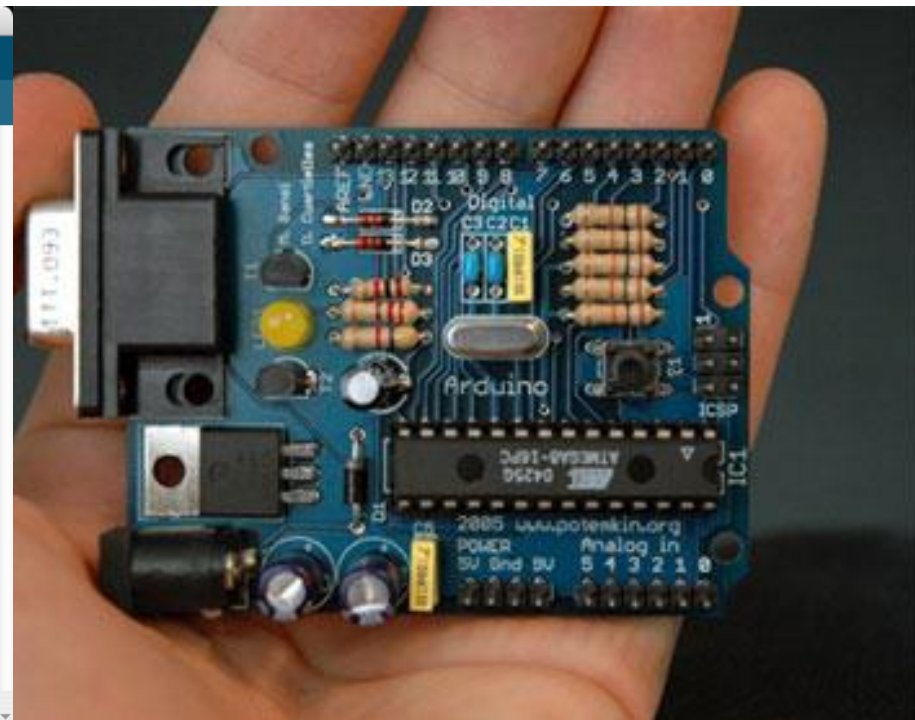


```
Arduino - 0003 Alpha
led_blink
/* Blinking LED
 *
 * turns on and off a light emitting diode(LED) connected to a digital
 * pin, in intervals of 2 seconds. Ideally we use pin 13 on the Arduino
 * board because it has a resistor attached to it, needing only an LED
 *
 * Created 1 June 2005
 * copyright 2005 DojoDave <http://www.0j0.org>
 * http://arduino.berlios.de
 *
 * based on an original by H. Barragan for the Wiring i/o board
 */

int ledPin = 13;           // LED connected to digital pin 13

void setup()
{
  pinMode(ledPin, OUTPUT); // sets the digital pin as output
}

void loop()
{
  digitalWrite(ledPin, HIGH); // sets the LED on
  delay(1000);                // waits for a second
  digitalWrite(ledPin, LOW);  // sets the LED off
  delay(1000);                // waits for a second
}
```





# ++ RF tags

## + RF tags:

a simple coil+capacitor circuit that resonates, when entering into an electro-magnetic field. the resonance amplitude can be measured by antennas.

using one antenna the RF tag can be detected, using two or an array of antennas it also can be located.

rotation of an RF tag can not be measured, but attaching two tags on a single objects allows the calculation of the angle based on the position of the two tags.

maximum number of tags is limited.

examples:      musical trinkets  
                    AudioPad



**Figure 2.** An RF tag used in the Audiopad system.

# ++ RF tags

## + example: Zowie Interactive Ellie's Enchanted Garden

an interactive story telling game, where figures can be moved in a game model. RF tags are used to identify and locate these figures. The device is connected to a computer and drives a multi-media enhanced story, which is controlled by the figures.

used to be very popular, because it could be hacked easily, using the sensor device for different applications: AudioPad

discontinued product, but still might be found used on eBay



# **++ RFID tags**

## **+ passive RFID tags:**

same principle as simple RF tags, but come with an embedded microchip, which in the simplest case just stores an ID number.

Once entering in an electromagnetic field, the chip is powered by its coil antenna and emits its ID number back via radio.

More sophisticated versions can store more information than just an ID (a few kBytes) or some models can be read AND written.

Additional security through data encryption possible.

## **+ active RFID tags:**

similar to passive tags, but are self powered (battery)

## **+ technical details:**

operating frequency: 125 kHz - 2.4GHz

reading range: 2cm - 3m

# ++ RFID tags

## + example applications:

keys (phobs), product logistics (transport, storage)

## + pros/cons

- + tags can be produced cheaply
- + robust and accurate
- + no line of sight needed
- readers are more expensive
- serious privacy concerns

