On-line Gesture Recognition

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Presentation Outline

Slides available at http://personales.upv.es/luileito/lectures/gestures-upv.pdf

Introduction

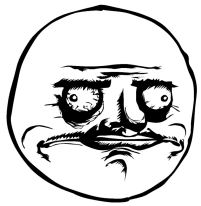
Definition

Gesture /ˈdʒstʃə/ *noun*

The use of motions of the limbs or body as a means of expression.

synonyms: signal, sign, motion, indication, gesticulation

"Gestures are hand-drawn strokes that do things."

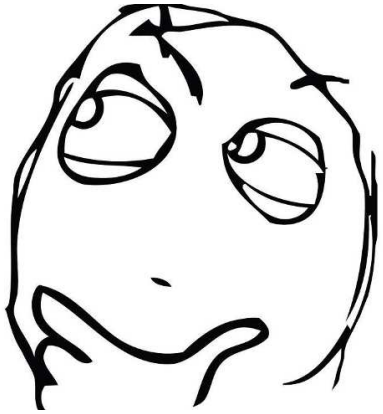


— Lipscomb (1991)

Definition

- **Off-line** gesture recognition:
  post-hoc, processed after user interaction
  static data, no temporal info available

- **On-line** gesture recognition:
  realtime, direct manipulation
  sequential, time series data



Historical Precedents

sketchpad

Sutherland (1963)

RAND tablet

Davis and Ellis (1964)

Gestures Today

Minority Report. Image by 20th Century Fox & DreamWorks

Input Devices

Wii. Image by Nintendo Co., Ltd.

Input Devices

T(ether). Image by Massachusetts Institute of Technology

Input Devices

Kinect for Xbox 360. Image by Microsoft Corporation

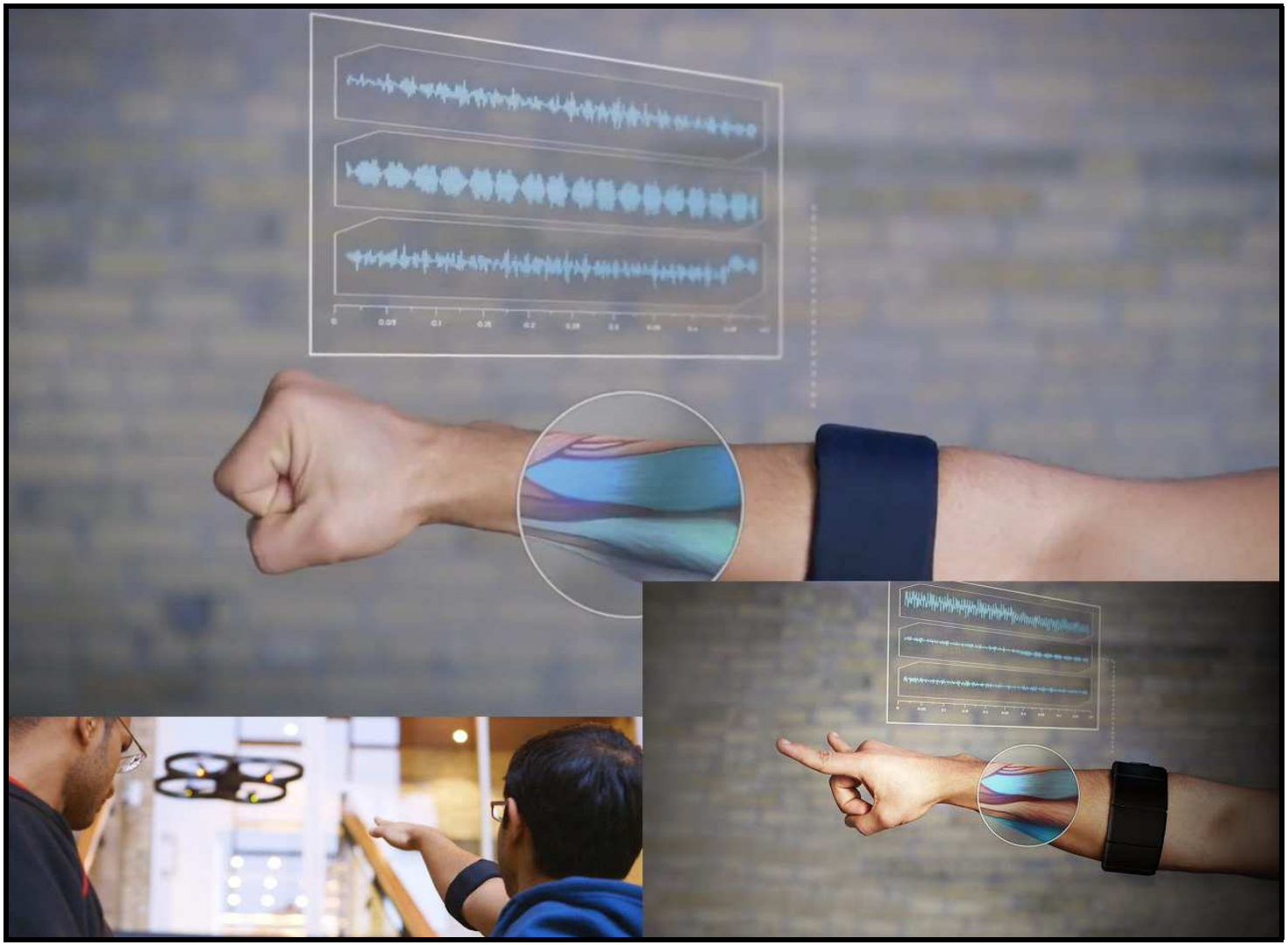
Input Devices

Humantenna. Image by Microsoft Research

Input Devices

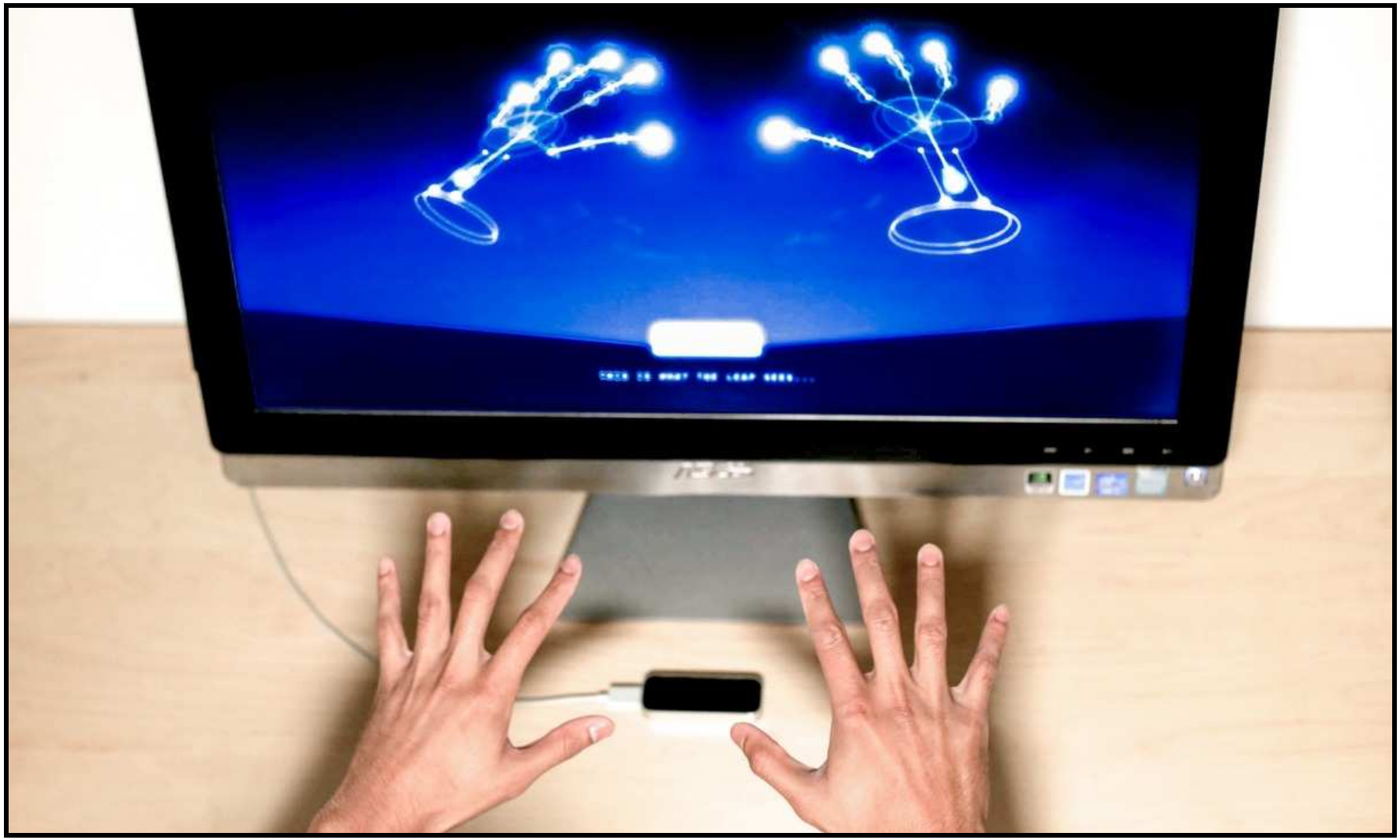
Skinput. Image by Carnegie Mellon University

Input Devices



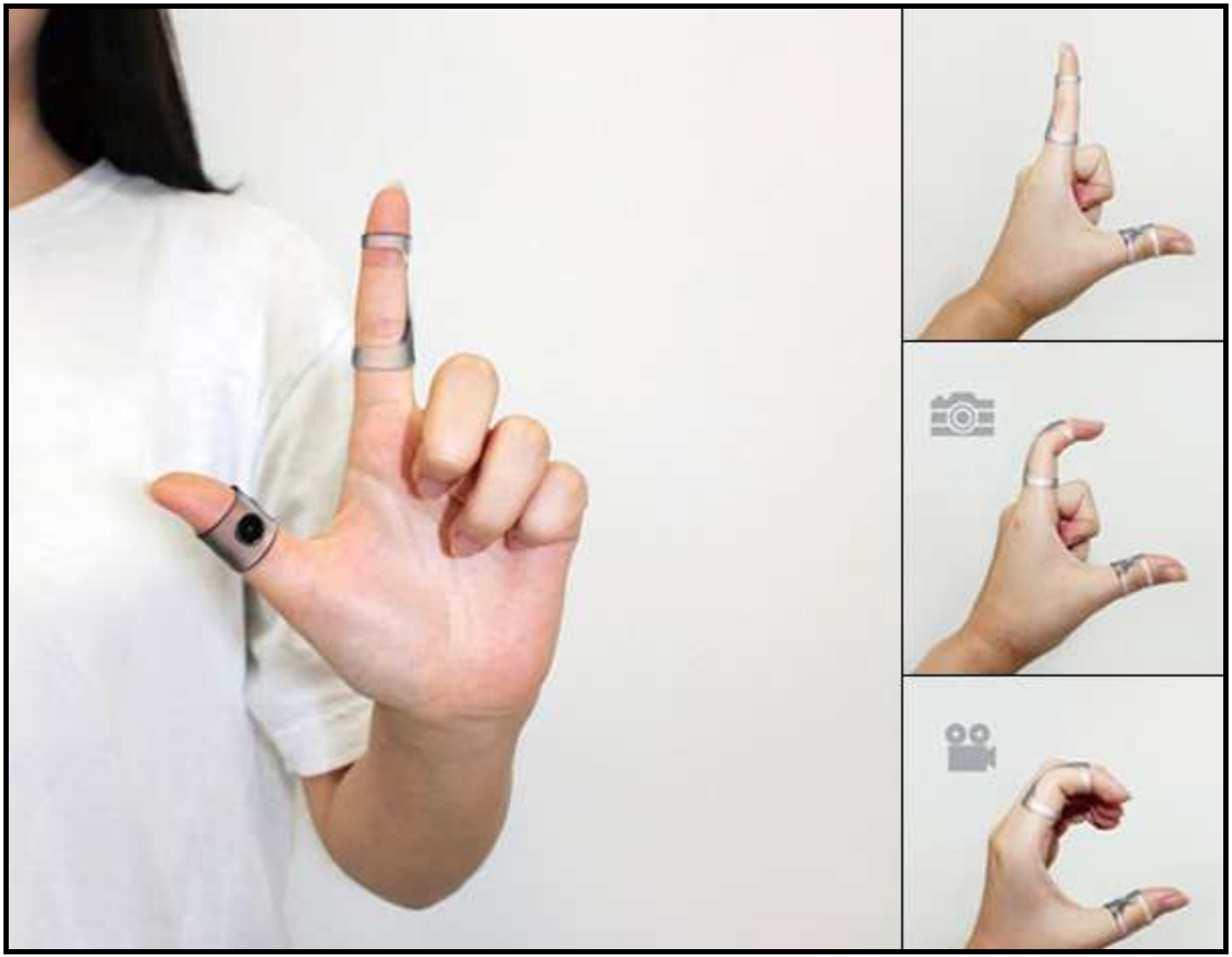
Myo. Image by Thalmic Labs

Input Devices



Leap motion. Image by Leap Motion, Inc.

Input Devices

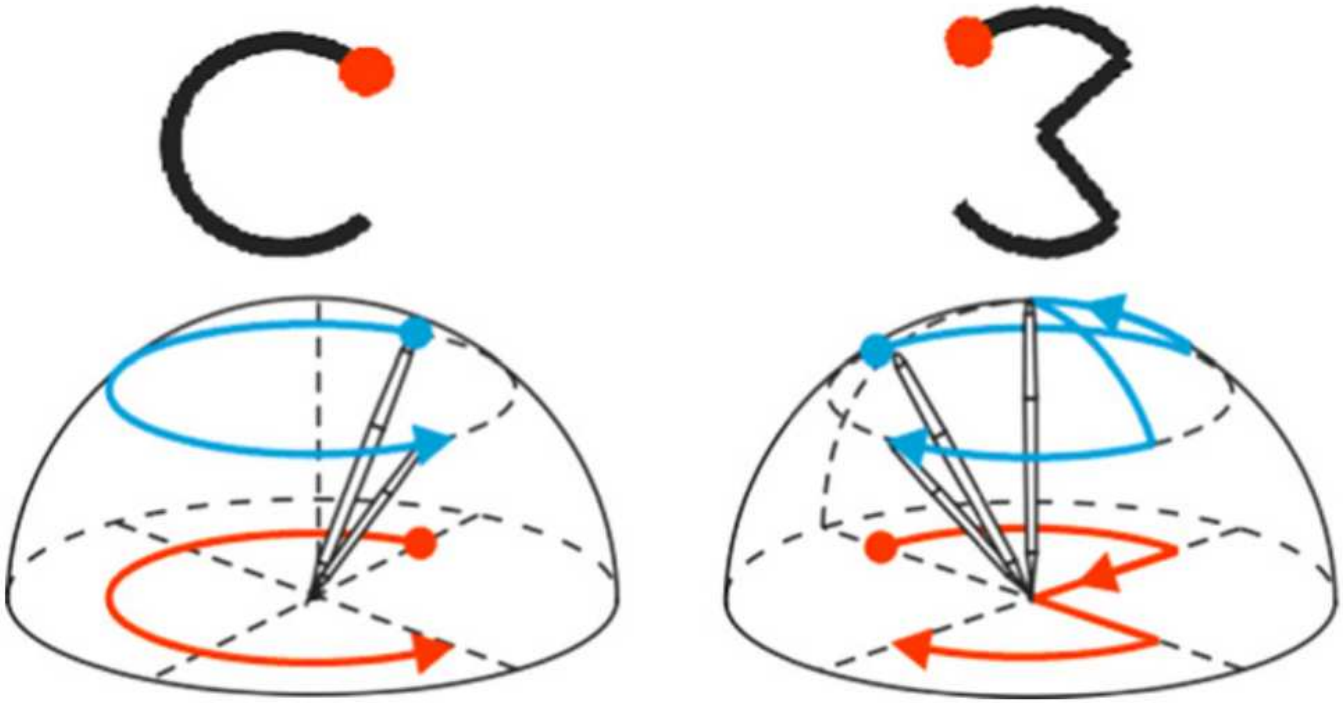


Air Clicker. Image by Yanko Design

Input Devices

TapTap. Image by Woodenshark LLC

Input Devices



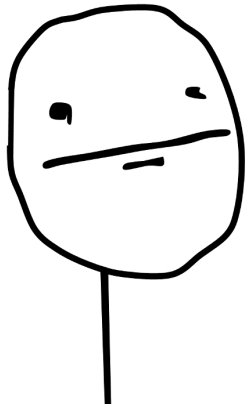
Pen Tail gestures, by Tian et al. (2012)

Advantages

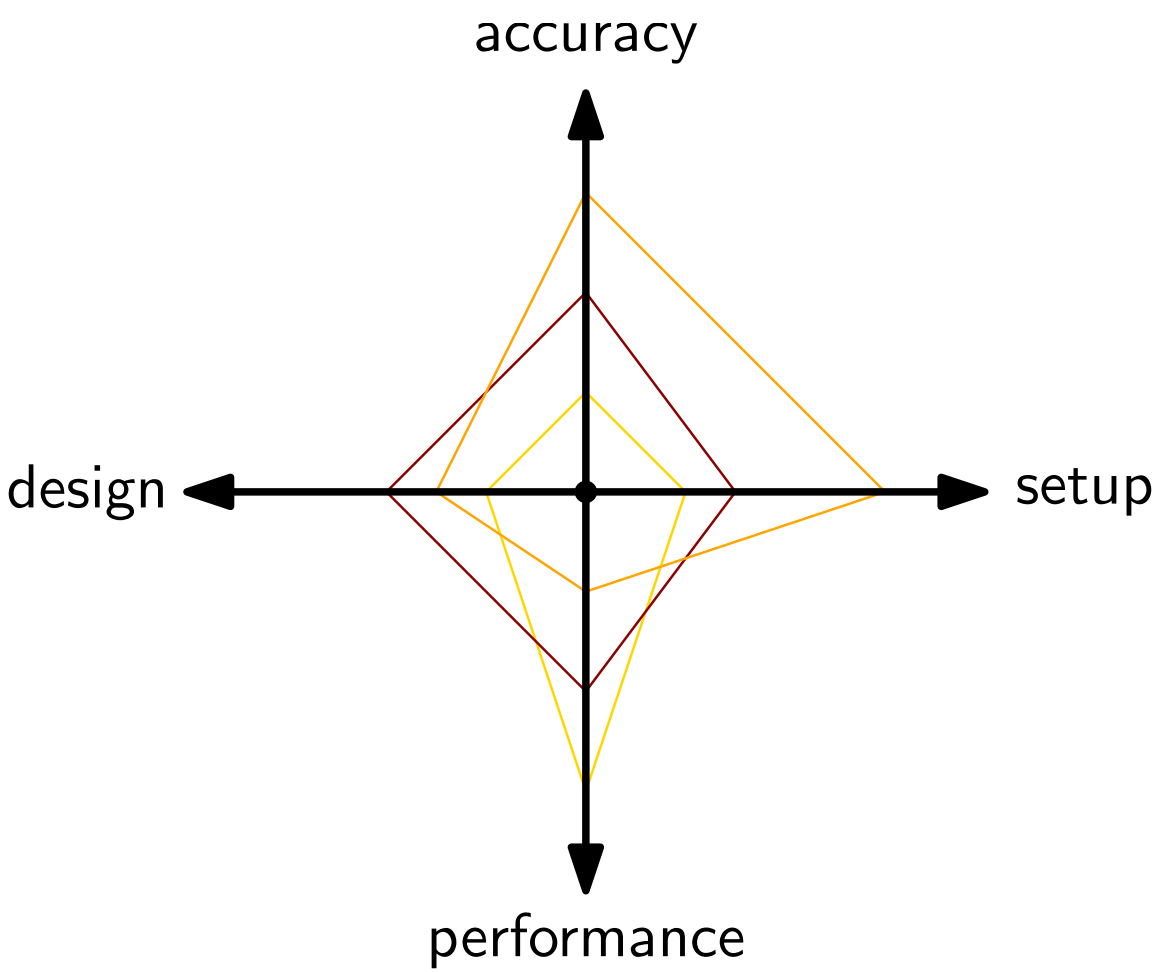
- Natural communication
- Expressiveness
- Ergonomics
- Usability
- Fun

Disadvantages

- May break fundamental interaction principles:
  Discoverability, **Reliability**, Scalability, etc.
- Ambiguity: **non-deterministic decoding**
- Lack of standards
- Cultural issues



Trade-offs



Preliminaries

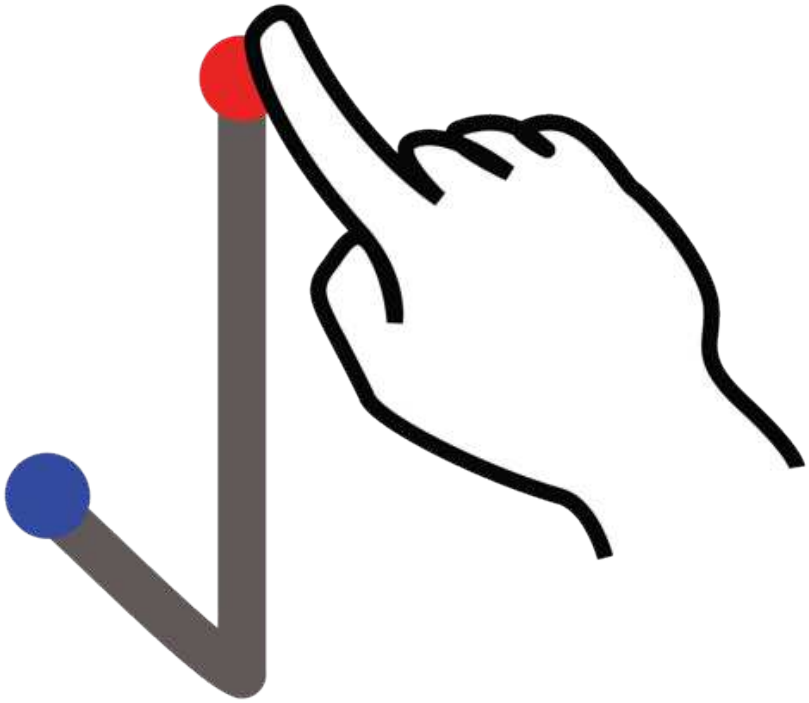
Interaction Paradigms

Mid-air

Onscreen

Definition

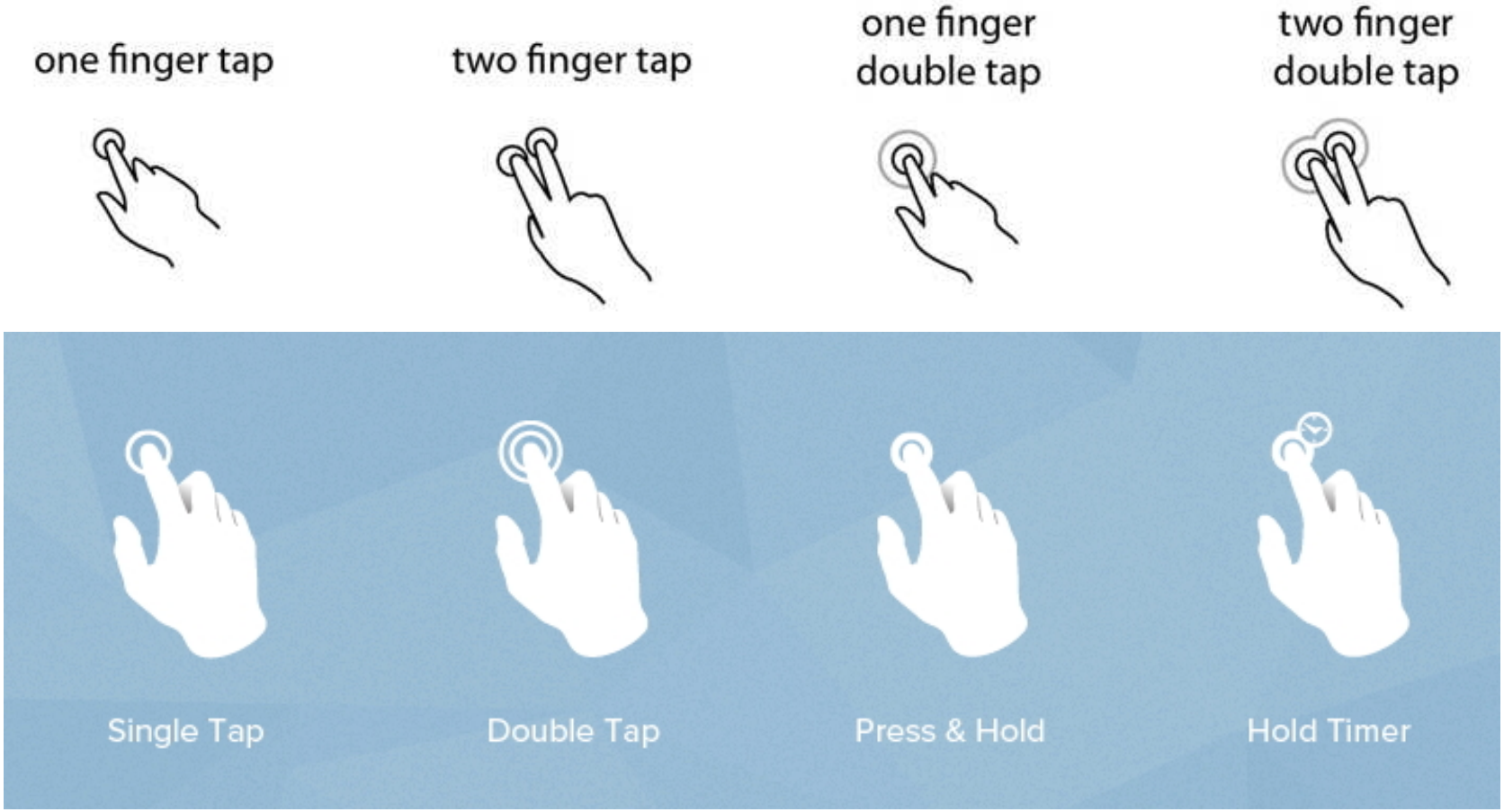
stroke = pointer **down** → pointer **move** → pointer **up**



$$\boldsymbol{s} = \{(x_1, y_1, t_1) \cdots (x_j, y_j, t_j) \cdots (x_N, y_N, t_N)\}$$

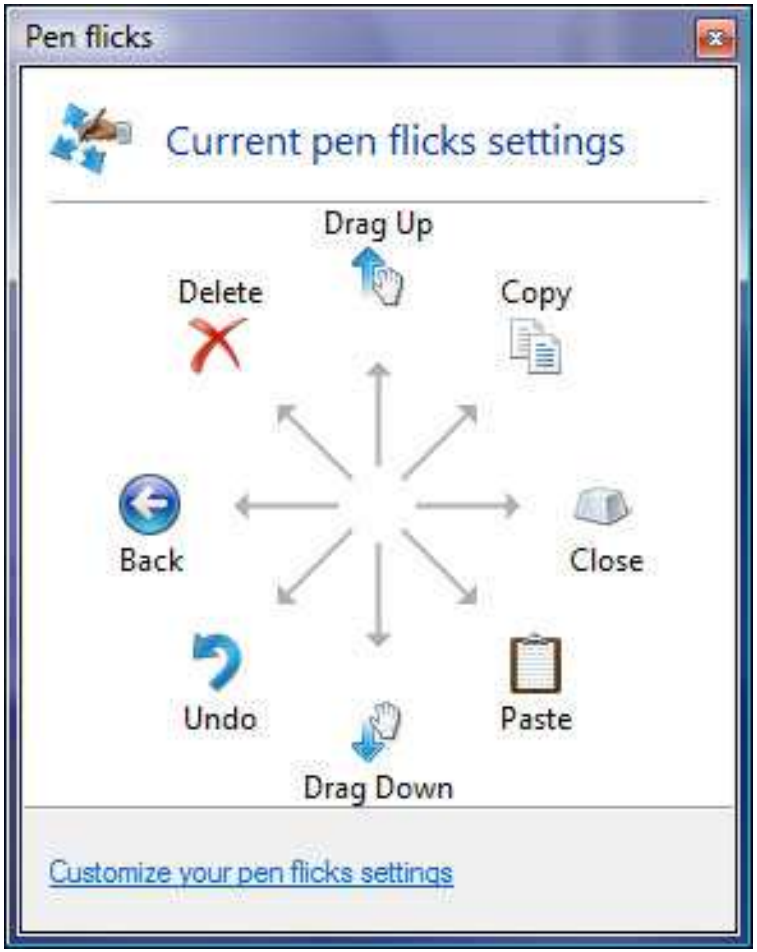
A Taxonomy

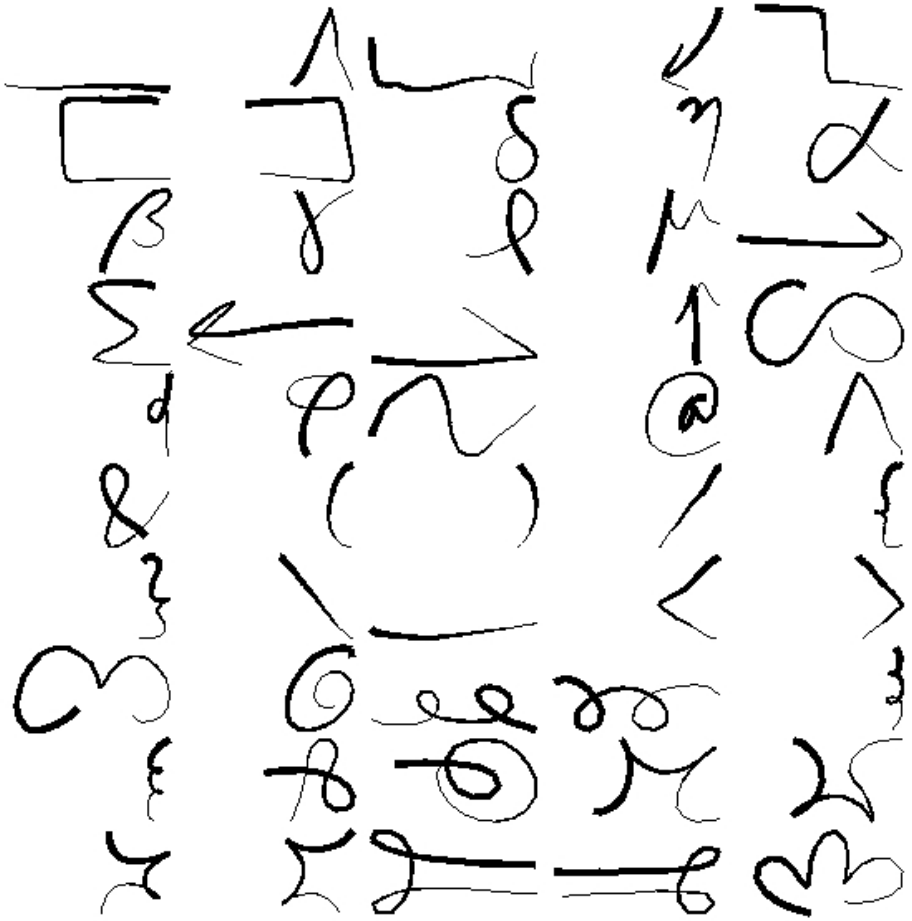
zero-order gestures



A Taxonomy

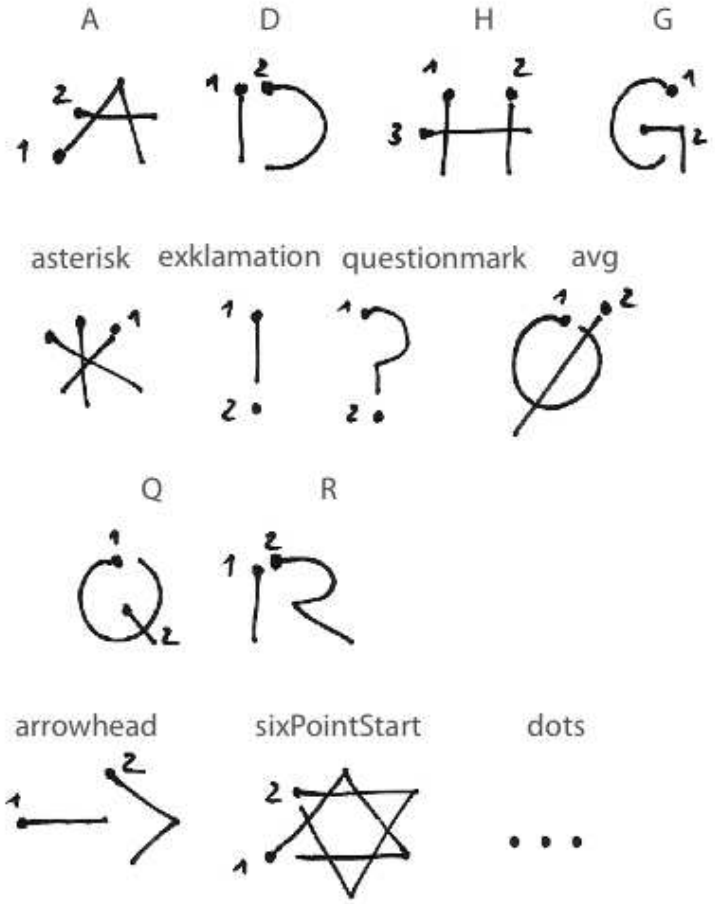
first-order gestures (unistrokes)



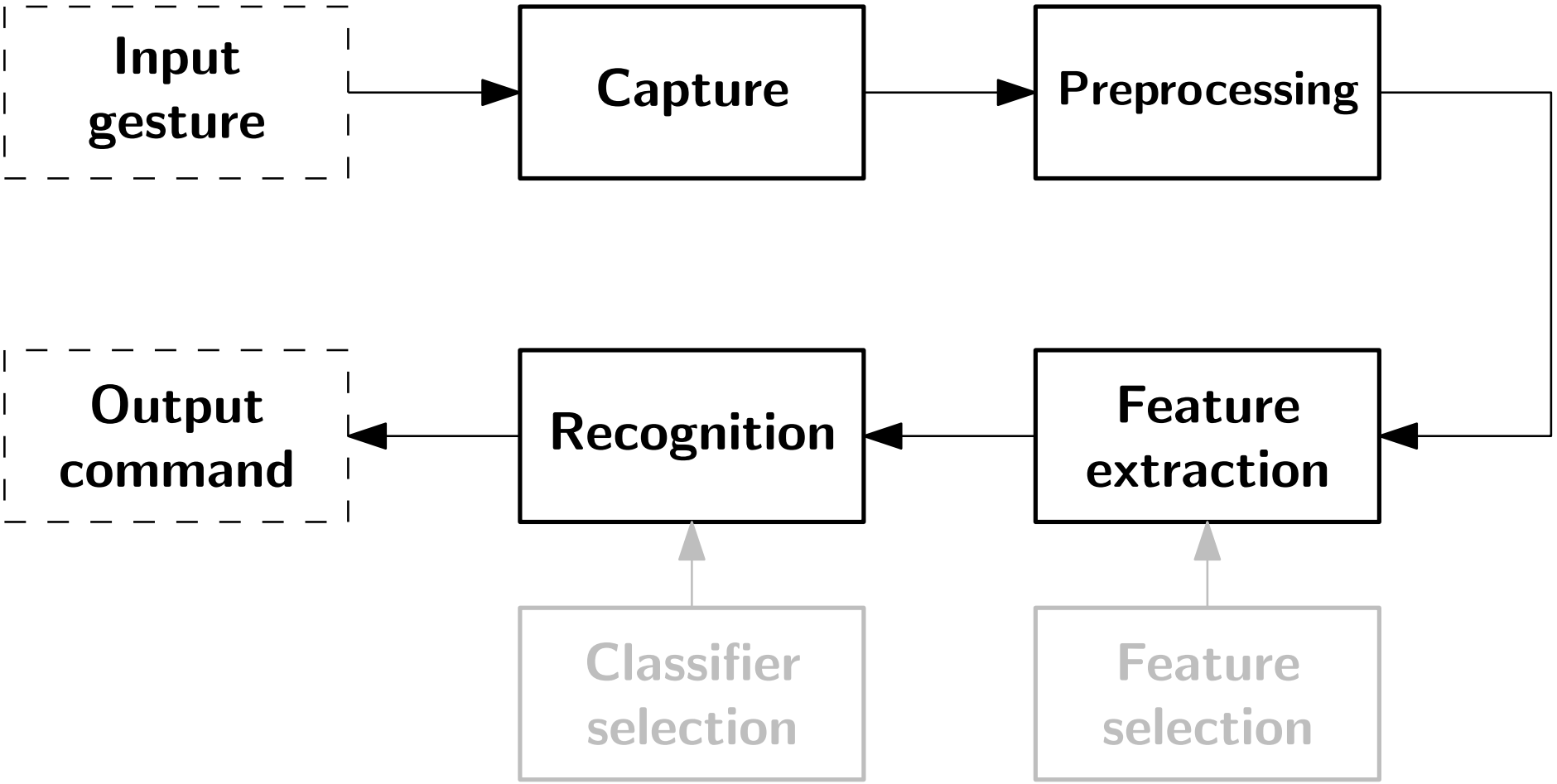


A Taxonomy

higher-order gestures (multistrokes)

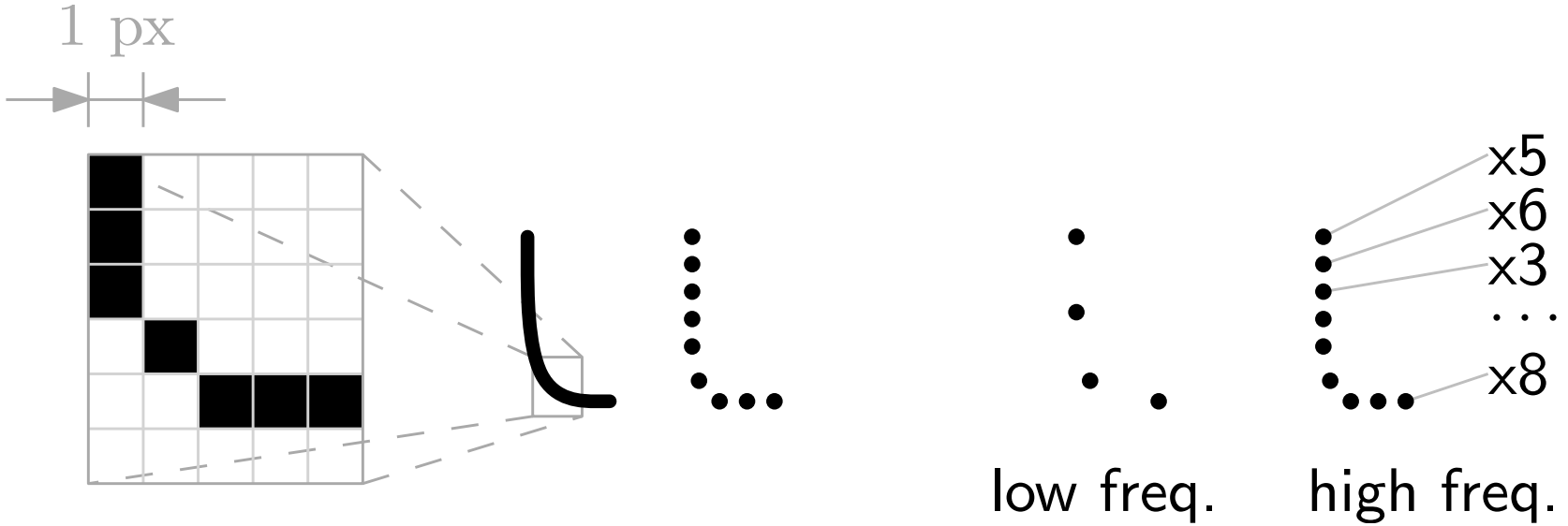


Processing Pipeline



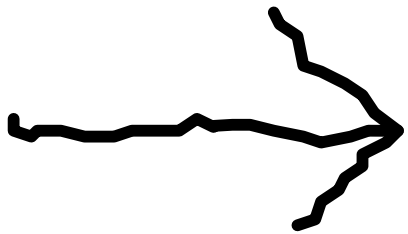
Capture

- Event-based
- Polling (constant frequency)

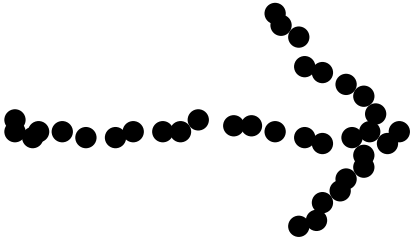


Sampling rate matters!

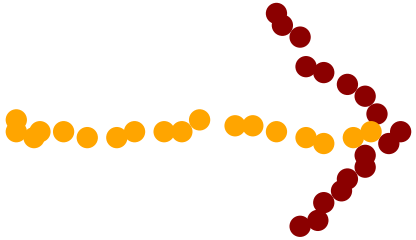
Preprocessing



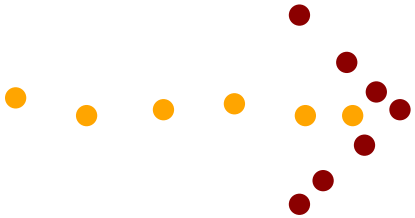
input



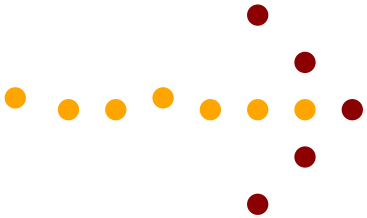
capture



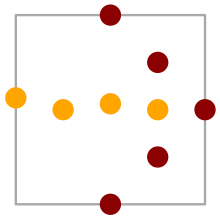
segmentation



noise removal*



resampling*



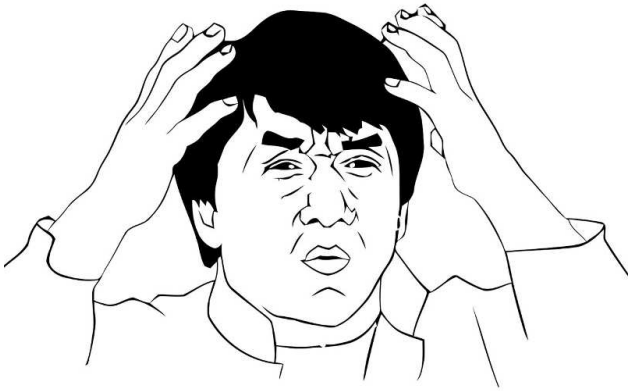
normalization*

*optional steps

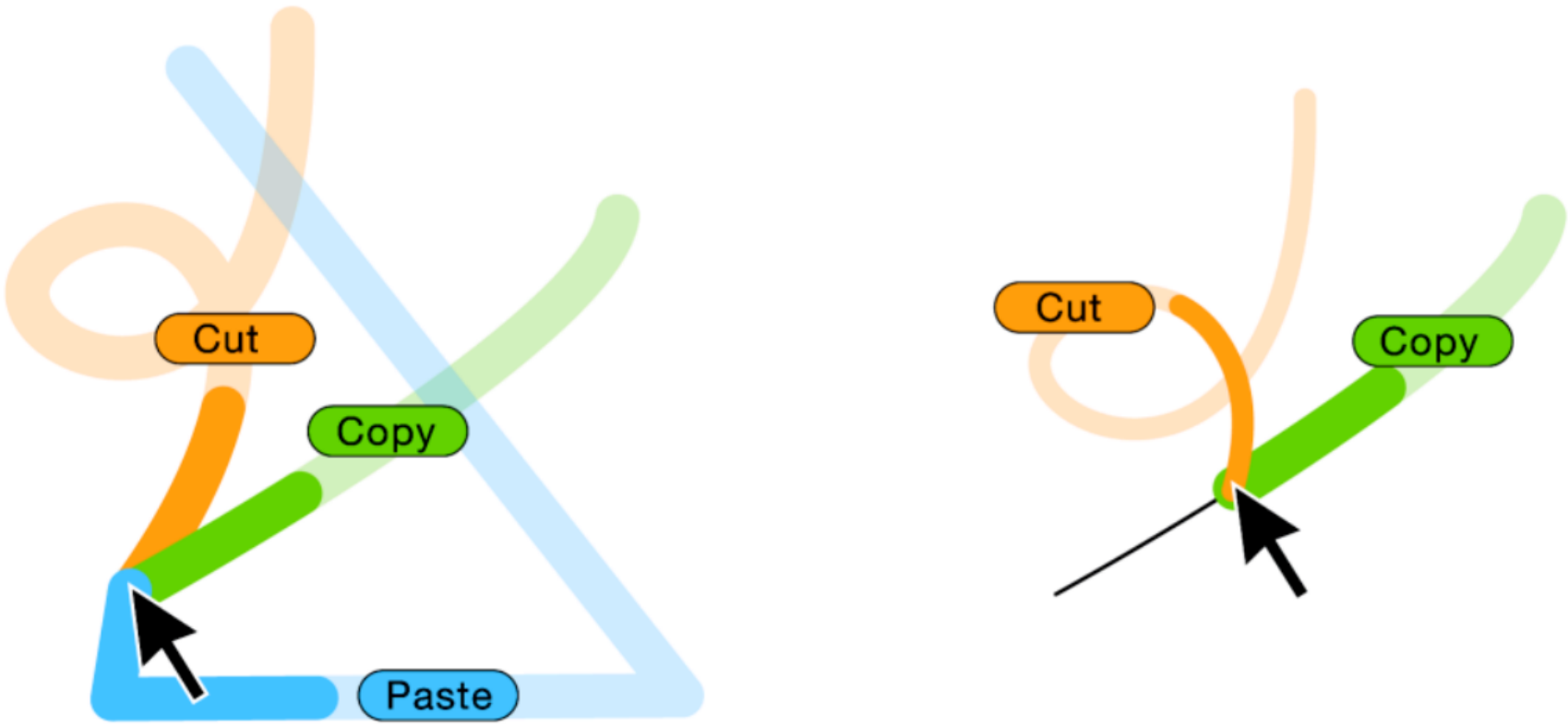
Features

Recognition Techniques

- Hashing: dictionary lookup, zone coding, chain codes
- Parametric: linear fitting, corner detection
- Matching: DTW, k-NN, “dollar family”
- Statistical: linear classifier, NNs, HMMs, CRFs
- Ad hoc: knowledge-based, decision trees, FSM



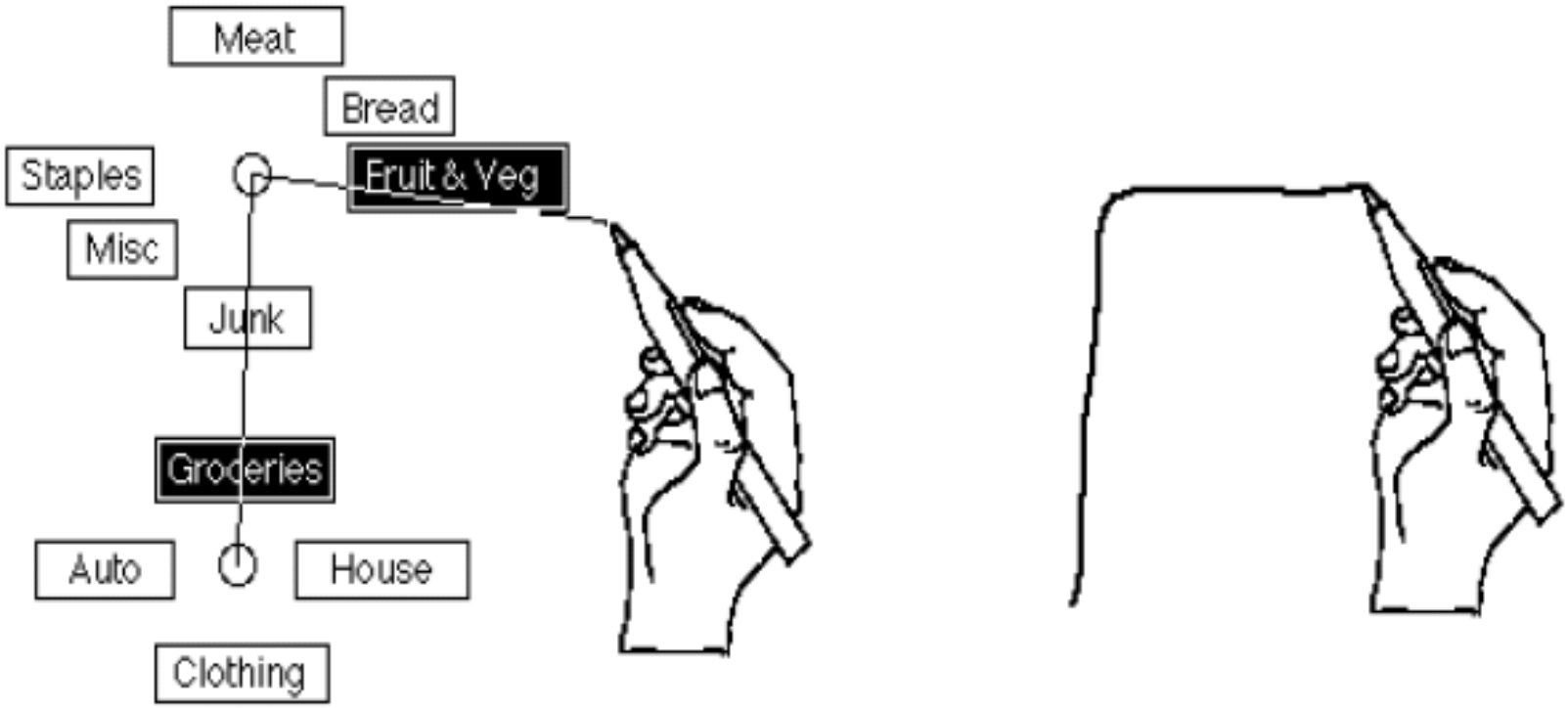
Continuous Recognition



OctoPocus, by Bau and Mackay (2008)

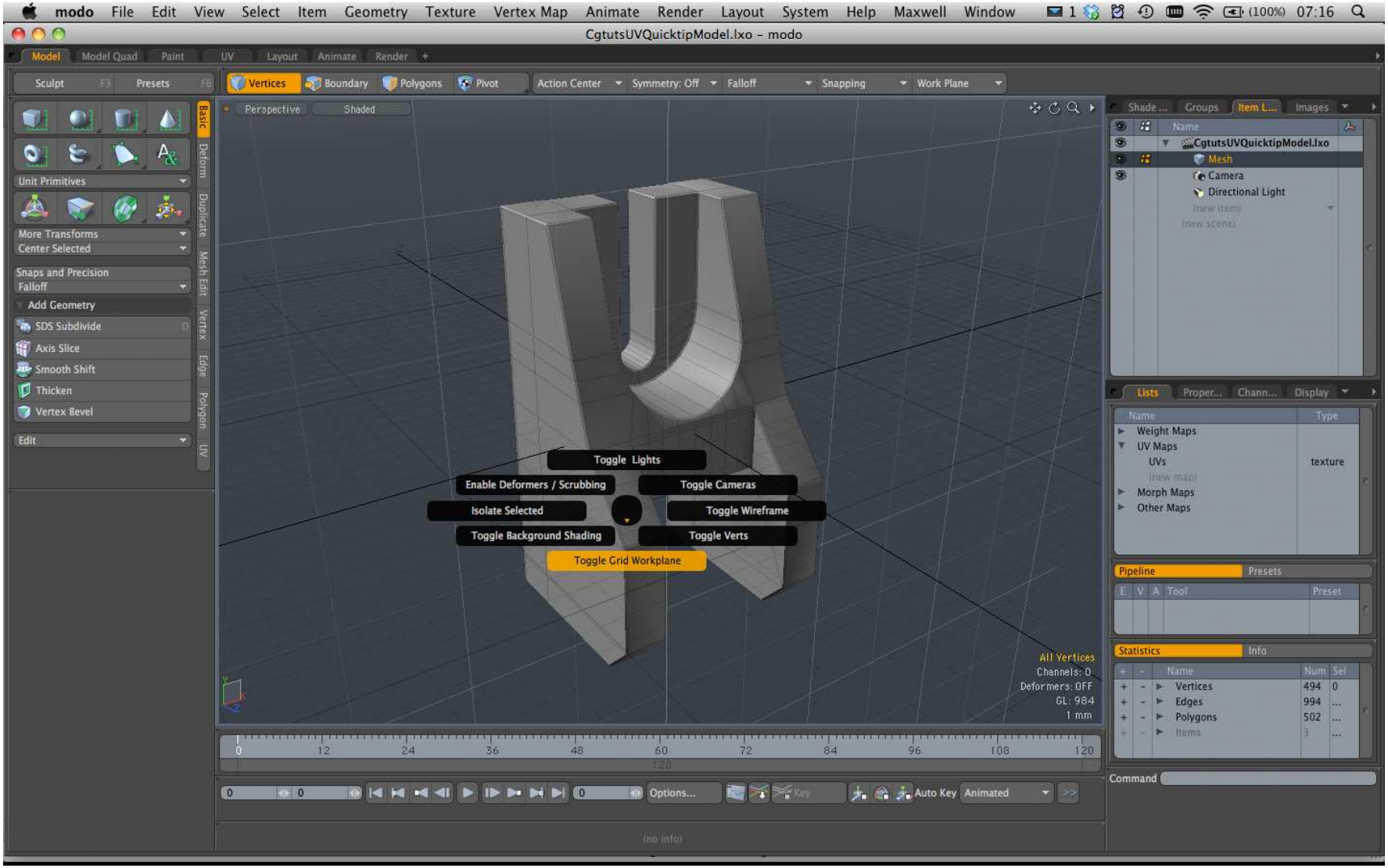
Some Techniques

Marking Menus



by Kurtenbach (1991)

Marking Menus



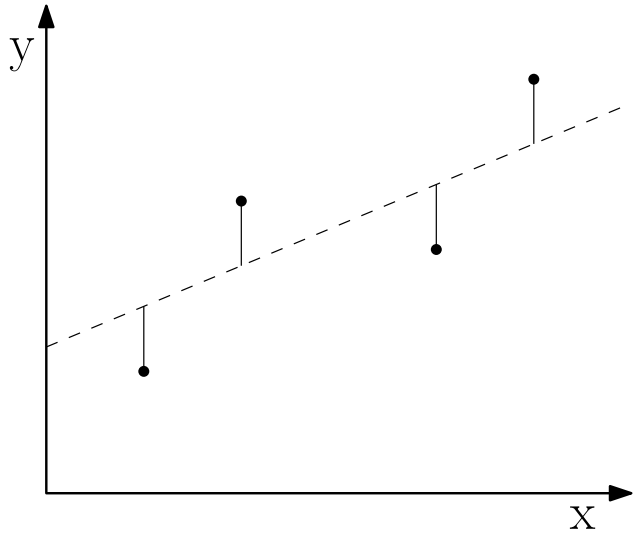
Blender. Image by Blender Foundation

Linear Fitting

$$\hat{\boldsymbol{y}} = a + b\boldsymbol{x}$$

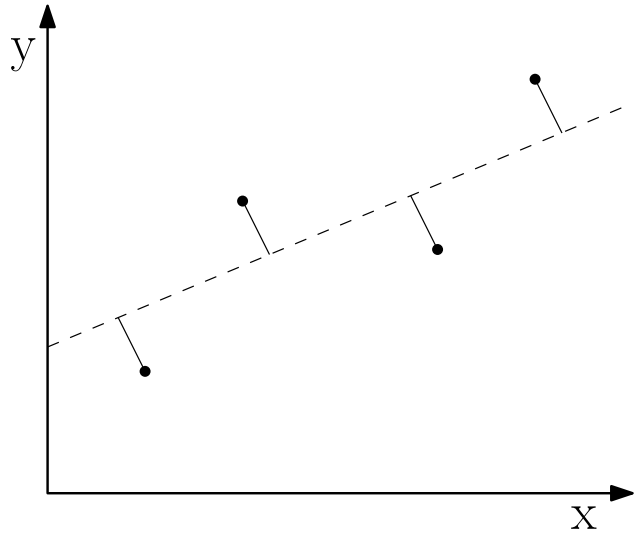
minimize $R^2 = \sum_{i=1}^{N} {r_i}^2$

vertical offsets



$$r_i = y_i - (a + bx_i)$$

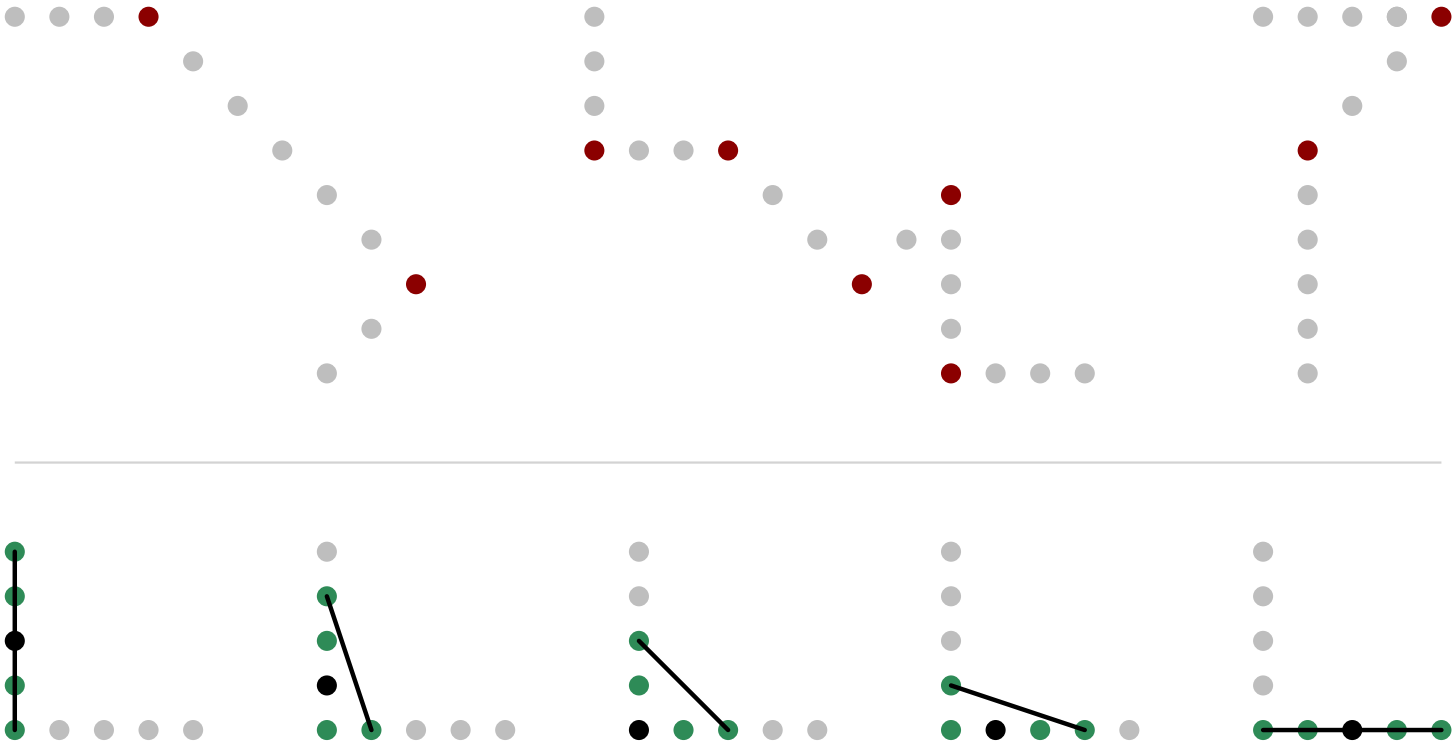
perpendicular offsets



$$r_i = \frac{|y_i - (a + bx_i)|}{\sqrt{1 + b^2}}$$

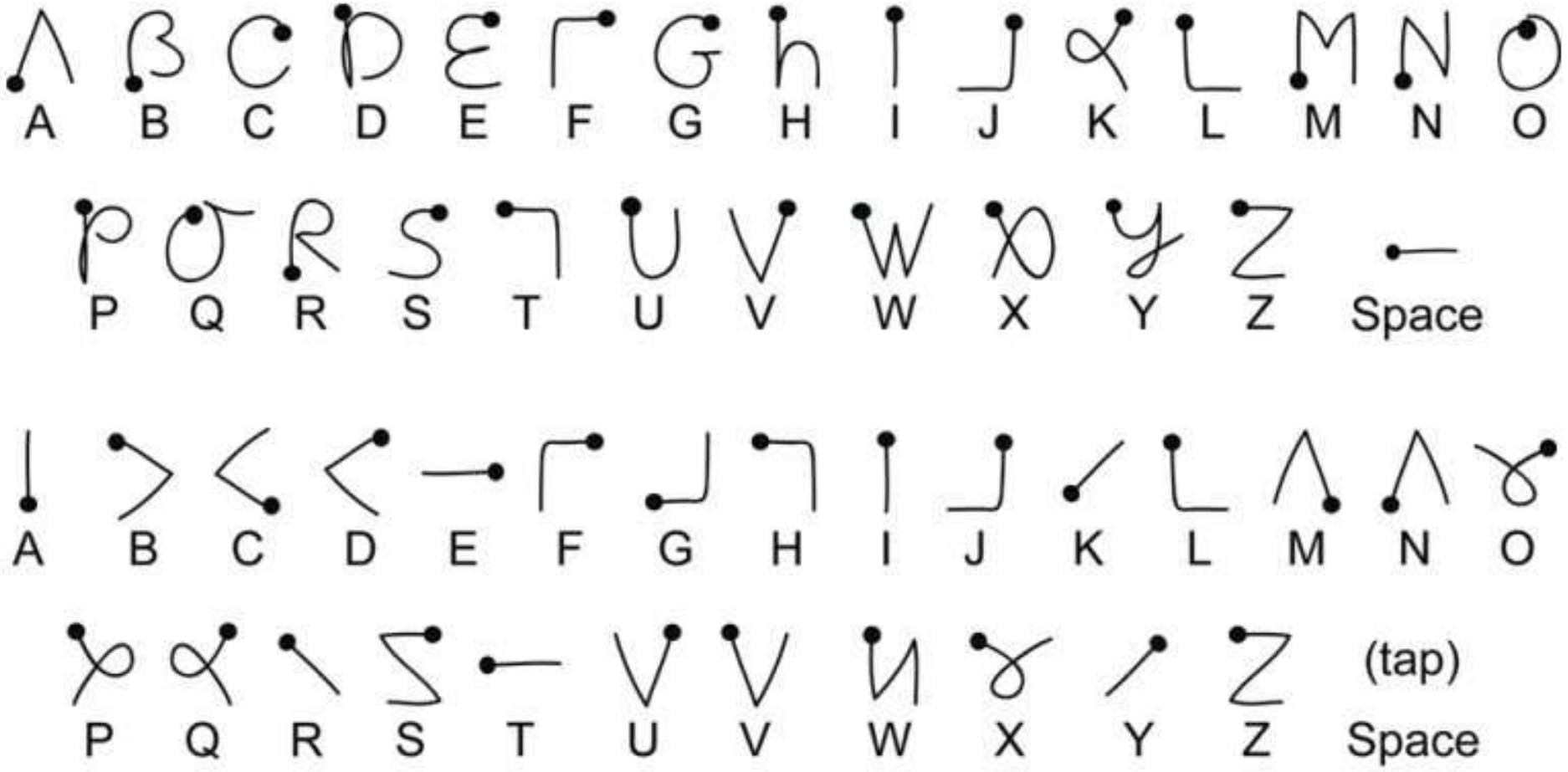
Corner Detection

PDL, ShortStraw, Firefox's QuickGestures, etc.



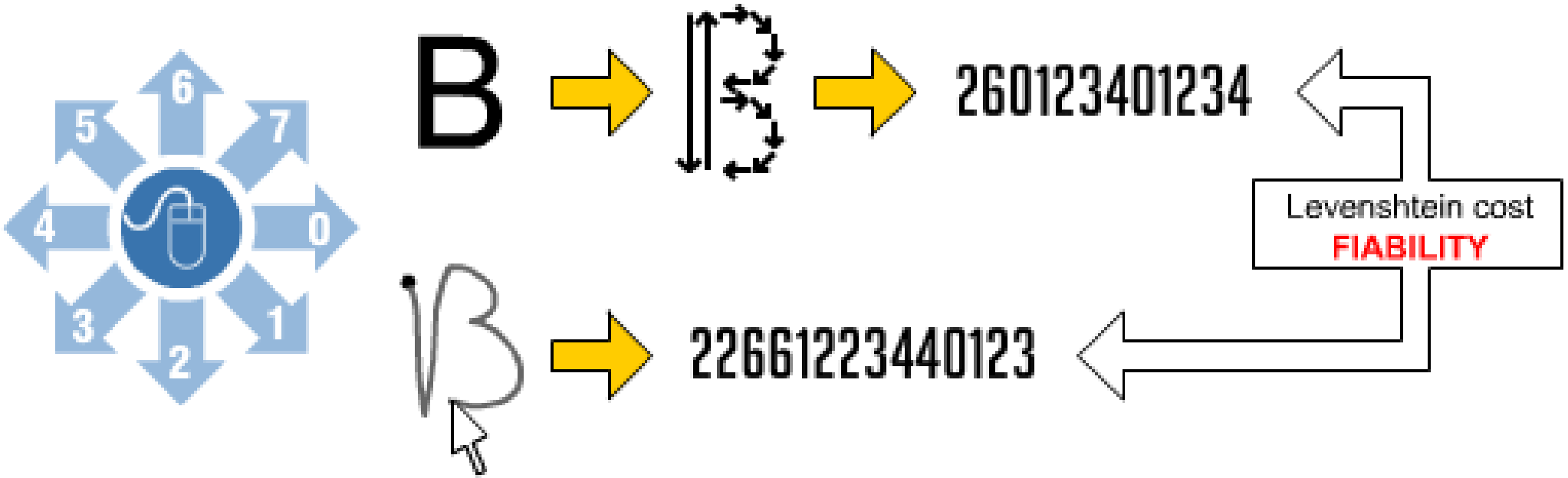
$$G = s_1, \ldots, s_n, \ldots, s_N \mid s_n \in \{L, R, U, D\}$$

Graffiti & Unistrokes



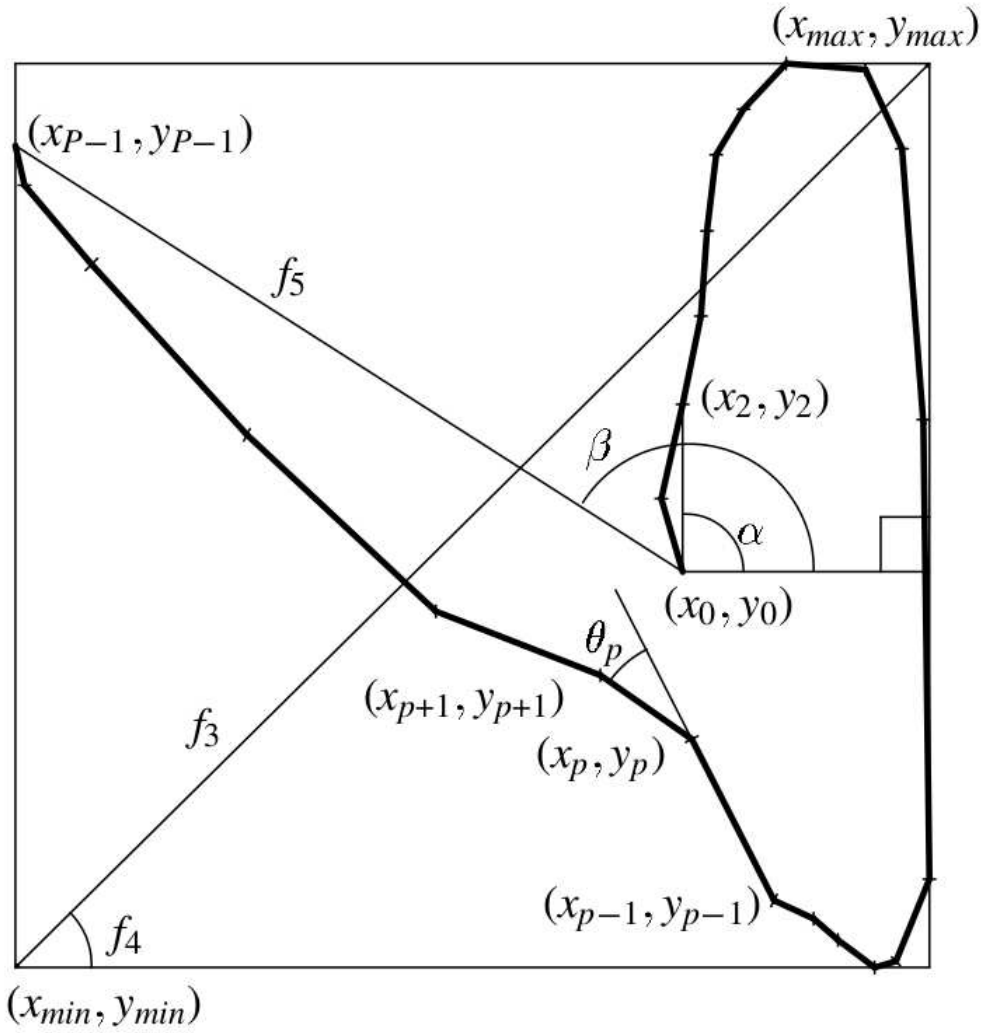
Comparison by Castellucci and MacKenzie (2008)

Graffiti & Unistrokes



Demo: http://www.bytearray.org/wp-content/projects/mousegesture/GestureDemo.swf

Rubine recognizer



by Rubine (1991)

Rubine recognizer

linear classifier using $F = 13$ stroke features

$$c = f\left(\boldsymbol{w}^T \boldsymbol{g}\right) = w_o + \sum_{i=1}^{F} \Sigma^{-1} \mu_i$$

$$w_0 = -\frac{1}{2} \sum_{i=1}^{F} w_i \mu_i$$

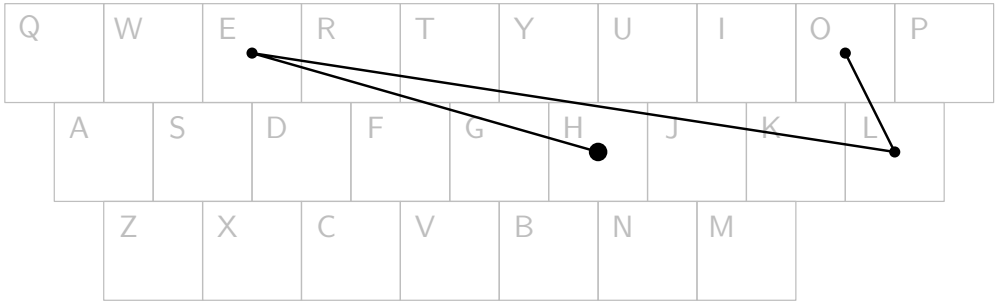
weight estimation:
perceptron, LSBF, LDA, SVM, logistic regression, etc.

Shapewriting

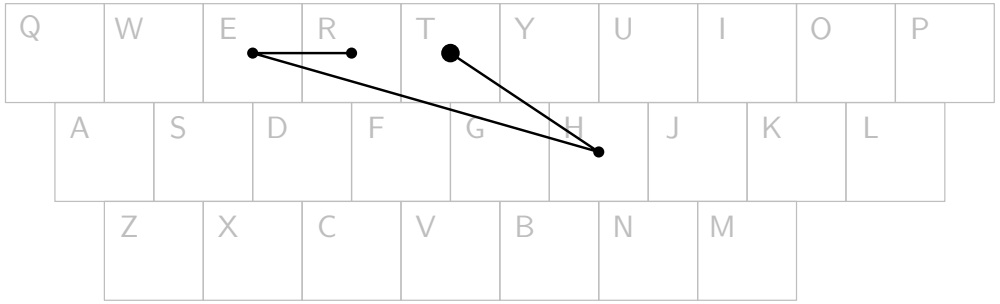
SHARK^2, by Kristensson and Zhai (2004)

Shapewriting

sokgraph of “hello”



sokgraph of “there”

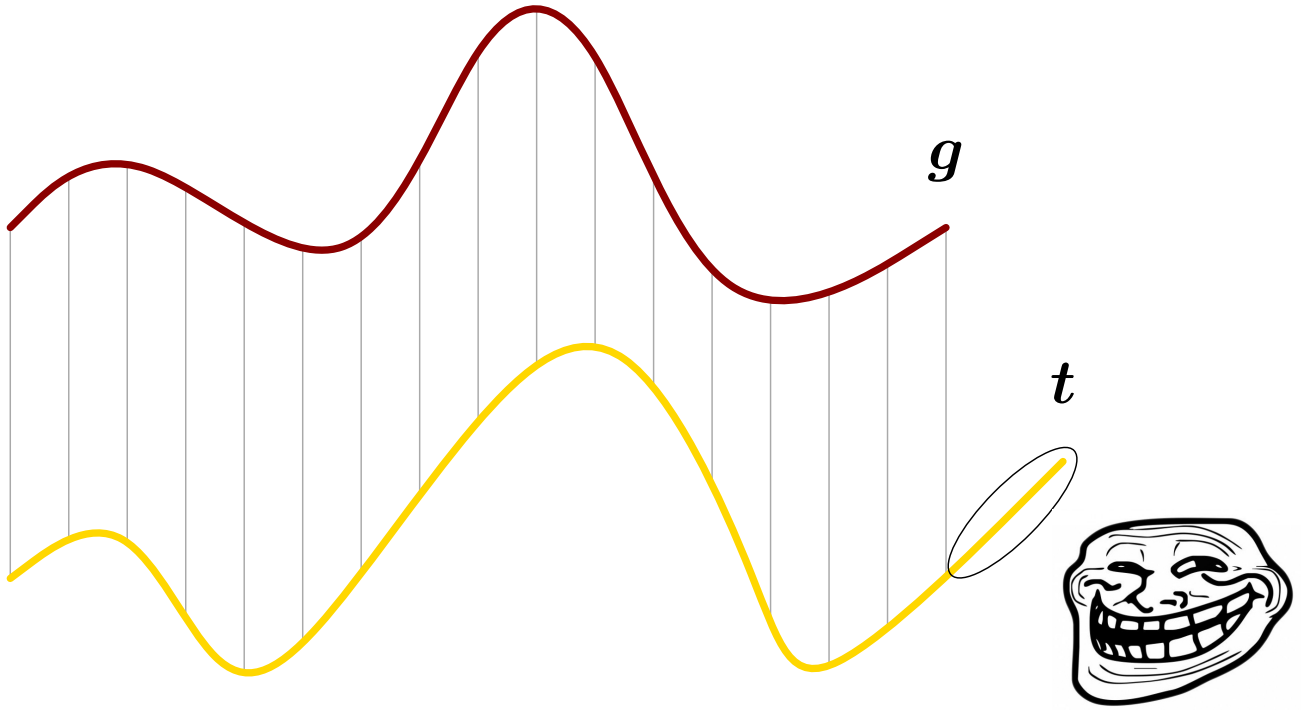


$$\hat{W} = \arg\max_{W} P(W|\boldsymbol{g})$$

$$\hat{W} = \arg\max_{W} \frac{P(\boldsymbol{g}|W)P(W)}{P(\boldsymbol{g})} = \arg\max_{W} P(\boldsymbol{g}|W)P(W)$$

Euclidean Matching

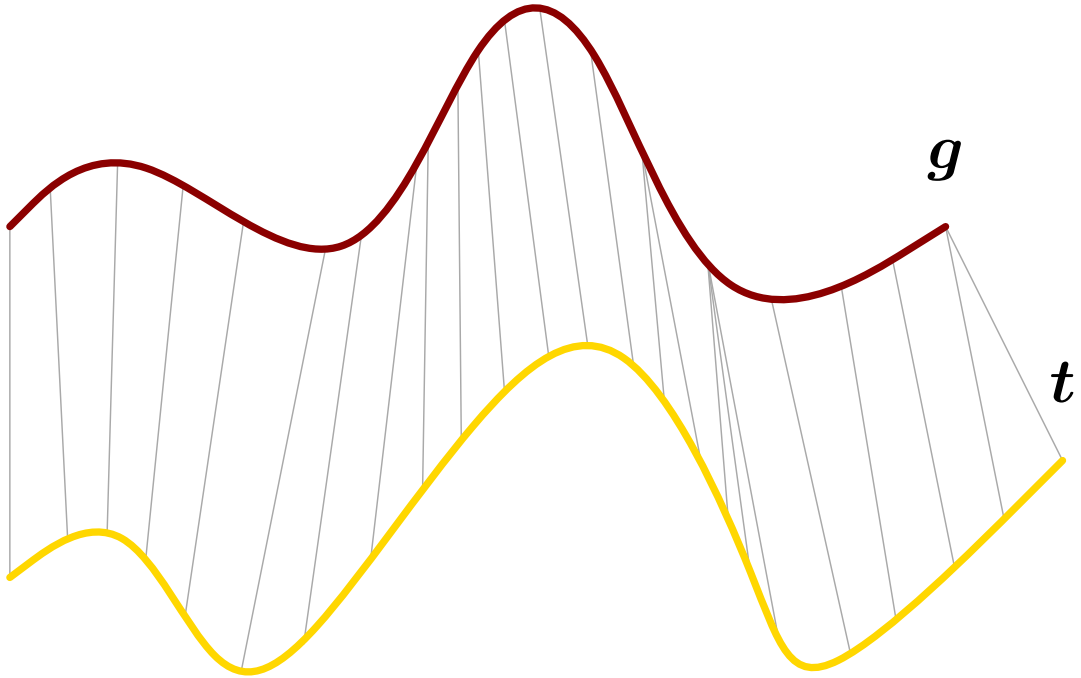
point-wise distances



$$D(\boldsymbol{g}, \boldsymbol{t}) = \frac{1}{|\boldsymbol{g}|} \sum_{i=1}^{|\boldsymbol{g}|} \|g_i - t_i\|$$

Elastic Matching

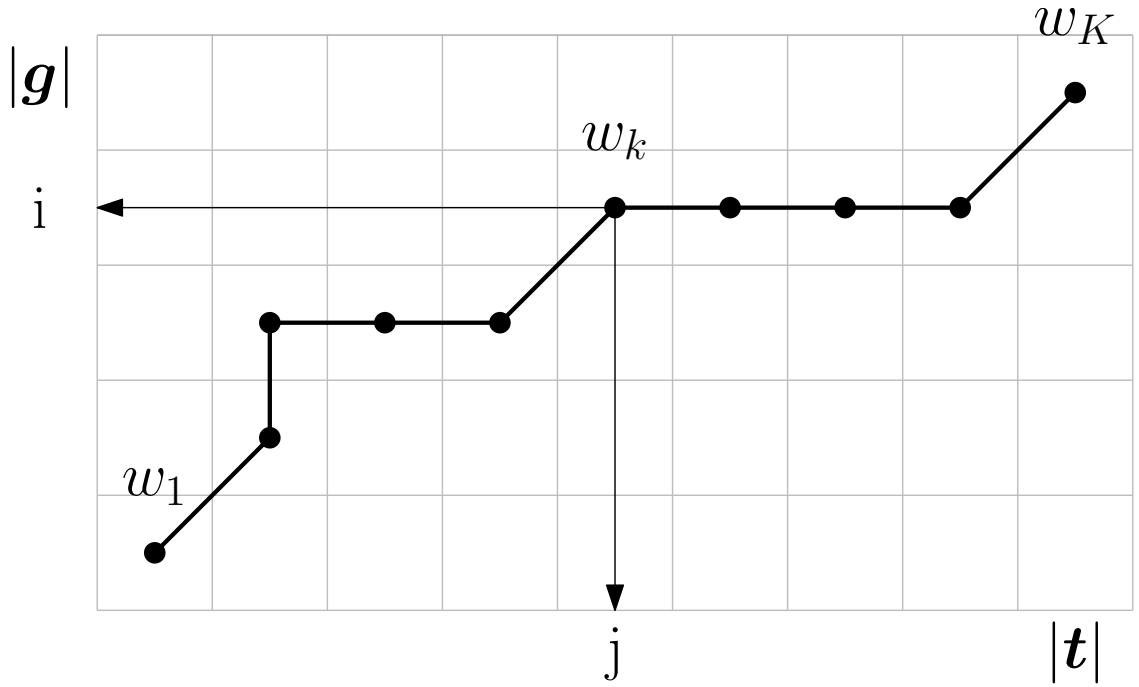
dynamic programming



$$D(\boldsymbol{g},\boldsymbol{t}) = \min_{W \in \mathcal{W}} \frac{1}{|W|} \sum_{k=1}^{|W|} w_k$$

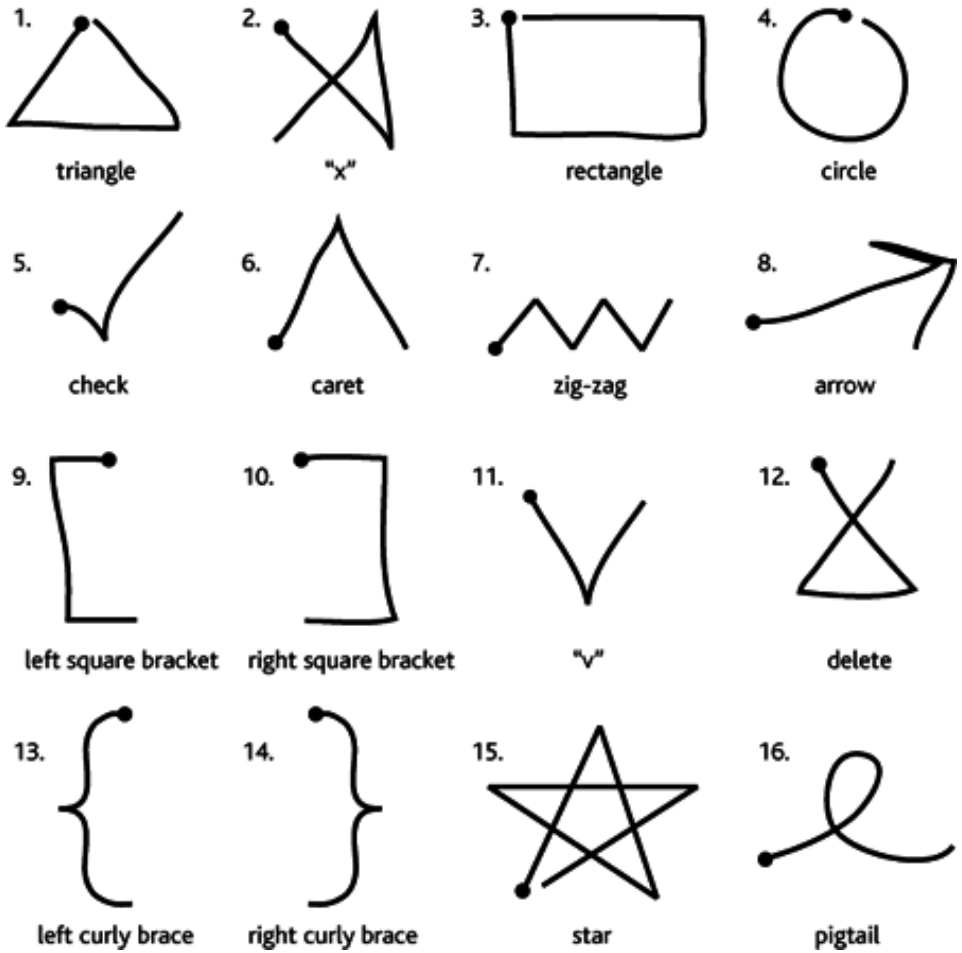
Elastic Matching

$$W = w_1, \ldots, w_k, \ldots, w_K$$



$$\gamma(i,j) = d(i,j) + \min\{\gamma(i-1,j), \gamma(i,j-1), \gamma(i-1,j-1)\}$$

The Dollar Family: $1 recognizer

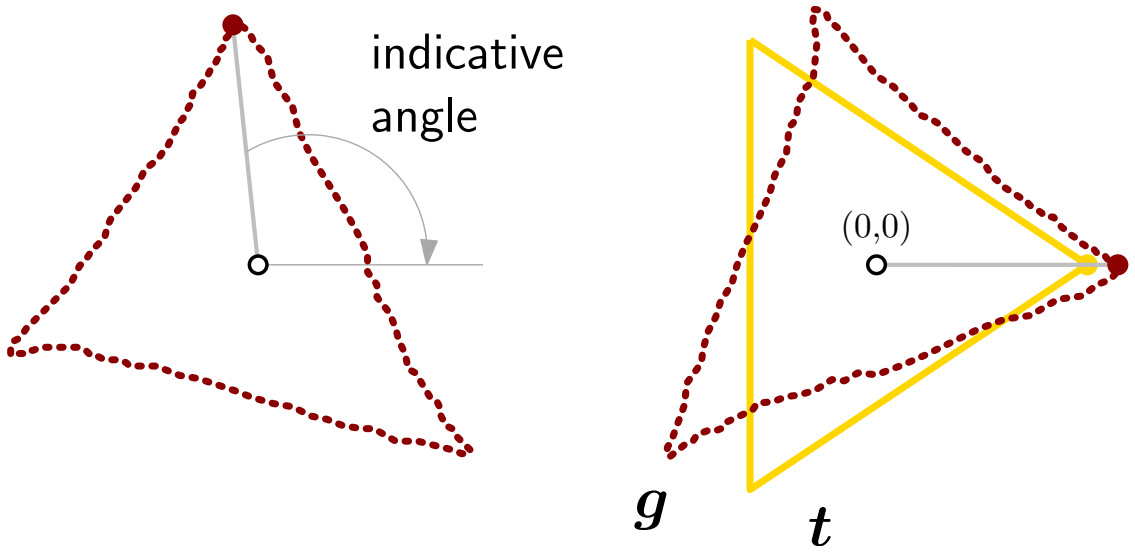


by Wobbrock et al. (2007)

https://depts.washington.edu/aimgroup/proj/dollar/

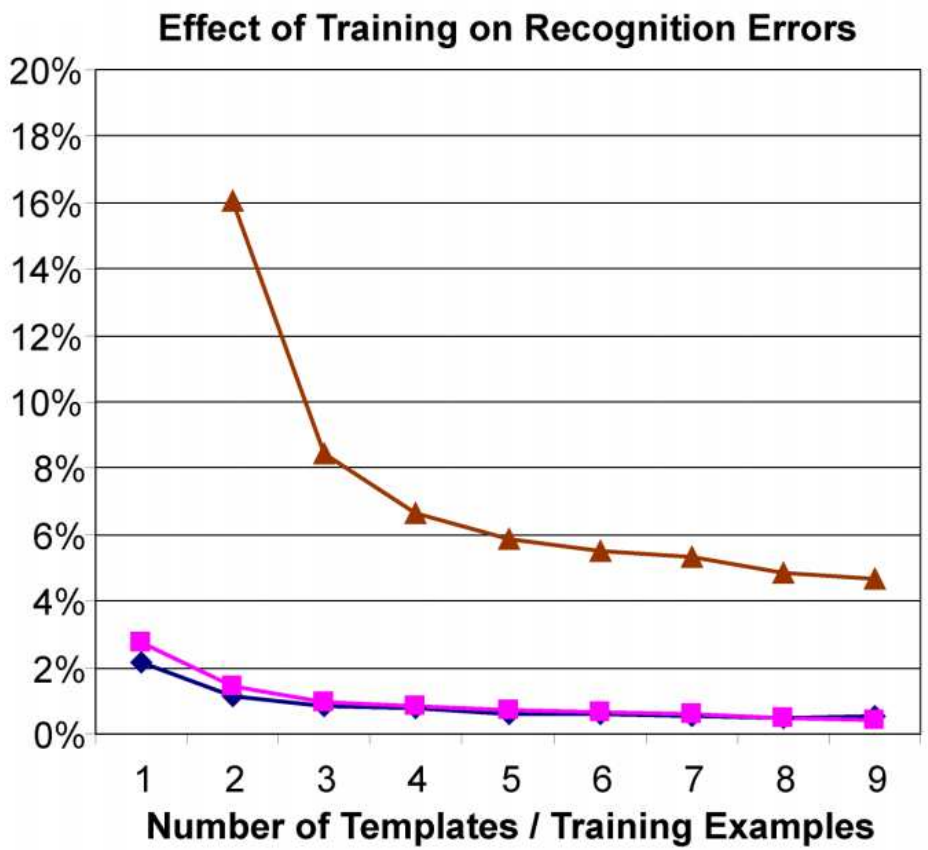
The Dollar Family: $1 recognizer

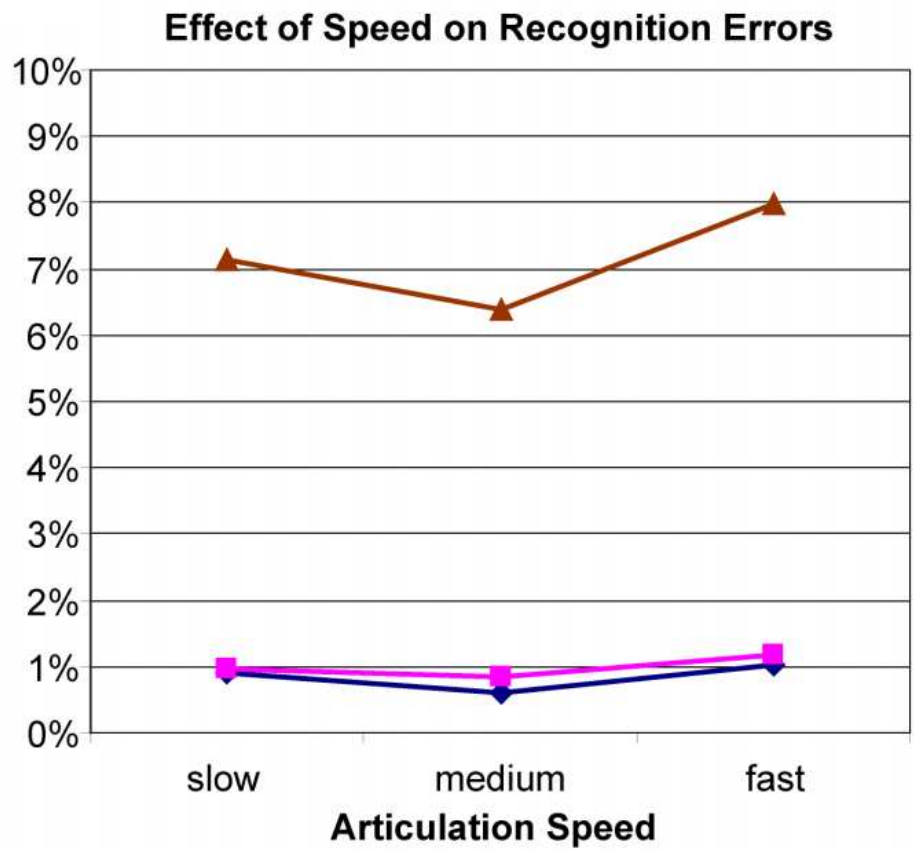
Preprocessing: resampling, rotation, scaling, translation

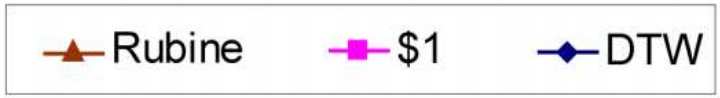


$$D(\boldsymbol{g}, \boldsymbol{t}) = \arg\min_{-\frac{\pi}{4} \leq \theta \leq \frac{\pi}{4}} \frac{1}{N} \sum_{i=1}^{N} \|g_i - t_i(\theta)\|$$

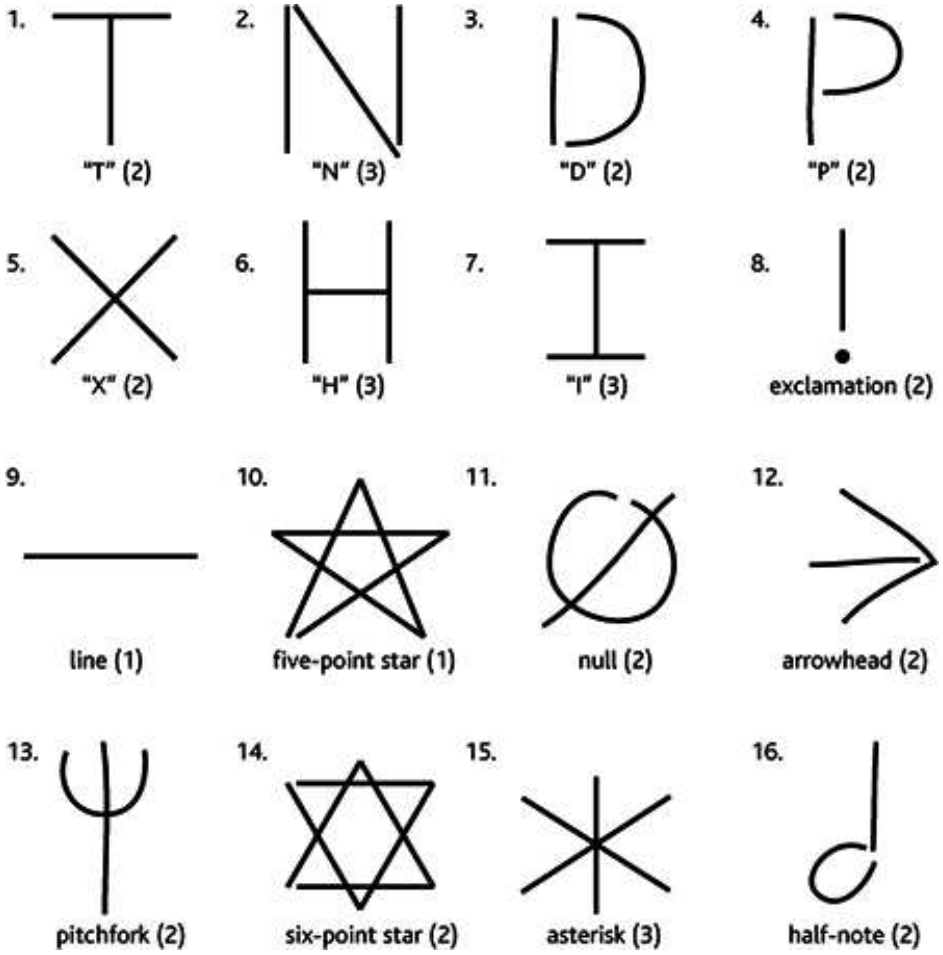
The Dollar Family: $1 recognizer







The Dollar Family: $N recognizer

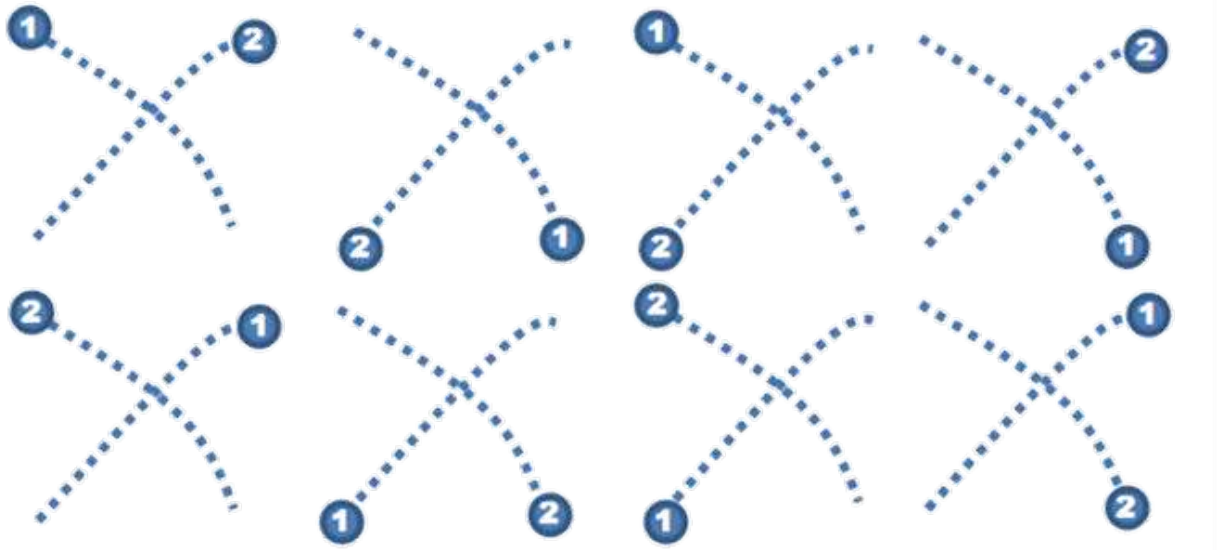


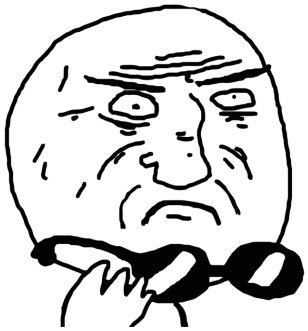
by Anthony and Wobbrock (2010)

https://depts.washington.edu/aimgroup/proj/dollar/ndollar.html

The Dollar Family: $N recognizer

$N = $1 with combinatory overhead: $\mathcal{O}(n\ s\ 2^s)$ per template

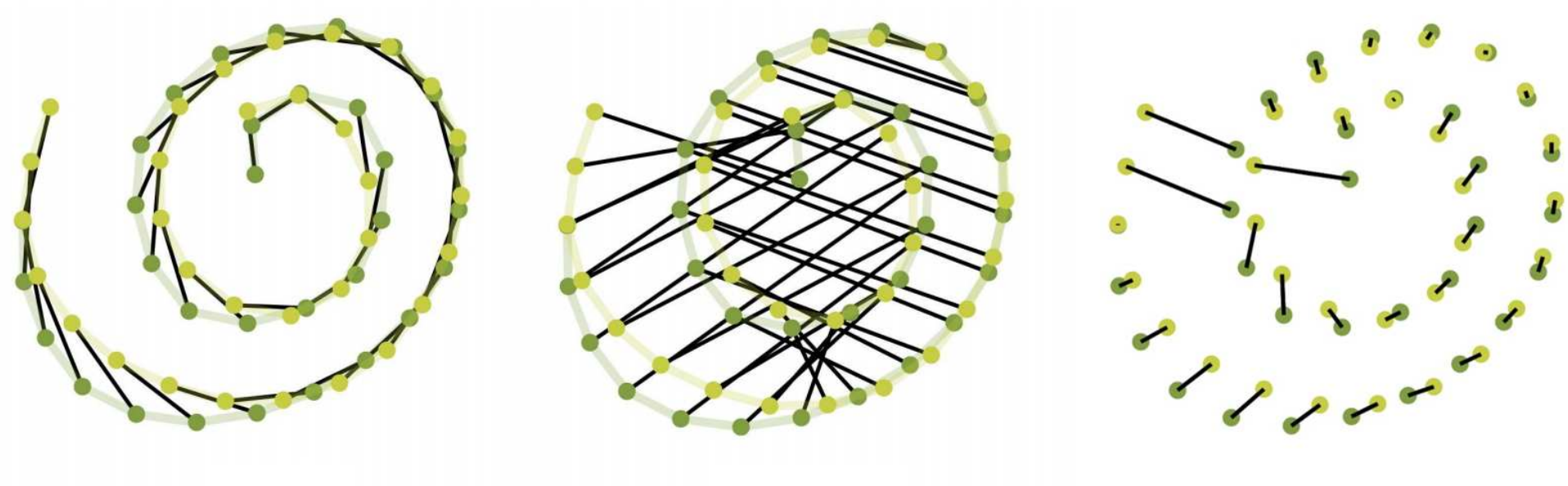




Memory drained out with 20 templates ($n = 32$ pts)

in a quad-core computer with 4 GB RAM.

The Dollar Family: $P recognizer



by Vatavu et al. (2012)

https://depts.washington.edu/aimgroup/proj/dollar/pdollar.html

The Dollar Family: $P recognizer

variation of the Hungarian algorithm

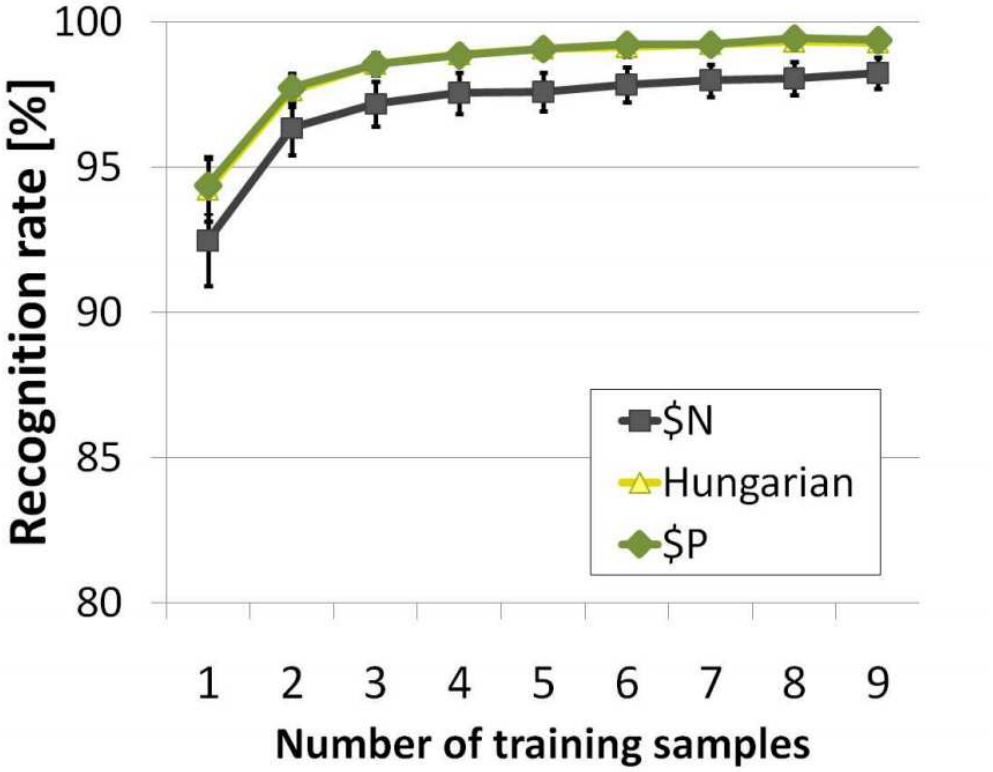
$$D(\boldsymbol{g}, \boldsymbol{t}) = \min \left\{ \|\boldsymbol{g} - \boldsymbol{t}\|, \|\boldsymbol{t} - \boldsymbol{g}\| \right\}$$

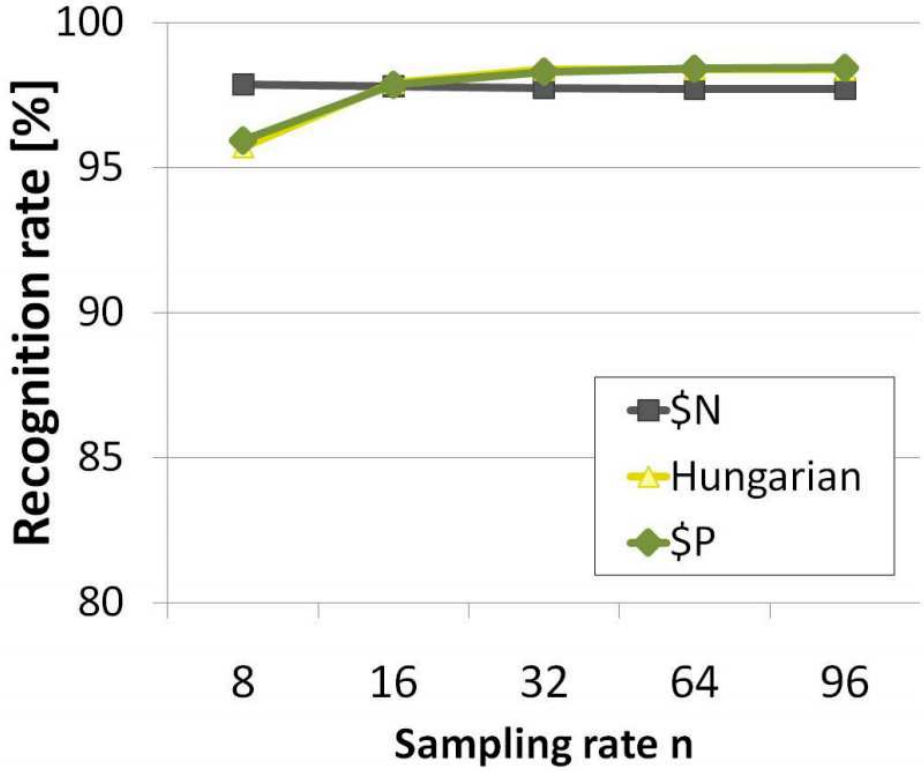
Haussdorf's alternatives:

$$D(\boldsymbol{g}, \boldsymbol{t}) = \max_i \min_j \|g_i - t_j\|$$

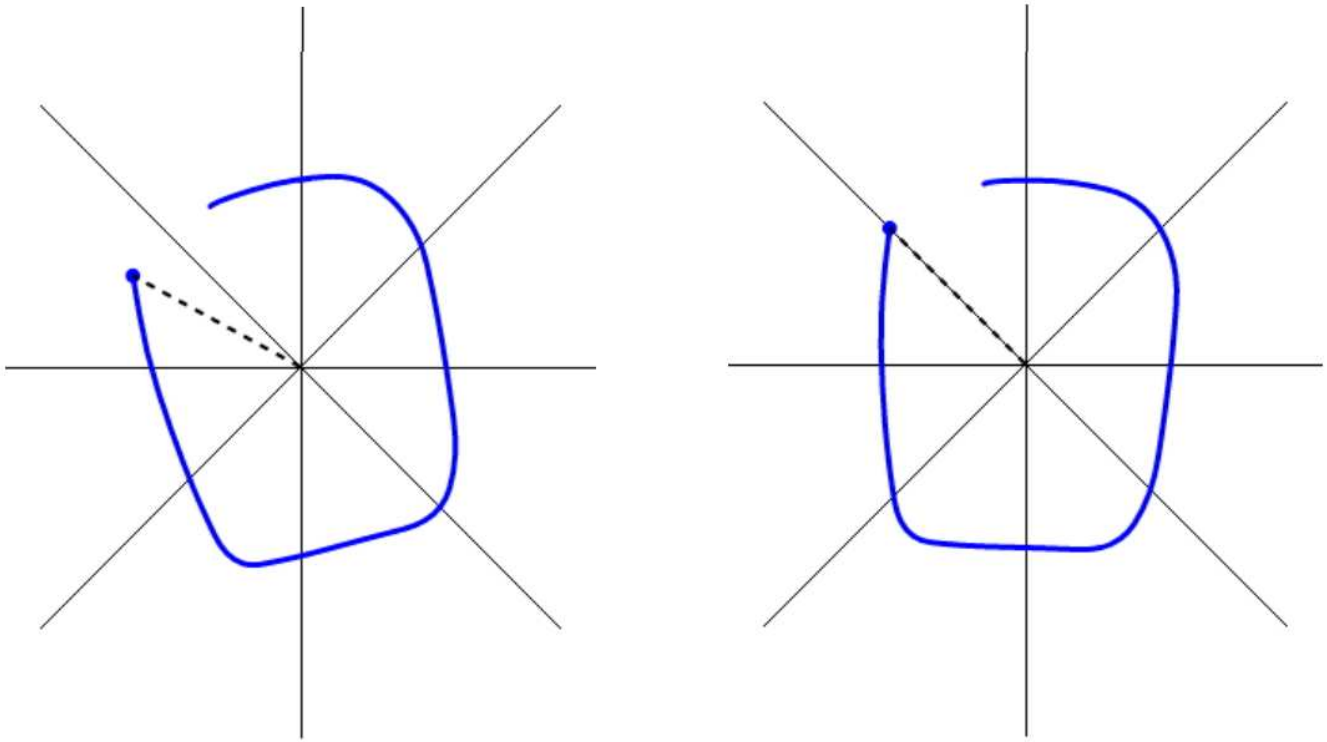
$$D(\boldsymbol{g}, \boldsymbol{t}) = \frac{1}{N} \sum_{i=1}^{N} \min_j \|g_i - t_j\|$$

The Dollar Family: $P recognizer





The Dollar Family: Protractor



by Li (2010)

The Dollar Family: Protractor

closed-form solution, minimum angular distance

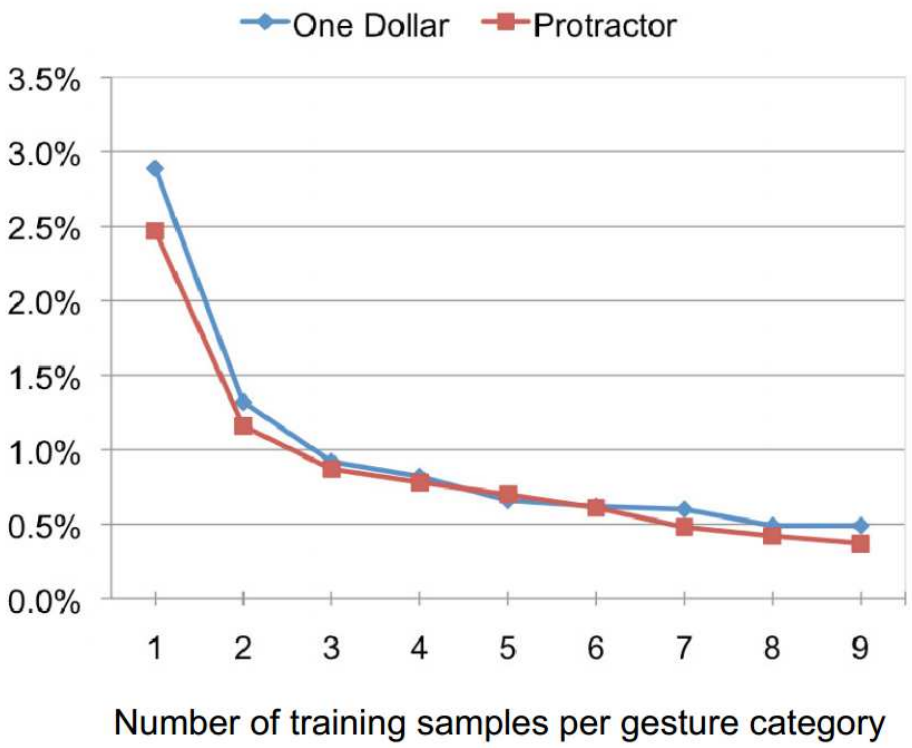
$$D(\boldsymbol{g}, \boldsymbol{t}) = \frac{1}{\arccos(a \cos\hat{\theta} + b \sin\hat{\theta})}$$

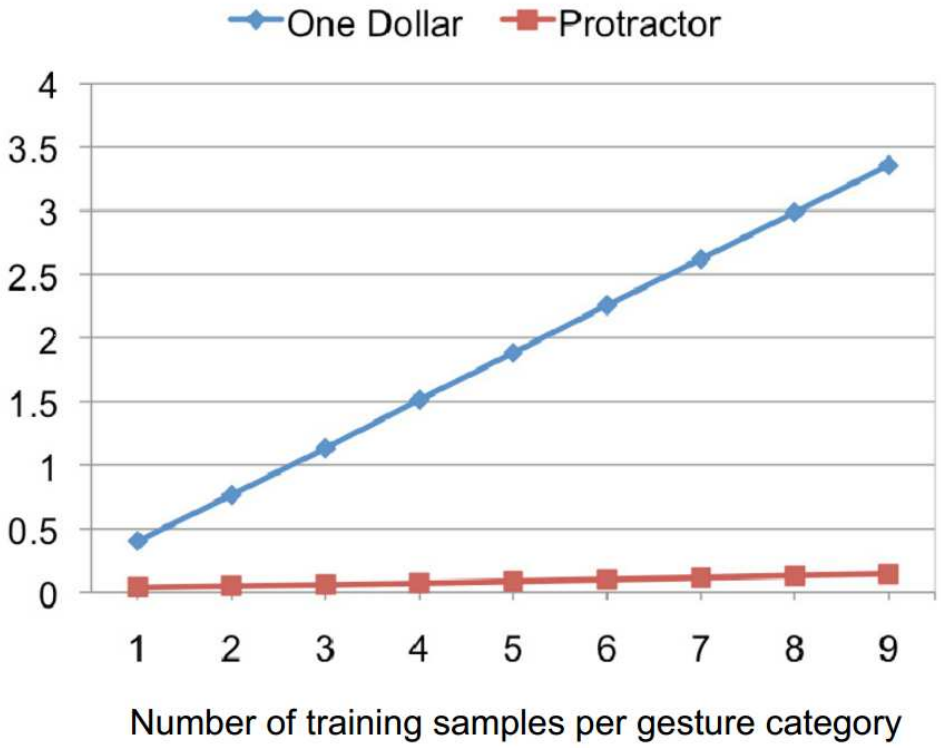
$$\hat{\theta} = \arctan\frac{b}{a}$$

$$a = \sum_{i=1}^{N} (x_{gi}\, x_{ti} + y_{gi}\, y_{ti})$$

$$b = \sum_{i=1}^{N} (x_{gi}\, y_{ti} - y_{gi}\, x_{ti})$$

The Dollar Family: Protractor





MinGestures for MIUIs

disambiguate gestures from text with high accuracy & performace

LABEL	ACTION	RESULT
Substitute		Lorem Ipsan
Reject		Lorem ...
Merge		LoremIpsum
Delete		Lorem
Insert		Lorem et Ipsum

LABEL	ACTION	RESULT
Split		Lor em
Validate		Lorem Ipsum
Undo		Lorem Ipsum
Redo		Lorem
Help		<help event>

by Leiva et al. (2014)

Demo: http://cat.prhlt.upv.es/mg/

MinGestures for MIUIs

disambiguating features:

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i y_i}$$

$$\Delta_x^- = \sum_{i=2}^{N} \max(x_{i-1} - x_i, 0)$$

$$\varphi = \frac{\max(\boldsymbol{x}) - \min(\boldsymbol{x})}{\max(\boldsymbol{y}) - \min(\boldsymbol{y})}$$

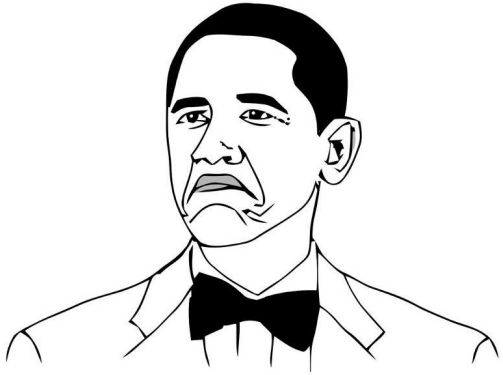
classification rule:

$$\theta = \frac{\hat{\boldsymbol{y}} - b}{\boldsymbol{x}} \pm \epsilon$$

MinGestures for MIUIs

	E-pen		Mouse	
System	**training**	**test**	**training**	**test**
$1 recognizer	41.2	40.5	45.0	46.6
Marking Menus	18.5	19.5	12.8	13.1
Modified $1	16.0	15.6	7.48	7.56
Rubine	14.6	14.1	15.4	15.7
MinGestures	**0.77**	**1.32**	**0.26**	**0.43**

Error rates in %



Recap

Takeaways

- Gestures aim to improve human-computer interaction
- Many recognition techniques suitable for different input devices
- Recognition trade-offs: design, setup, performance, accuracy
- Gestures should be **simple**:
  For humans to *perform* and *recall*
  For computers to *recognize*

TFM Proposals

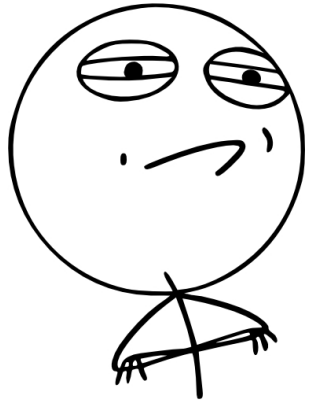
1. Integration: free-form gestures in context

2. Error analysis & recovery:

   When should the recognizer ask the user? How much to ask?

3. Segmentation: automatic gesture parts identification

4. Generation: grammar-based, kinematic theory, etc.



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Videography

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