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Contents

• Motivation: why eye patterns?
• Building blocks of eye patterns
  – Areas of Interest
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Dynamic Replay of Gaze Paths

- How much can you remember after the replay?
- How can you compare several gaze paths?
Yarbus’s Early Scanpath Recording

1. examine at will
2. estimate wealth
3. estimate ages
4. guess previous activity
5. remember clothing
6. remember position
7. time since last visit

Source: Yarbus (1967), p. 174
Static Visualizations Can Tell a Lot

- They can be useful in characterizing typical gaze paths if the explaining variable is known (or can be guessed) in advance
- *Task* is often an important explaining variable
Typical Static Visualizations

- Fixations are represented as circles
- Radius is proportional to duration
- Saccades are represented by lines
Hypothesis: experts and novices will produce different gaze paths

Differences could be observed visually – but expertise was *not* the explaining variable

Comparison is still very difficult È analytical methods desirable

Source: Aula, Majaranta, & Räähä (2005)
A Variety of Goals

- **Dynamic vs. static**
  - Dynamic playback: full information
  - Static visualization: more amenable to analysis

- **Real time vs. post hoc**
  - Real time: prediction in attentive interfaces
  - Post hoc: analysis of empirical data

- **Goal of the analysis**
  - Activity detection
  - Attention detection
Activity Detection 1: Distribution of Fixation Durations

Source: Pelz, Canosa, & Babcock (2000)
Activity Detection 2: Sequences of Fixation Durations

Source: Pelz, Canosa, & Babcock (2000)
Sequences – an Abstraction of the Data

- **Fixation sequence:** TTBNNNLBL
- **Gaze sequence:** TBNBLBL
- **Abstracted away**
  - duration
  - exact location

Source: West et al. (2006)
Possible Problems

- Inaccuracy of eye trackers – borderline fixations assigned incorrectly
- With natural targets, it is difficult to know what the interesting areas are
  - especially in advance
  - but also after the data has been collected
Clustering

- Blocks of fixations that seem to belong together are computed automatically *from the data*
- Privitera & Stark (2000)
- DeCarlo & Santella (2004)
Gaze Clusters

Source: DeCarlo & Santella (2004)
String Edit Distance 1/2

- Minimum number of insert and delete operations needed to transform one string into the other
- Example: find the distance between TTBNNLBL and TBBNLBL
- Trivial solution:
  TTBNNLBL \( \not\sim \) XXXXXXXXXXX \( \not\sim \) TBBNLBL 15
- Distance always at most the sum of the lengths of the strings
- A better solution:
  TTBNNLBL \( \not\sim \) TXBNXNLBL \( \not\sim \) TBBNLBL 3
String Edit Distance 2/2

- Origin in stringology and data structure research
- Can be efficiently computed by dynamic programming
- Also called “Levenshtein distance”
- Extensively used (and extended) in bioinformatics

- For us: can serve as a measure of similarity of two gaze paths
Is It a Good Measure?

- What do “delete” and “insert” mean in terms of AOI’s?
  - One user has seen something that the other has not
  - This may be highly significant or meaningless depending on the area in question – this is ignored by the metric

- A transposition is a costly operation (1 delete + 1 insert = 2)
  - In practice, it may have little meaning

- Is the cost function the right one?
Variations

• Take “transpose” as one of the primitive (cost 1) operations
• Make the cost function more dynamic
  – Different costs depending on the areas
  – Different costs depending on the operation
  – ...
• A collection of cost functions (“penalties”) can be used: the Needleman-Wunsch algorithm
Eye Patterns as Strings

- Each gaze path is represented as a string
  ABCABBCDFGGGA
  AGGFFDSBBACBA
  GAGFFDSBBACBA
  GSF
  GFGFGFGAAGGF
  ABABABFFCDDFGGA

- Are they similar? How similar? Are there groups of similar paths?
Shortest Common Supersequence

- Find a sequence, as short as possible, so that you can embed each of the gaze paths in that sequence
- Probably not a good idea
  - Almost similar paths can produce a much longer supersequence
    ABCA
    ABDA
    ABEA
    ABFA
    ABGA
  - NP-complete computationally hard

È supersequence ABCDEFGA
Averaging Gaze Paths

Source: Hembrooke, Feusner, & Gay (2006)
Possible Problem

- The average path *may* look quite different from any of the paths in the set
- Hembrooke, Feusner, & Gay claim that this is not the case
- More experience needed
Interactive Tool: eyePatterns

- Let the user explore the collection of gaze paths interactively
- Functions include
  - Visualize sequence similarity
  - Find common patterns in the paths, including longest common subsequence
  - Compute transition probabilities between AOI’s
  - Compute average gaze path ("consensus sequence")

Visualization of Sequence Similarity

Source: West et al. (2006)
Cluster-Based Visualization

Source: West et al. (2006)
Are Sequences Too Simple?

- Another abstraction: probabilistic automata
- In particular, Hidden Markov Models
- Lots of room for experimentation!
References