Implementation of New Interaction Techniques:

Eye Tracking

Päivi Majaranta
Visual Interaction Research Group
TAUCHI

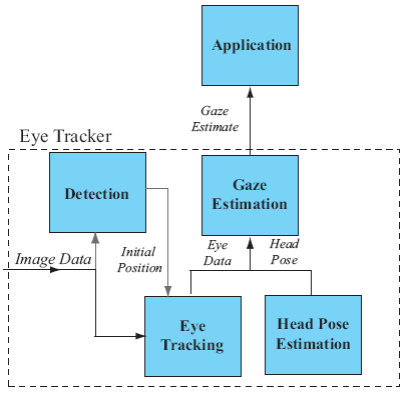
TAUCHI - Tampere Unit for Computer-Human Interaction

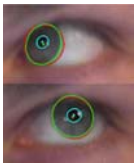
Contents

- Part 1: Basics
  - Eye tracking basics
  - Challenges & solutions
  - Example applications
  - Programming basics
- Part 2: Beyond the basics
  - Advanced examples
  - Tips for specific cases
  - Programming tools & APIs
  - Project topics

Part 2: Beyond the Basics

Eye Tracker Components





Daunys et al. 2007. Eye Tracking Hardware Issues
http://www.cogain.org/results/reports/COGAIN-D5.3.pdf

Daunys et al 2006: New Approaches to Eye Tracking
http://www.cogain.org/results/reports/COGAIN-D5.2.pdf

Open source & low cost solutions

- Opengazer (video)
  - open-source gaze tracker for ordinary webcams
    http://www.inference.phy.cam.ac.uk/opengazer
- openEyes
  - open-source open-hardware toolkit for (mobile) low-cost real-time eye tracking
    http://thirtysixthspan.com/openEyes/

http://www.cogain.org/eyetrackers/low-cost-eye-trackers

TAUCHI - Tampere Unit for Computer-Human Interaction

UI Designs for low-cost trackers

Solution Examples - Thinking outside of the box ☺

- Dasher
  http://www.inference.phy.cam.ac.uk/dasher
  http://www.youtube.com/watch?v=wpOxbesRNBc
- EyeWrite (run)
  http://depts.washington.edu/ewrite/eyewrite.html
- pEYEwrite (video)
  http://gonzo.uni-weimar.de/~urbina/Research/EyeTyping/English/eyetyping_en.html
- Stargazer
  http://www.itu.dk/research/inc/?p=171

Fixation Algorithms

- Dispersion based
  - Max. area (/ distance / deviation)
  - Min duration
- Velocity based
  - Max velocity for a fixation
  - Exceeding max → saccade

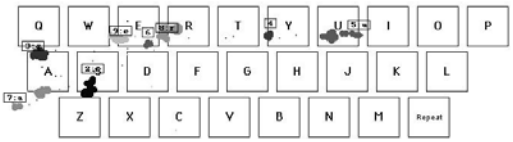
Salvucci and Goldberg 2000 http://doi.acm.org/10.1145/355017.355028

TAUCHI - Tampere Unit for Computer-Human Interaction

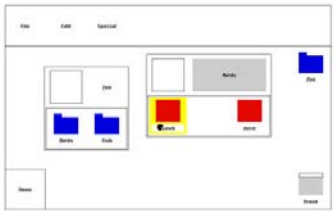
Example: Fixation algorithm by LC Technologies

- Source code available online:
  - http://www.eyegaze.com/doc/FixationSourcecode.htm
- Dispersion based
  - Gaze deviation threshold
  - Min. number of samples (default: 3)
  - Outlier handling
    - Noise ignored, fixation not ended if the subsequent sample falls within threshold
    - Blink (lost data) does not end fixation if next sample falls within the threshold

Context-aware fixation detection



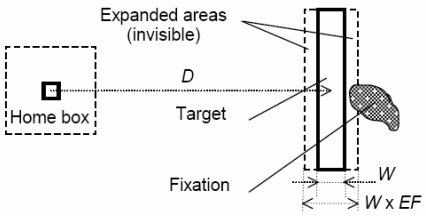
gaze point + language model



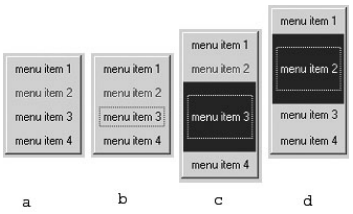
gaze point + task context

Salvucci 1999; Salvucci & Anderson 2000
http://www.mcs.drexel.edu/~salvucci/publications.html

Expanding Targets



Invisible



Visible

(left) Miniotas et al. 2004. http://doi.acm.org/10.1145/985921.986037
(right) Spakov & Miniotas 2005. http://doi.acm.org/10.1145/1088463.1088486

Example: MyTobii Web Browsing

http://www.tobii.com/assistive_technology/products/mytobii_p10.aspx

TAUCHI - Tampere Unit for Computer-Human Interaction

Drift Correction

- Included in modern eye trackers
- Dynamic drift correction
  - Context/task dependent correction
  - Recalculate at successful selection (note: cancel on error)
- Combining information from several channels
- User-initiated drift correction
  - Typically 1-point recalibration

Picture: Metrovision VISIOBOARD recalibration target (initiated by extra long dwell at any location)

Smoothing

- Simple averaging
  - Averaging by n consecutive samples
- Weighted/evaluative averaging
  - Take account the previous samples / average
  - Restart/reset thresholds (distance, velocity)
  - Outliers and data gaps (blink)

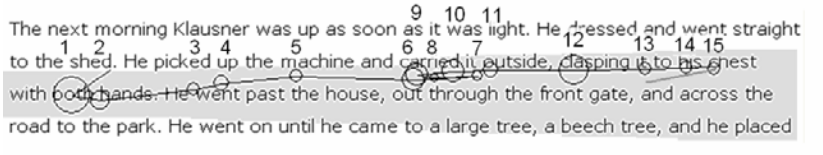
TAUCHI - Tampere Unit for Computer-Human Interaction

Level of Smoothing

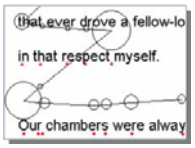
- Depends on application!

  e.g.
  - Dasher requires fast response → no/little smoothing
  - Click by eye mouse requires stable fixation on an icon → benefits from smoothing (combined with "sticky fixation" similar to "snap-to-grid")
- Context dependent averaging
  - Snap to grid, snap to nearest object (& grab-and-hold)

Attentive application
Example: iDict & sticky, magnetic lines



Filtered feedback to the user
(a red dot below the text line):
- y = line
- x = fixation x centre



Hyrskykari 2006. http://acta.uta.fi/pdf/951-44-6643-8.pdf

Gaze-aware multimedia application

- Example: eyeBook by Ralf Biedert (run)
  - Illustrations, colors, music and sound effects change to support the reading experience

EyeScroll

Kumar et al. 2007. http://hci.stanford.edu/research/GUIDe/index.html

See also:
Numajiri et al. 2002: “Speed Browser Controlled by Eye Movements”

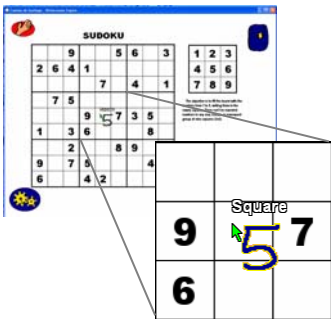
TAUCHI - Tampere Unit for Computer-Human Interaction

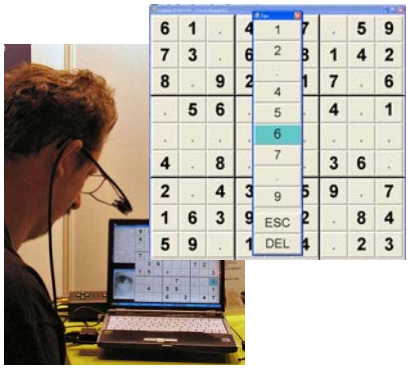
Misc UI Ideas
GUIDe: Gaze-enhanced User Interface Design

http://www.youtube.com/watch?v=mOfA9Q5oc3M

Kumar et al. 2007. http://hci.stanford.edu/research/GUIDe/index.html

Misc UI Ideas
Example: Eye-controlled Sudoku





(Left) Sudoku/Road to Santiago by Javier Hernandez Sanchiz, for information & download:
http://www.cogain.org/downloads/leisure-applications/road-to-santiago
(Right) Sudoku by Petr Novak & Vratislav Fabian (http://cyber.felk.cvut.cz/i4c/)

TAUCHI - Tampere Unit for Computer-Human Interaction

Tobii Programming

- Tobii SDK
  - *Tobii Eye Tracker Components API (COM)*
  - *Tobii Eye Tracking Low Level API (DLL)*
  - *Protocol API (access via TCP/IP from any OS)*
  - SDK package includes examples for C#, VC++ & VB6
- Requirements
  - Windows XP + service pack 2 (recommended)
  - Microsoft .NET 1.1. or later
  - Tobii Eye Tracker Server software 2.x
- MyTobii Partner Application SDK
  - MPA Interface, with examples for C++ and VB6
- (ETU Driver developed at UTA)

Tobii Eye Tracker Server
TETServer

- Software controlling the eye tracker hardware
- Runs as a Windows service application
- Buffer for last calibration
  - Saves last calibration on exit

TAUCHI - Tampere Unit for Computer-Human Interaction

Tobii Eye Tracker Components API (TetComp)

- COM Objects
- Capsules Tobii low level API
- Provides GUI tools (activeX)
  - E.g. Calibration tools
- Component installation
  - *TetComp.dll, tet.dll, ttime.dll*
  - Requires
    - Microsoft Winsock 2 library (*ws2_32.dll*)
    - *GdiPlus.dll*, *msvcp71.dll, msvcr71.dll*

For detailed instructions, see User's Guide to Tobii Programming Interfaces

TETComp Basics

- TetClient: get gaze data
- TetTrackStatus: check tracking ability

- TetCalibProc: calibration window
- TetCalibPlot: calibration result

TAUCHI - Tampere Unit for Computer-Human Interaction

TetClient Methods

Method	Description
Connect	Connect to an eye tracker.
Disconnect	Disconnect from an eye tracker.
StartTracking	Start gaze tracking.
StopTracking	Stop gaze tracking.
GetNumPendingPostGazeData	Tell how many gaze data samples there are left in the gaze data queue.
GetTimeStamp	Get current Tobii time stamp.
LoadCalibrationFromFile	Load the eye tracker with a calibration stored in a file.
SaveCalibrationToFile	Save the calibration in use to file.
ClearCalibration	Clear the calibration under construction.
AddCalibrationPoint	Start the sampling of gaze data to the calibration under construction.
InterruptAddCalibrationPoint	Interrupt the adding of a calibration point.
CalculateAndSetCalibration	Set a new calibration in use based on the calibration under construction.
GetCalibrationResult	Get information about a calibration. The source may be either the one in use or one stored in a file.
RemoveCalibrationPoints	Remove points from the calibration under construction.
PerformSystemCheck	Check if there are any system errors present.
GetSerialNumber	Get the hardware serial number.

User's Guide to Tobii Programming Interfaces 1.0

TetClient Events

Event	Description
OnTrackingStarted	Tracking was successfully started.
OnTrackingStopped	Tracking was stopped programmatically or by an error.
OnGazeData	There is new gaze data available during tracking.
OnPostGazeData	There is new gaze data available during tracking.
OnAddCalibrationPointStarted	Calibration was successfully started.
OnAddCalibrationPointEnded	Calibration was stopped programmatically or by an error.
OnCalibrationGazeData	There is new gaze data available during calibration.
OnPostCalibrationGazeData	There is new gaze data available during calibration.

GazeDataDelivery
*- TetGazeDataDelivery_**RealTime** → OnGazeData*
*- TetGazeDataDelivery_**Post** → OnPostGazeData*

User's Guide to Tobii Programming Interfaces 1.0

TAUCHI - Tampere Unit for Computer-Human Interaction

Gaze Data

```
typedef struct TetGazeData {
    LONG timestamp_sec;
    LONG timestamp_microsec;
    FLOAT x_gazepos_lefteye;
    FLOAT y_gazepos_lefteye;
    FLOAT x_camerapos_lefteye;
    FLOAT y_camerapos_lefteye;
    FLOAT diameter_pupil_lefteye;
    FLOAT distance_lefteye;
    LONG validity_lefteye;
    FLOAT x_gazepos_righteye;
    FLOAT y_gazepos_righteye;
    FLOAT x_camerapos_righteye;
    FLOAT y_camerapos_righteye;
    FLOAT diameter_pupil_righteye;
    FLOAT distance_righteye;
    LONG validity_righteye;
} TetGazeData
```

```
HRESULT GetGazeData(TetGazeData*
    pGazeData);

/*  Note:

    Gaze point coordinates go
    from top-left (0,0)
    to bottom-right (1,1)

    Distance is measured in mm.
    It should be used as relative
    measure (e.g. glasses cause errors)
*/
```

User's Guide to Tobii Programming Interfaces 1.0

Tobii Low Level API

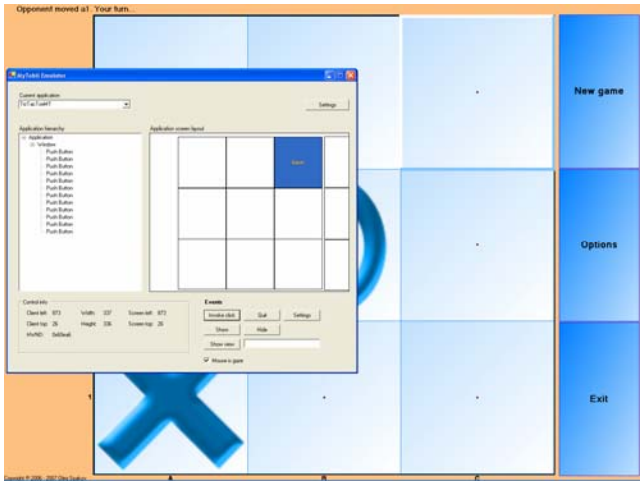
- tet.dll & ttime.dll
- Requires TCP/IP and UDP/IP connectivity between the application and TETServer
  - See SDK manual for port numbers
- DLL function calls
  - How to link a DLL (static at compile with .lib or dynamically during runtime using LoadLibrary()): http://en.wikipedia.org/wiki/Dynamic-link_library
- Callbacks / threads
  - Pay attention to timing & synchronization
- No GUI tools

TAUCHI - Tampere Unit for Computer-Human Interaction

MyTobii Partner Application SDK

- MPA Interface
  - For interfaces with button-like objects
  - Gaze data filtering, focus estimation, visual feedback handled by MyTobii
  - Implemented via Callbacks & control array
- MPACI
  - RegisterMessageCallback()
  - RegisterControls(hContainer)
    - controlData[controlCount].hwnd = (long) hwnd;
    - For each: x, y, width, height

MyTobii Emulator for Testing



TAUCHI - Tampere Unit for Computer-Human Interaction

SMI EyeLink Programming

- DLL library eyelink_exptkit.dll
  - UTA's version may be a bit outdated
- In-house made C++ class PIEyelink (by Poika Isokoski)
  - Handles dynamic loading of DLL functions as needed (during runtime)

SMI iViewX Programming

- EyeMouseDrv.dll & EyeMouseConfig.dll
  - Custom tailored for UTA's needs by SMI (in a joint project)
- In-house made C++ class wrapper for essential DLL function calls
  - Handles dynamic loading of DLL functions as needed (during runtime)

TAUCHI - Tampere Unit for Computer-Human Interaction

Misc. Implementation Tools: Grid-based Frameworks

- Work with any pointing device (& various other devices)
- Require no programming skills
- Example: **SAW** – Special Access to Windows
  - Free download: http://ace-centre.hostinguk.com
  - Ready-made example grids
  - See e.g. EyeMusic: http://www.cogain.org/media/videos/dart-eyemusic

Suggested project topics: Gaze + vision

- Topic: Gaze-enhanced First Person Shooter (FPS) Game (Aim the gun or control movements by gaze and manual gestures)
- Modalities: Gaze (combined with mouse and/or keyboard), computer vision
- Equipment: Tobii (or EyeLink) eye tracker
- Advisor: Päivi Majaranta, Erno Mäkinen (& Poika Isokoski)

TAUCHI - Tampere Unit for Computer-Human Interaction

Suggested project topics: Gaze

- Topic: Gaze-controlled crossword puzzle (Design an interface for filling in crosswords with gaze)
- Modalities: Gaze (alone)
- Equipment: Tobii eye tracker (with MyTobii interface)
- Advisor: Päivi Majaranta

Suggested project topics: Gaze + speech

- Topic: Speaking with Gaze
  (Add speech output to eye typing, design interface for voice phone call by gaze)
- Modalities: Gaze input + speech output
- Equipment: Tobii (& SAPI)
- Advisor: Päivi Majaranta

TAUCHI - Tampere Unit for Computer-Human Interaction

Suggested project topics: Gaze + speech

- Topic: Look-and-Speak
  (Point by gaze, initiate the action by voice; target application to be decided together with the students)
- Modalities: Gaze + speech
- Equipment: Tobii (& SAPI)
- Advisor: Päivi Majaranta (gaze) & Markku Turunen (speech)

Suggested project topics: Gaze

- Topic: Gaze-Controlled Game Classics
  (Take any classic game & make it more fun by adding gaze input -- or make it totally controlled by gaze to make it possible to play by a disabled person, see http://en.wikipedia.org/wiki/List_of_open_source_games)
- Modalities: Gaze (alone or combined with any other modality)
- Equipment: Tobii eye tracker (with MyTobii interface)
- Advisor: Päivi Majaranta
- See also: http://www.cogain.org/links/gaze-controlled-games

TAUCHI - Tampere Unit for Computer-Human Interaction

Suggested project topics: Gaze + ?

- You are free to invent a topic of your own!
- Especially, good ideas for gaze-aware (attentive) applications are welcome!

Thank you for your attention!

Have fun with the project work! ☺