Pointing and Navigation

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Thanks to Yves Guiard for material on Fitts' law

Outline

Pointing

Fitts' law

Beating Fitts' law

Multiscale pointing

More laws of movement

The importance of pointing

The most frequent action in Graphical User Interfaces
(together with entering text)

Many targets, some very small
e.g., pointing between the two ‘l’ in the word “small” above

Screens are becoming larger ... and smaller

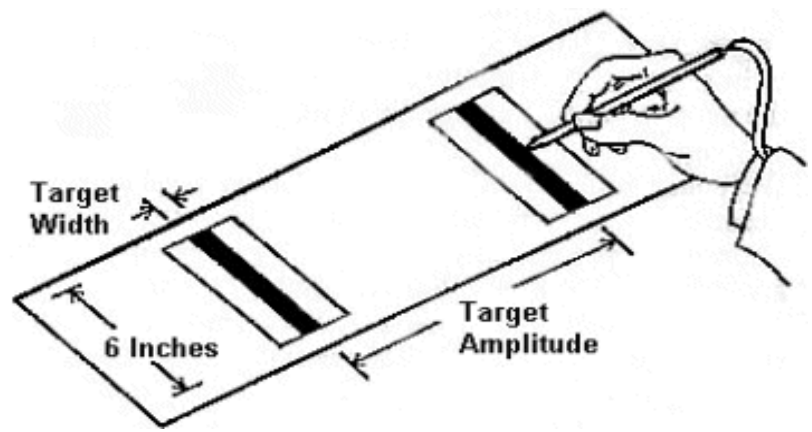
Pointing performance is limited by human capabilities,
not by the computer

If the computer knew where I want to point,
it could do it for me...

Fitts' pointing paradigm

Seminal work by Paul Fitts in 1954

Speed-precision trade-off in directed movements



Initial hypothesis

ID (bits) = $\log_2 (2D/W)$

$MT = k * ID$

ID = Index of Difficulty

MT = Movement Time

If this proves true, ID/MT (bit/s) = constant

This constant is the capacity of the human motor system to transmit information (Shannon)

In practice... (Fitts' original data)

TABLE 1

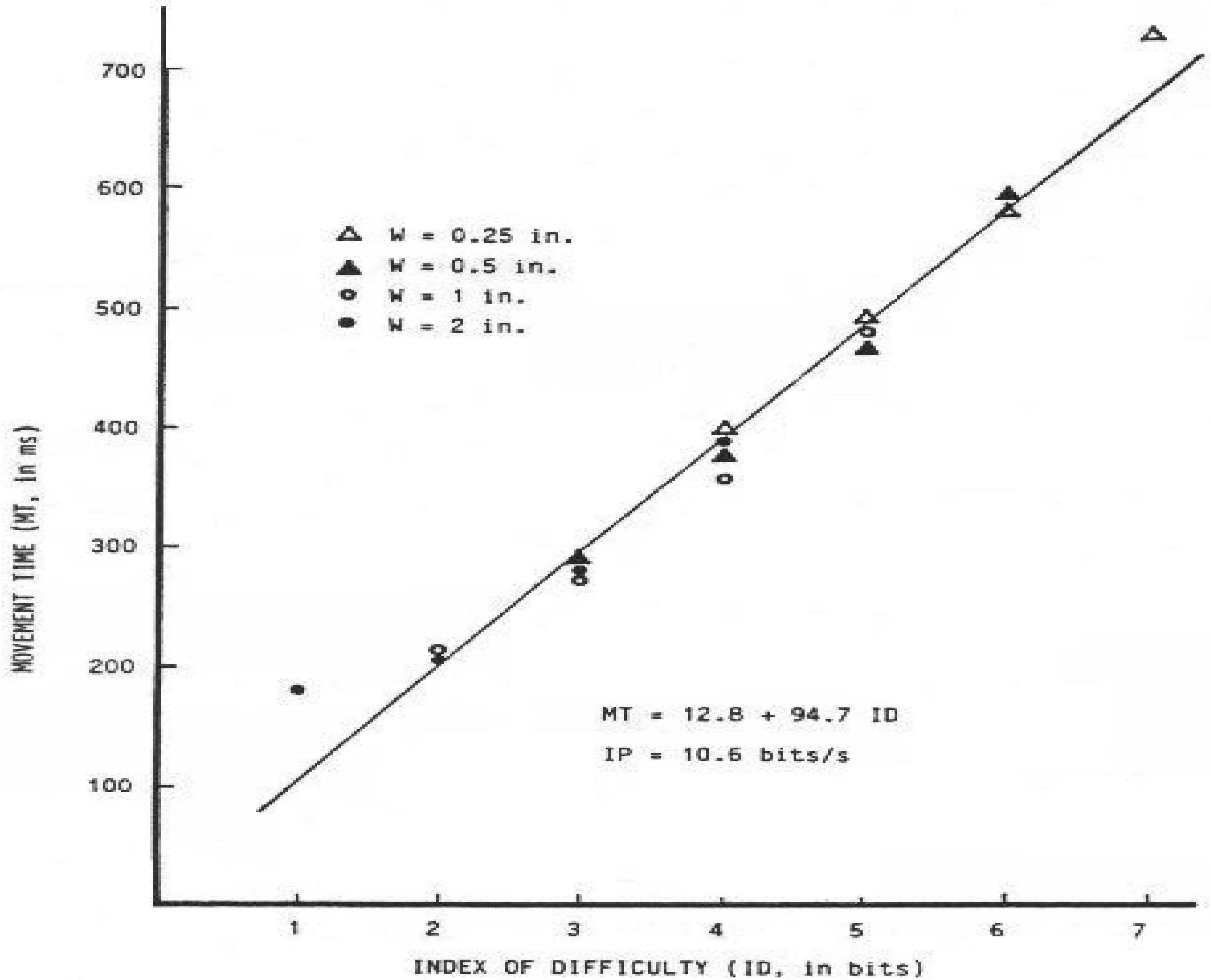
TASK CONDITIONS AND PERFORMANCE DATA FOR 16 VARIATIONS OF A RECIPROCAL TAPPING TASK

(N = the same 16 Ss at each condition)

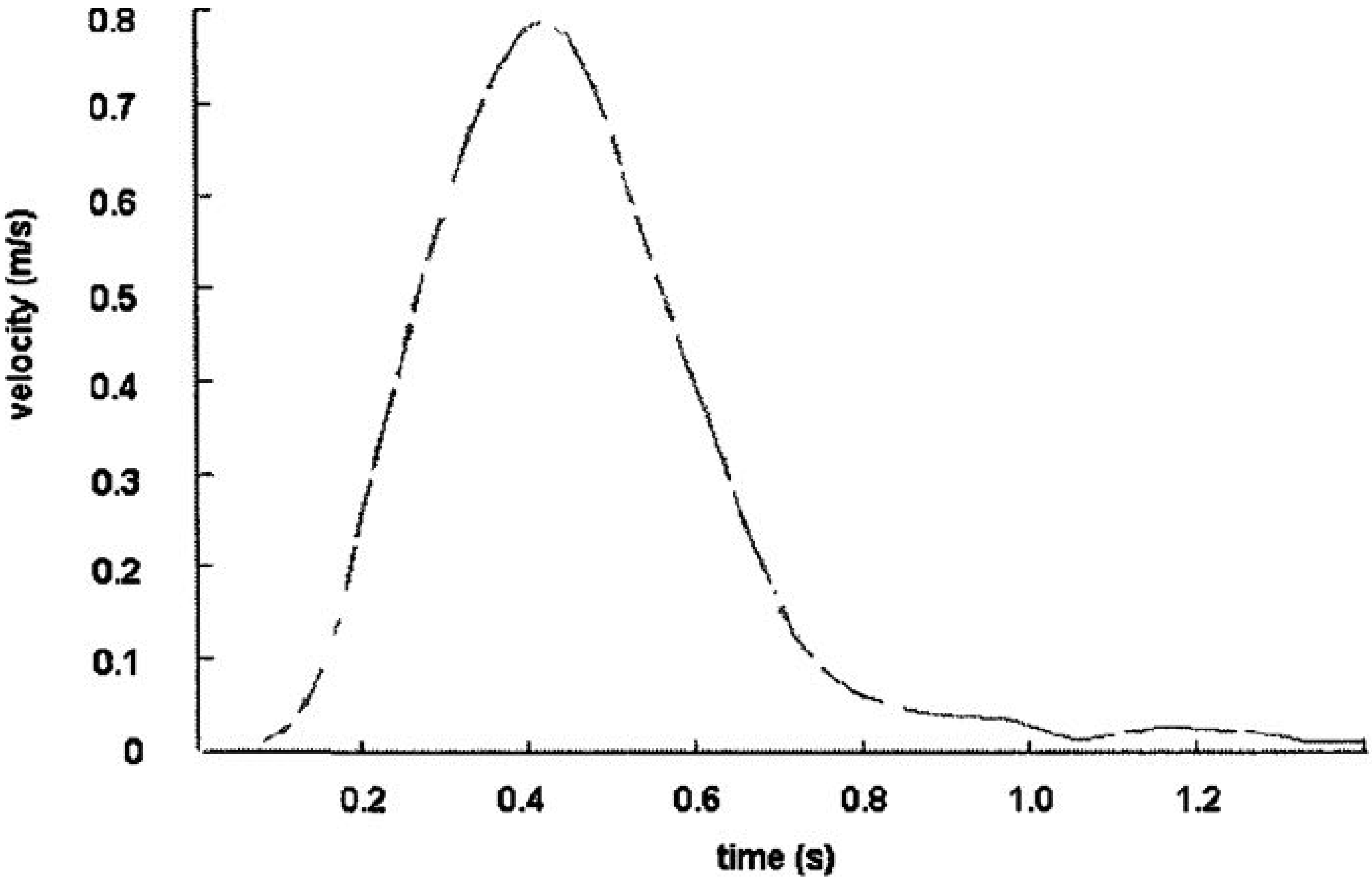
Tolerance and Amplitude Conditions			1-oz. Stylus				1-lb. Stylus			
W_s	A	I_d	t	Errors (%)	I_p	Rank	t	Errors (%)	I_p	Rank
.25	2	4	.392	3.35	10.20	11	.406	3.80	9.85	7
.25	4	5	.484	3.41	10.33	9	.510	3.83	9.80	8
.25	8	6	.580	2.78	10.34	8	.649	4.04	9.24	13
.25	16	7	.731	3.65	9.58	14	.781	4.08	8.96	15
.50	2	3	.281	1.99	10.68	5	.281	0.88	10.68	4
.50	4	4	.372	2.72	10.75	3.5	.370	2.16	10.81	2
.50	8	5	.469	2.05	10.66	6	.485	2.32	10.31	6
.50	16	6	.595	2.73	10.08	12	.641	2.27	9.36	11
1.00	2	2	.212	0.44	9.43	15	.215	0.13	9.30	12
1.00	4	3	.260	1.09	11.54	1	.273	0.85	10.99	1
1.00	8	4	.357	2.38	11.20	2	.373	1.17	10.72	3
1.00	16	5	.481	1.30	10.40	7	.526	1.32	9.50	10
2.00	2	1	.180	0.00	5.56	16	.182	0.00	5.49	16
2.00	4	2	.203	0.08	9.85	13	.219	0.09	9.13	14
2.00	8	3	.279	0.87	10.75	3.5	.284	0.65	10.56	5
2.00	16	4	.388	0.65	10.31	10	.413	1.72	9.68	9

Note.—W_s is the width in inches of the target plate. A is the distance in inches between the centers of the two plates. t is the average time in seconds for a movement from one plate to the other. The performance index, I_p, is discussed in the text.

In practice... (plot of Fitts' original data by Mackenzie)



Typical velocity profile



Several versions of Fitts' law

Log version

Fitts (1954) $MT = a + \text{b} \log_2(2\ \boldsymbol{D/W})$

Mackenzie (1992) $MT = a + \text{b} \log_2(\boldsymbol{D/W} + 1)$

Linear version

Schmidt et al. (1979) $MT = a * \boldsymbol{D/W}$

Power version

Meyer et al. (1988) $MT = a\ (\boldsymbol{D/W})^{1/2}$

In all cases, MT varies with the relative amplitude *D/W*

$ID = \text{f}(\boldsymbol{D/W})$ $MT = a + b{*}ID$

Fitts' law can be seen as a scale-invariance law

Validity of Fitts' law

Fitts' law is only valid within fairly small limits

Absolute amplitude less than about one meter
  otherwise, there is a speed plateau
Width larger than a fraction of a millimeter
  otherwise motor control is not precise enough

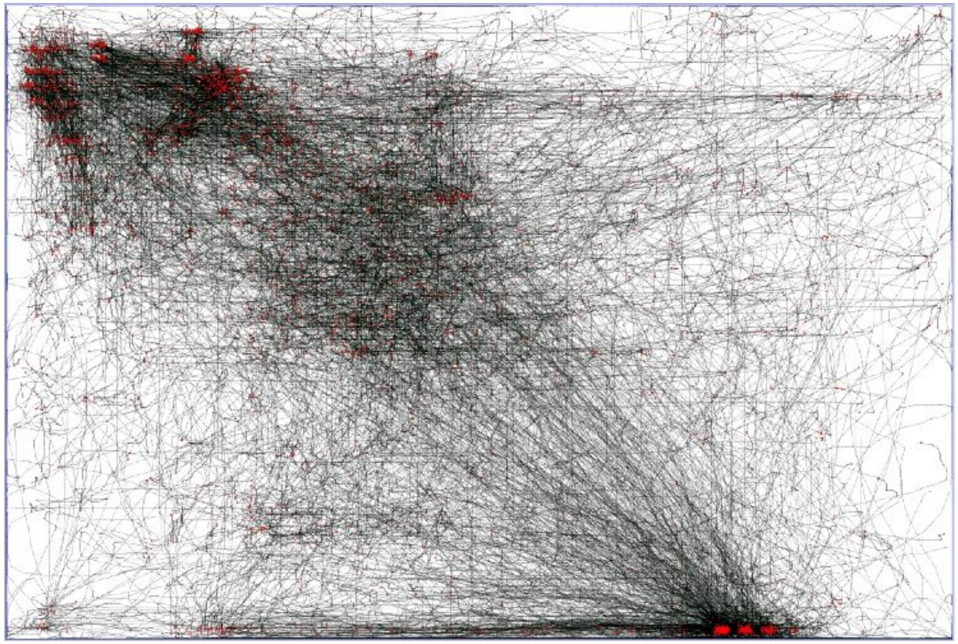
Performance beyond those limits degrades quickly

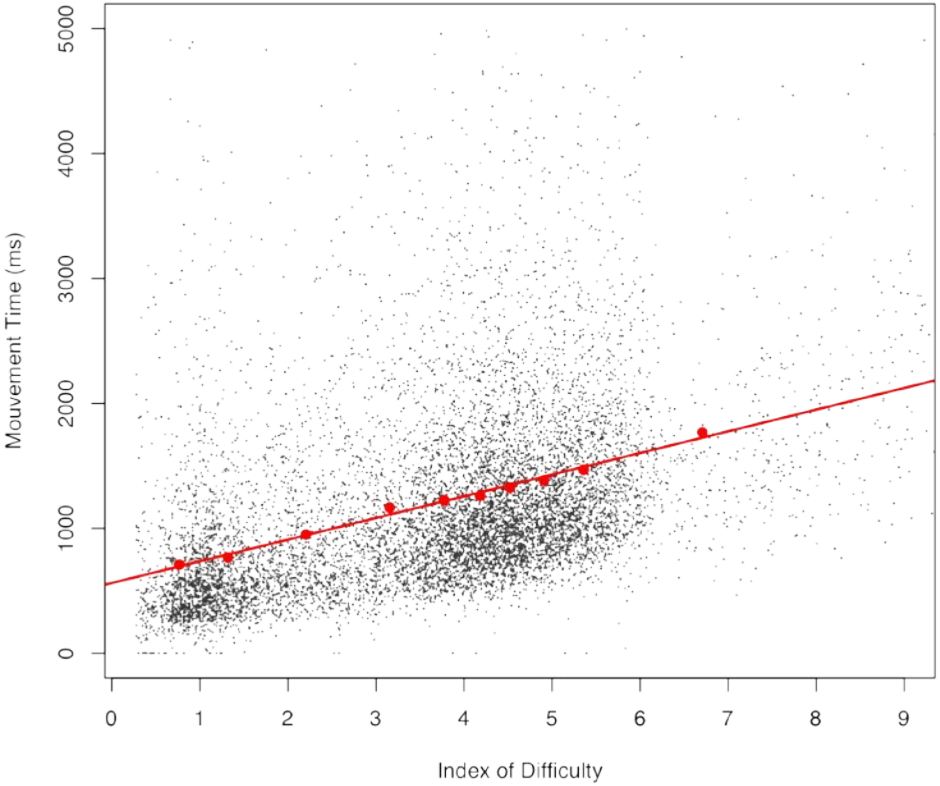
D/W is therefore bounded by about 2000,
and so the ID (in the log formulation) is less than about 12

Pointing in the wild

Large collection of pointing data in the field

24 users, 2 million aimed movements, 1 billion pixels (352km)





Can we “beat” Fitts’ law?

The index of performance IP = 1/b is about
10 bits/s in Fitts’ original experiment

Pointing using a device (mouse, joystick, touchscreen...)
has been shown to generally have a lower IP

Research question:

Can we use the computer to help us point faster?

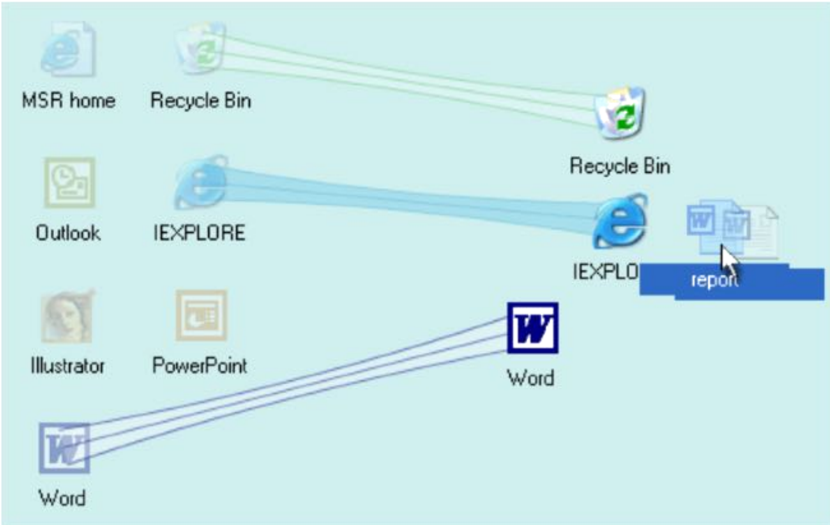
Other research question:

Can we expand the limits of validity of Fitts’ law?

Improving pointing performance

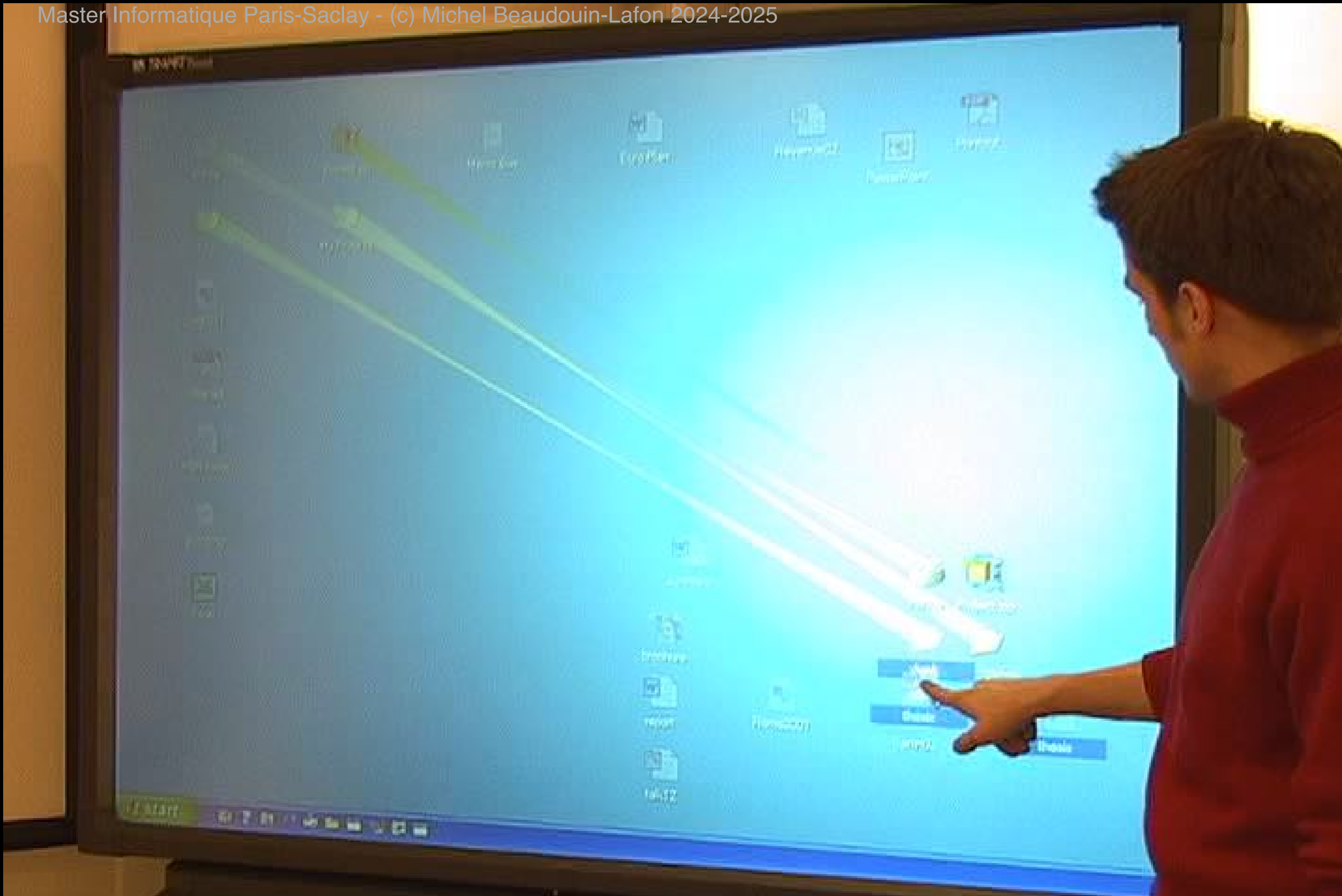
Idea 1: Reduce ID, i.e. decrease D and/or increase W

Reducing distance: “drag’n’pop” (Baudisch et al.)



Reducing distance: “MAGIC pointing” (Zhai et al.)

Track eye-gaze to teleport cursor close to the target



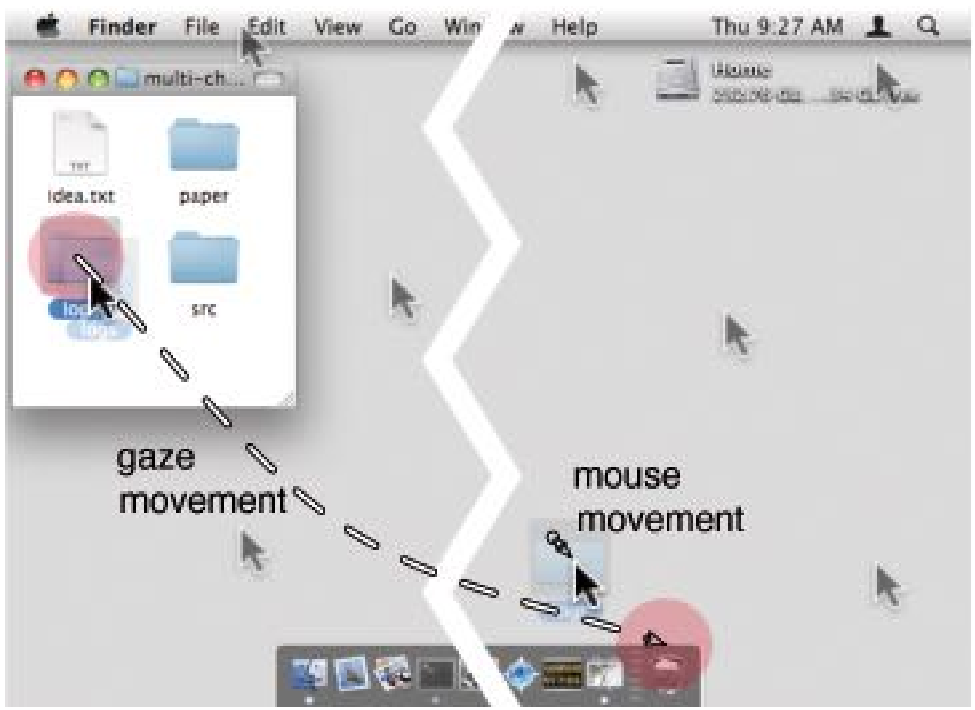
Drag-and-pop - Baudisch et al., 2003

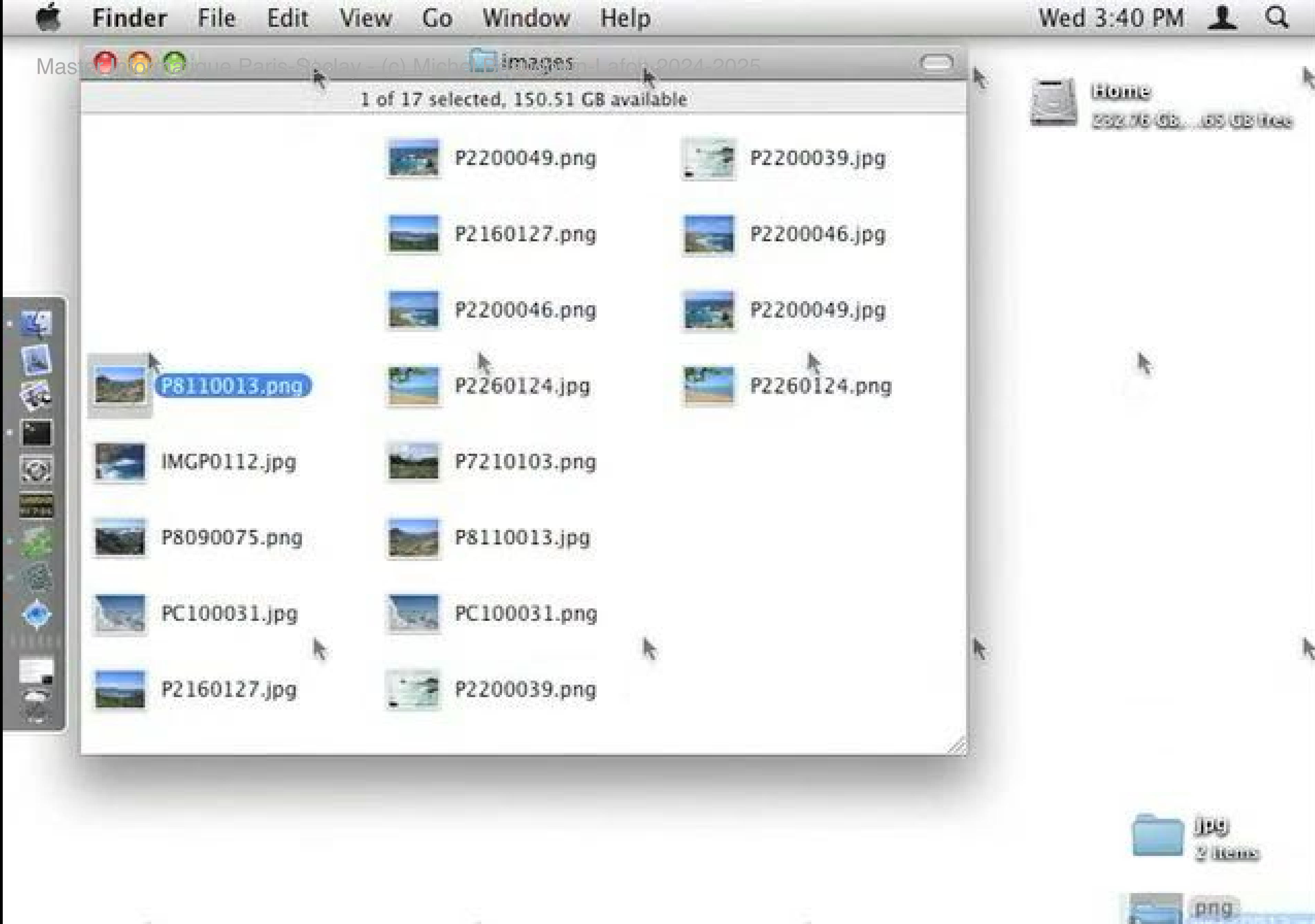
Improving pointing performance

Idea 1: Reduce ID, i.e. decrease D and/or increase W

Reducing distance: “rake cursor” (Blanch & Ortega)

- Multiple parallel cursors + eye tracking





Rake cursor - Blanch & Ortega, 2009

Improving pointing performance

Increasing target size: auto-expansion (McGuffin & Balakrishnan)

Expand potential targets when the cursor approaches them

Performance predicted by expanded target size

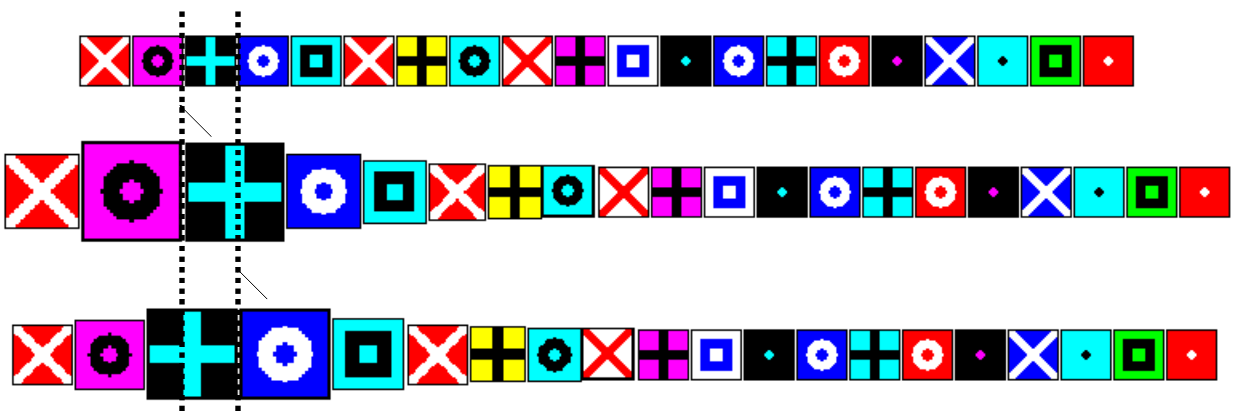
Even if the user does not expect the expansion (Zhai et al.)

Improving pointing performance

Application to the MacOS Dock

BUT

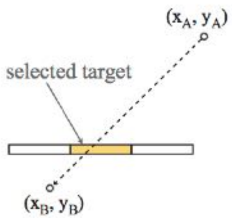
it does not work!



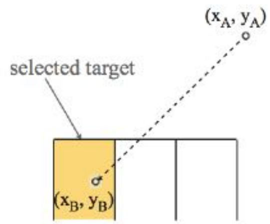
Improving pointing performance

Increasing size: semi-infinite targets

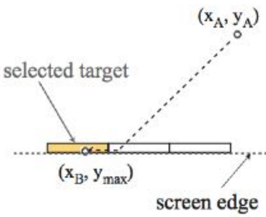
Pointing on the side of the screen



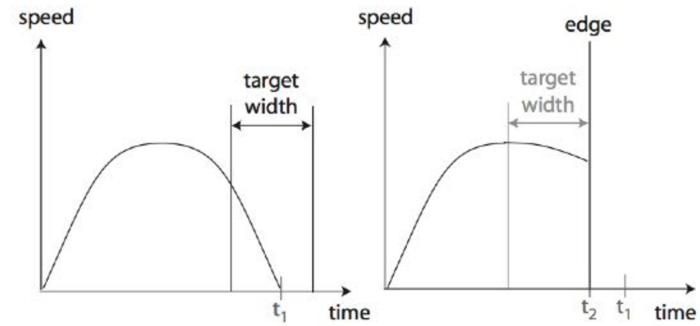
Crossing



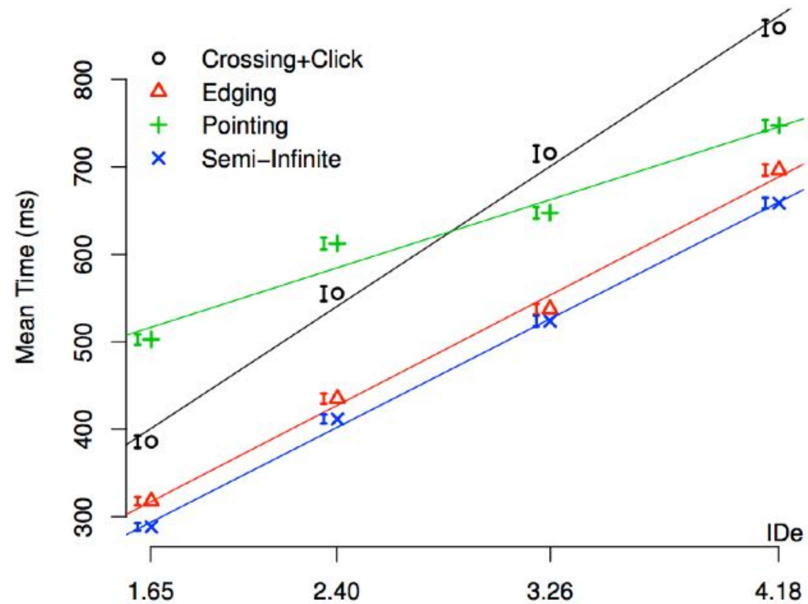
Semi-infinite pointing



Edging



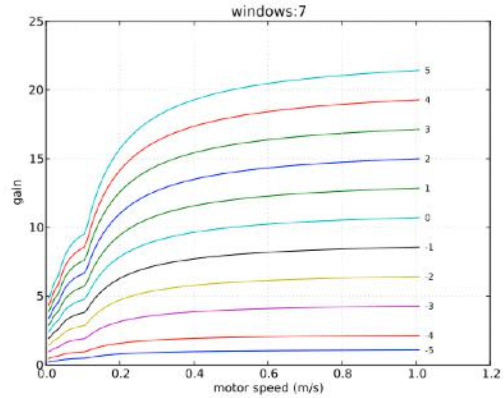
Edging is closest to semi-infinite pointing (Appert et al.)

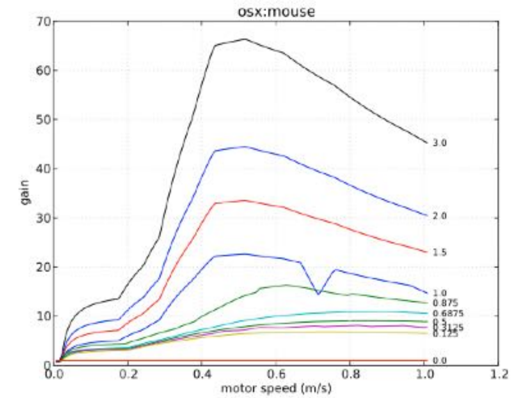


Improving pointing performance

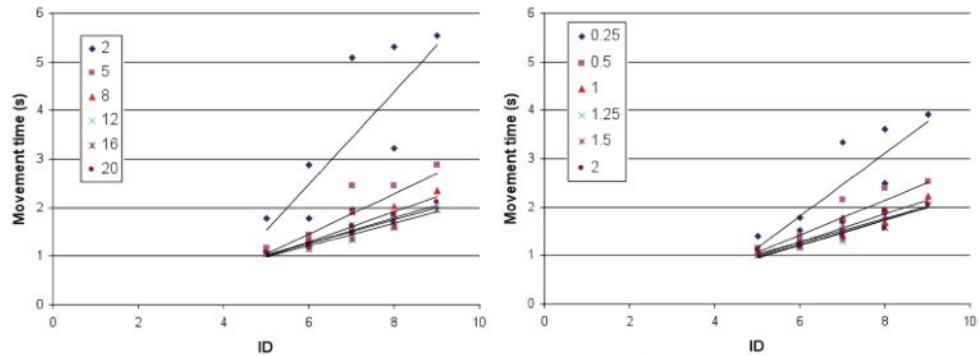
Idea 2: Increase maximal speed

- Manipulate the “control-display gain”, i.e. the ratio between the motion of the device and the corresponding motion of the cursor
- “Mouse acceleration”





- Effect of dynamic gain on pointing performance (Casiez)



(a) Constant Gain

(b) Pointer Acceleration

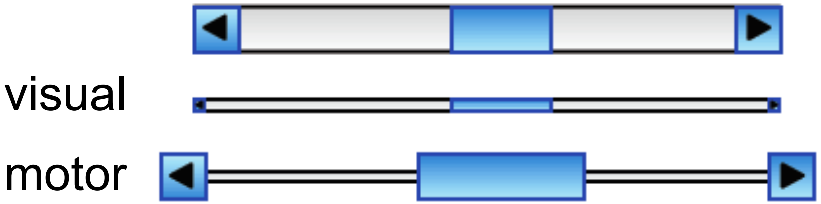
Improving pointing performance

Semantic pointing (Blanch et al.)

Each target has a visual size and a motor size

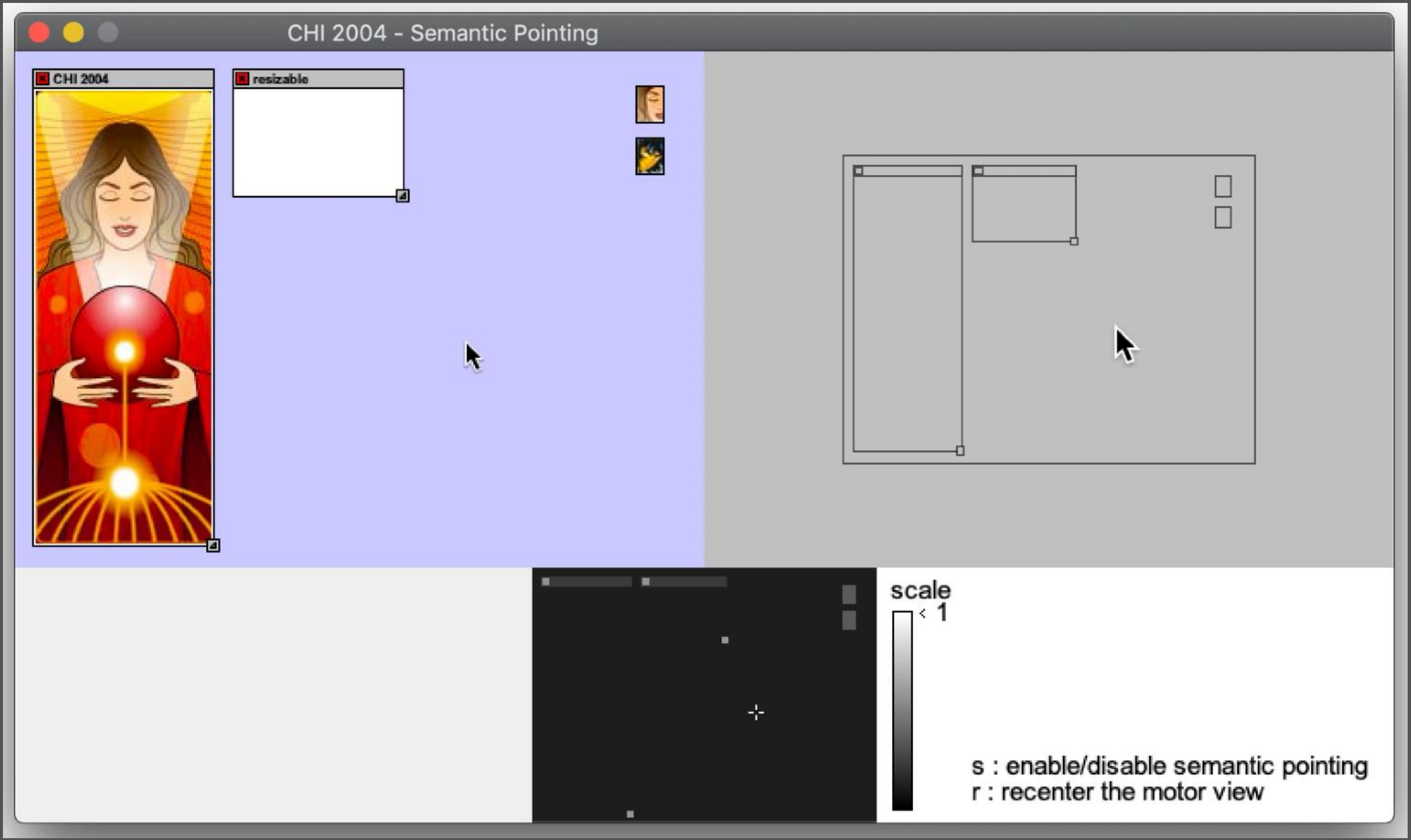
Cursor moves faster between targets,
and slows down when approaching a target

Sample applications:



Object pointing (Guiard et al.)

Skip empty space: pointing in constant time! (in theory...)

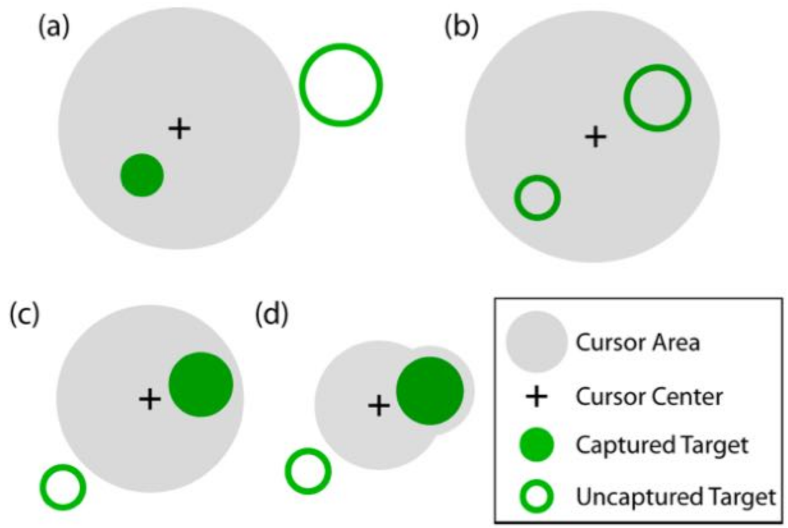


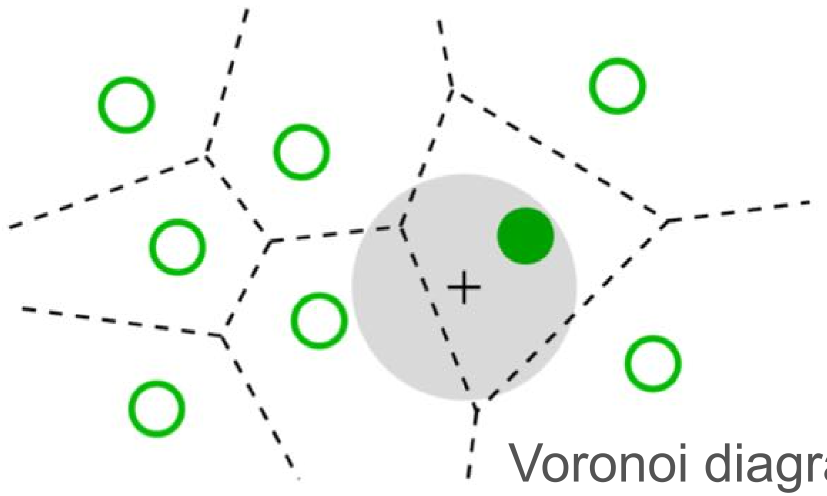
Semantic Pointing - Guiard, Blanch & Beaudouin-Lafon, 2004

Improving performance

Bubble cursor (Grossman & Balakrishnan): best known technique

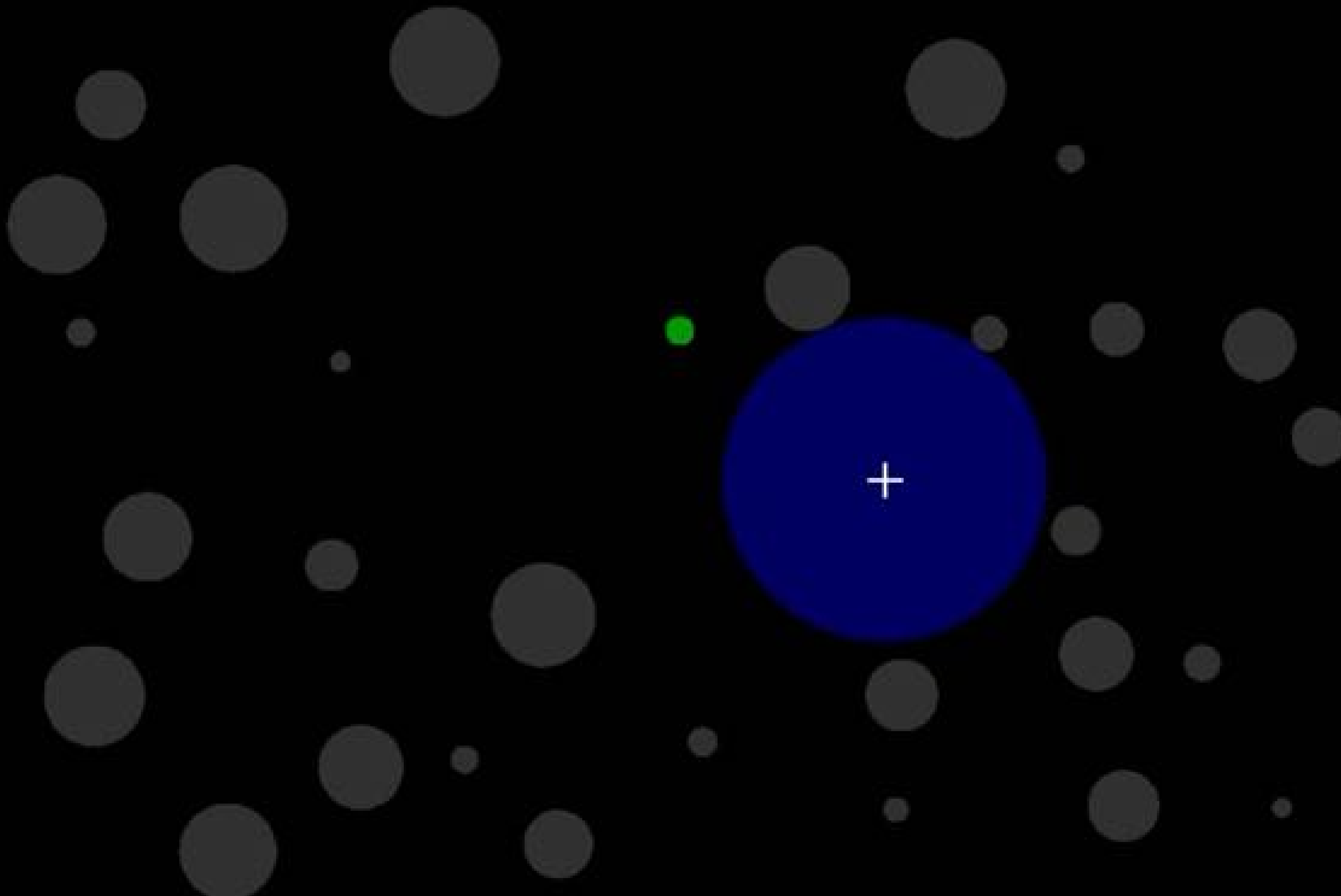
- Combines area cursors, object pointing and target expansion
- The cursor always designates the closest target





Voronoi diagram

Dynaspot (Chapuis et al.): combines bubble cursor with regular cursor to point in empty space



Bubble Cursor - Grossman & Balakrishnan, 2005

Dynaspot - Chapuis, Labrune & Pietriga, 2009

Improving pointing performance

Are we done yet?

NO!

Two categories of approaches:

- target-agnostic: do not need to know where targets are
- target-aware: needs to know potential targets

Target-aware techniques are more efficient,
but it is often difficult to know what the targets are

Probabilistic approaches: learn targets and user’s habits

Breaking the limits of Fitts' law

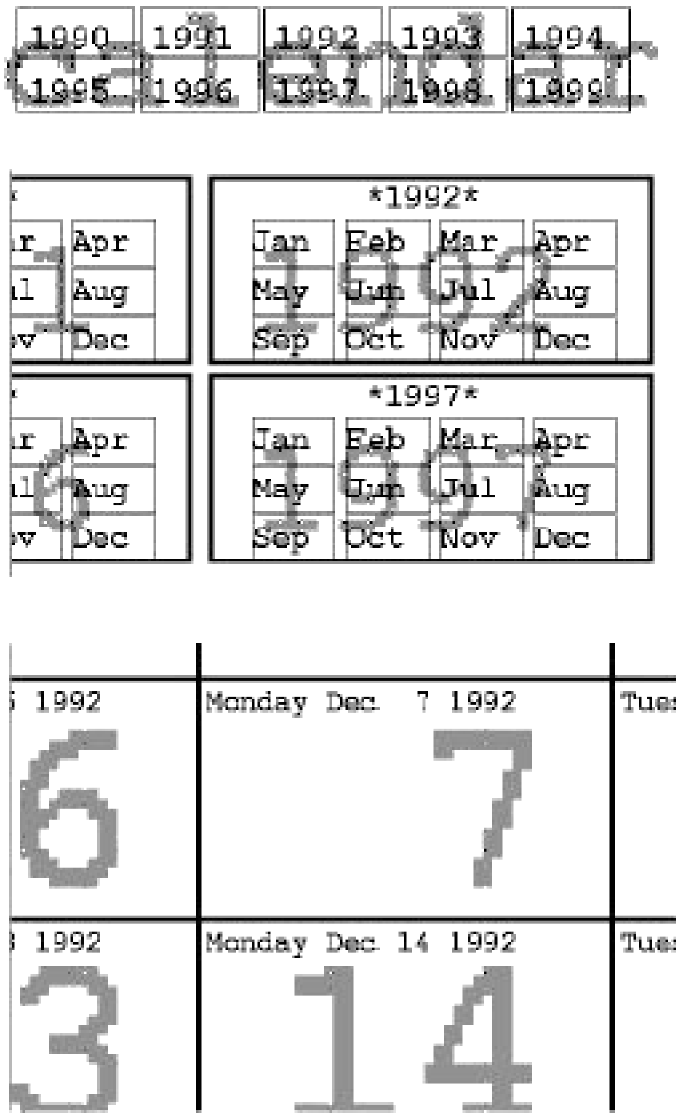
Fitts' law is valid only for ID < 12 bits, D < 1m, W > 0.5mm

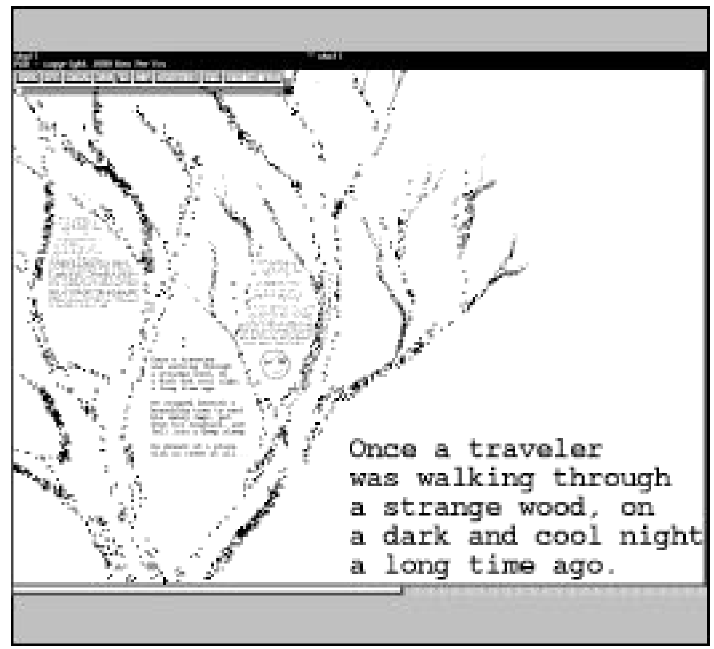
These physiological limits can be overcome in an information world that supports zooming

- Zooming in: small targets become bigger
- Zooming out: large amplitudes become smaller

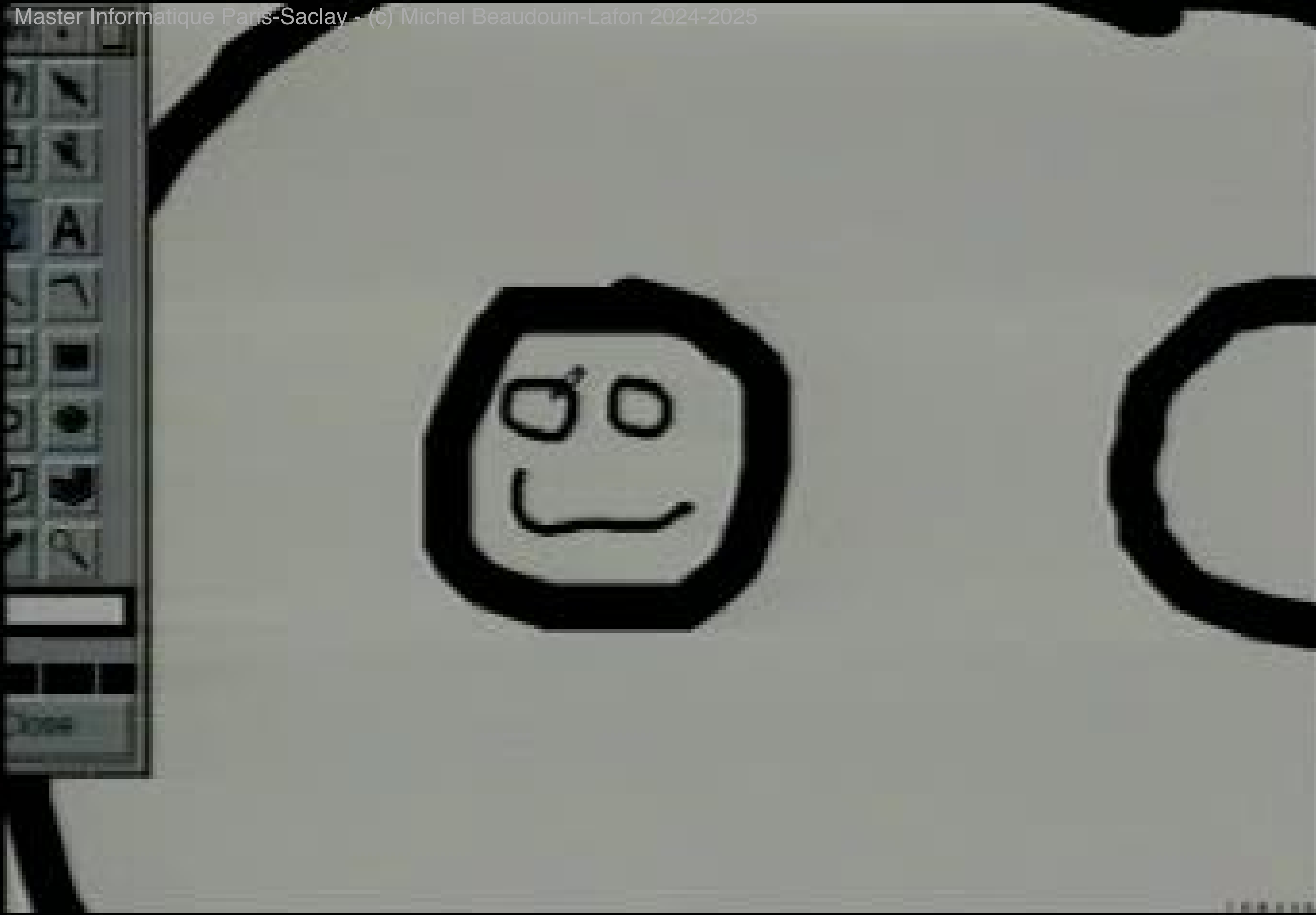
What is the performance of pointing in a zoomable world?

Zoomable User Interfaces





Pad (Perlin & Fox)



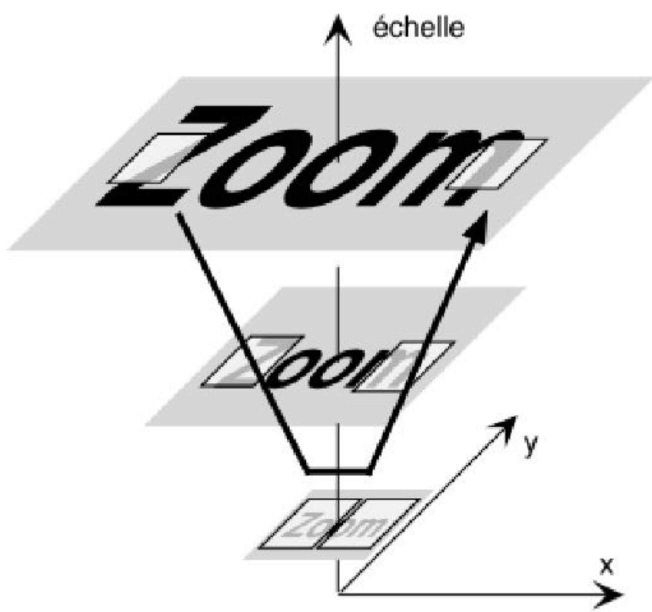
Pad++ - Bederson & Hollan, 1994

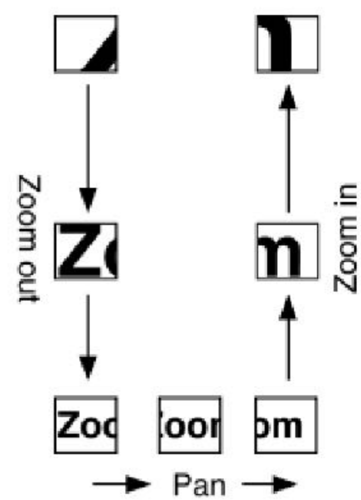
Space-scale diagrams (Furnas & Bederson)

Represent scale as a vertical dimension

Zooming = moving the viewing window up and down

The size of the viewing window is fixed

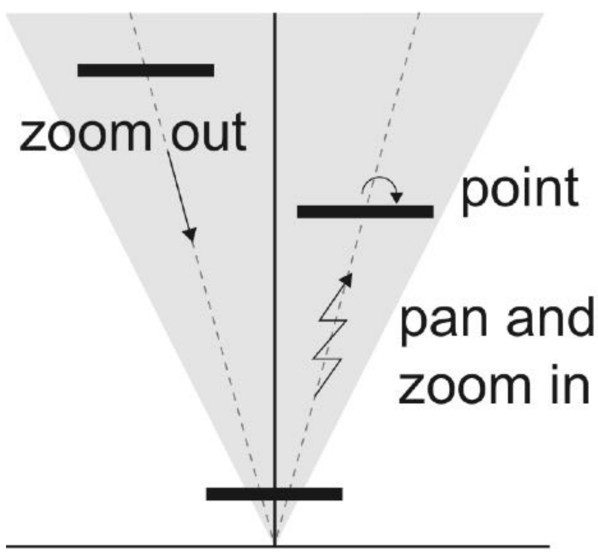


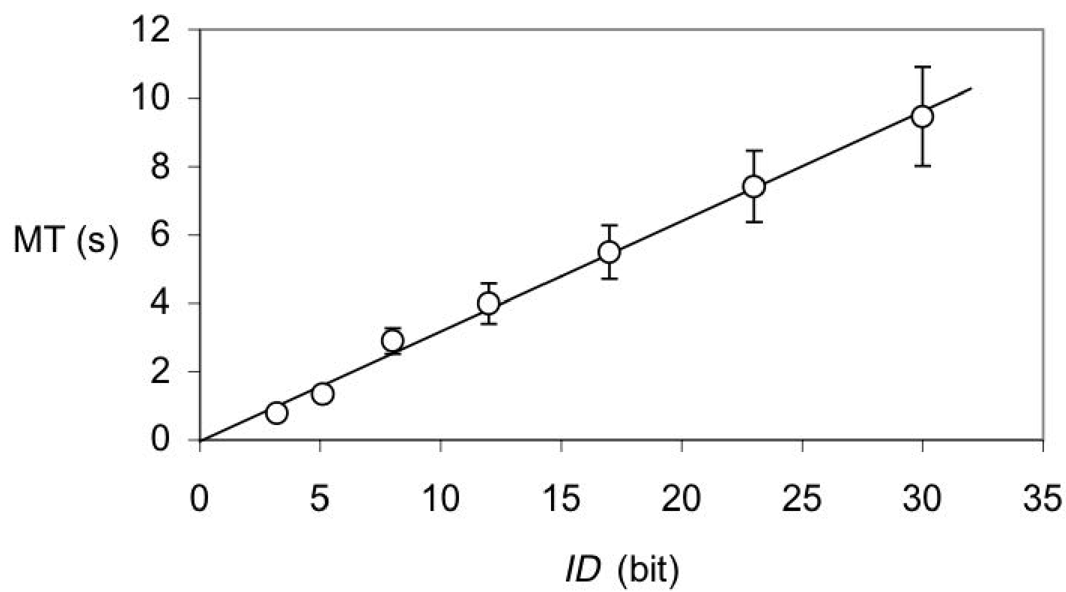


Multiscale pointing (Guiard & Beaudouin-Lafon)

Pointing in a zoomable world requires navigation:

- Zoom out to get the target in view
- Pan to put the target in the center
- Zoom in to enlarge the target (pan to adjust)

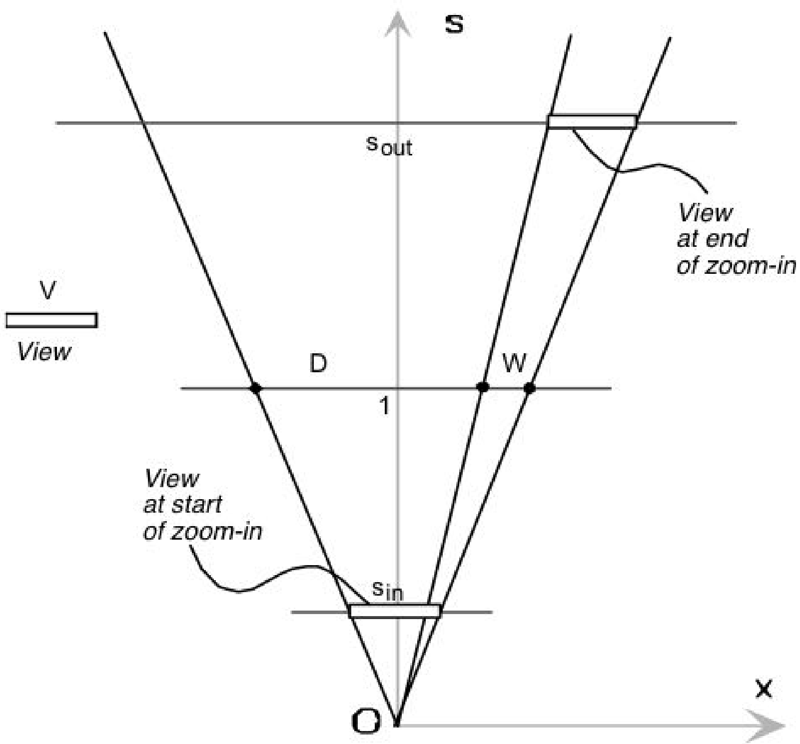


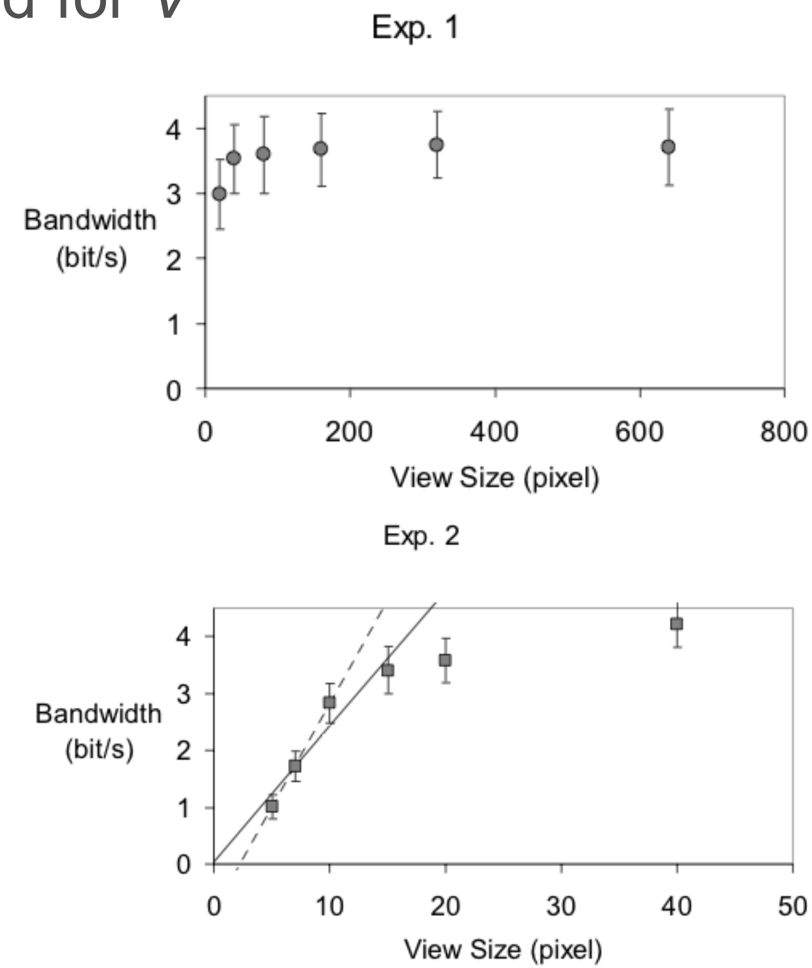


Effect of view size on pointing performance

Effect of view size: *MT* = k *ID* / *V*

But only up to a certain threshold for *V*





Orthozoom (Appert & Fekete)

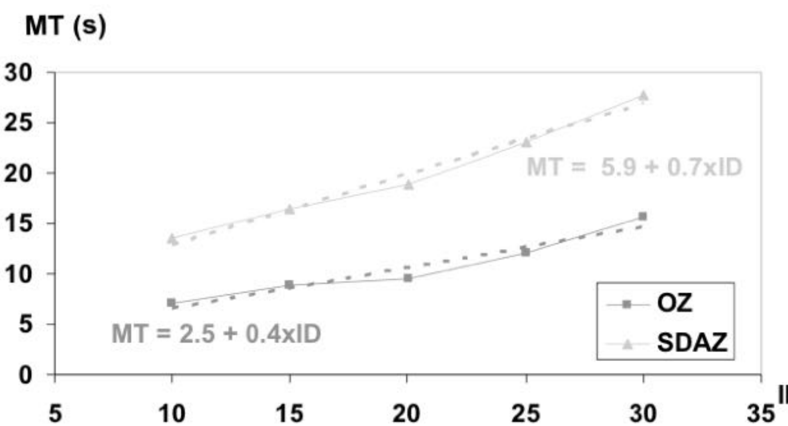
Extend scrollbar to pan and zoom 1D documents

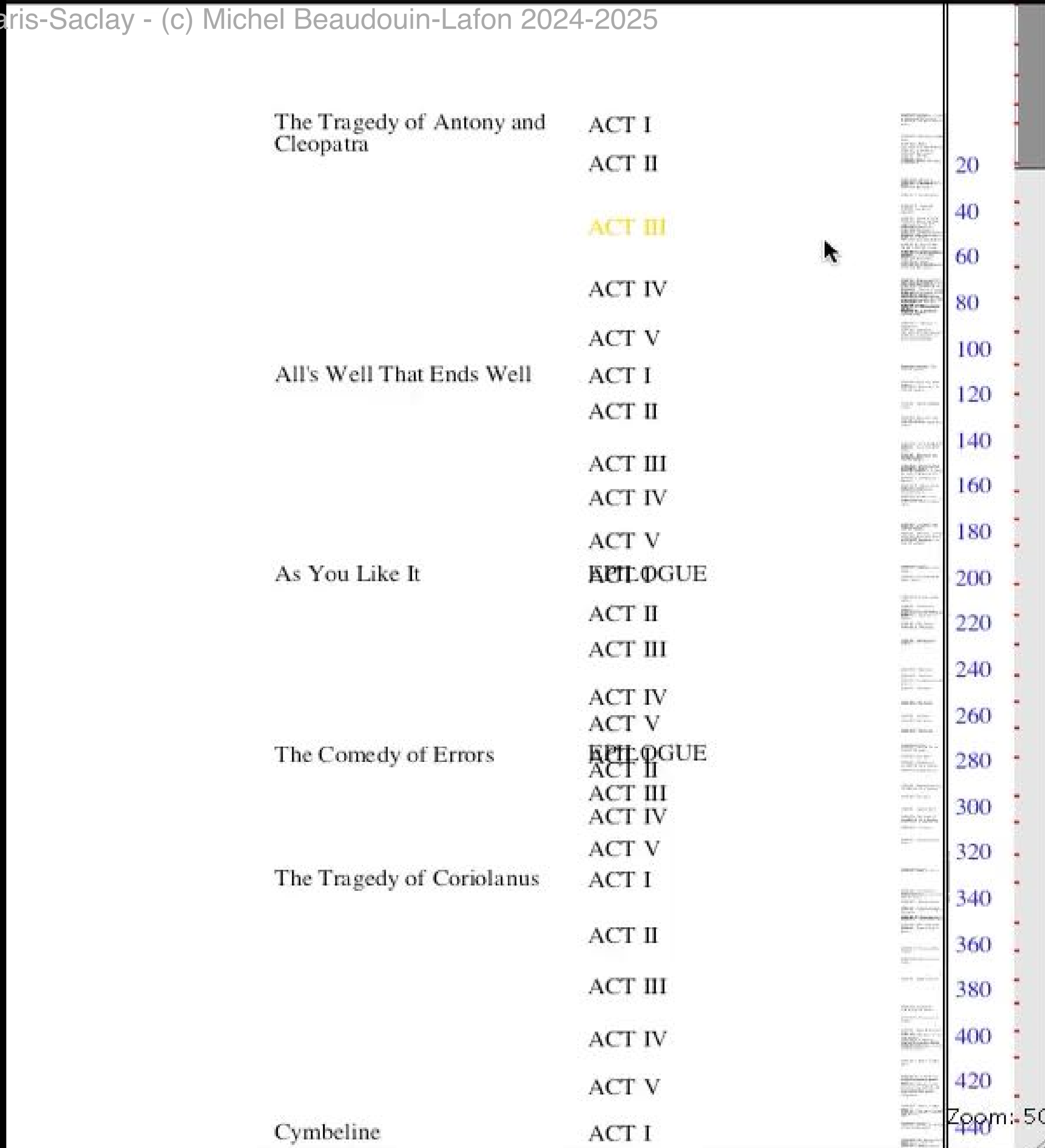
Use orthogonal dimension to zoom

(a) (b)

Navigating the plays of Shakespeare

Orthozooom is twice as fast as the best know technique: Speed-Dependent Automatic Zooming (SDAZ)

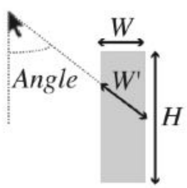




Orthozoom - Appert & Fekete, 2006

Other laws of movement

Generalizing Fitts' law to 2D pointing



$$ID_{W'} = \log_2\left(\frac{D}{W'} + 1\right)$$

$$ID_{min} = \log_2\left(\frac{D}{min(W,H)} + 1\right)$$

$$ID_{az} = \log_2\left(\left[\omega\left(\frac{D}{W}\right)^p + \eta\left(\frac{D}{H}\right)^p\right]^{\frac{1}{p}} + 1\right)$$

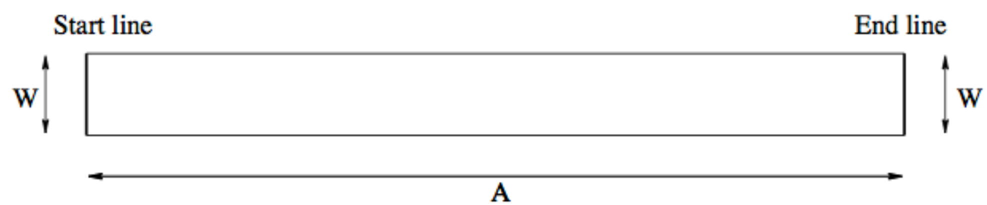
Goal-passing / crossing (Accot & Zhai)

$$ID = \log_2\left(\frac{D}{W} + 1\right)$$

Steering law (Accot)

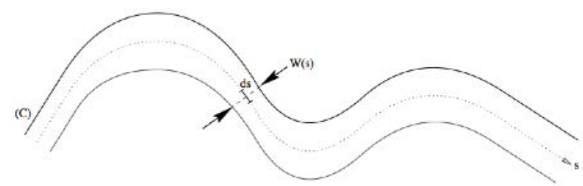
Tunnel:

$$MT = a + b\frac{A}{W}$$



General case:

$$T_C = a + b\int_C \frac{ds}{W(s)}$$



Crossy - crossing-based interface (Apitz & Guimbretiere)

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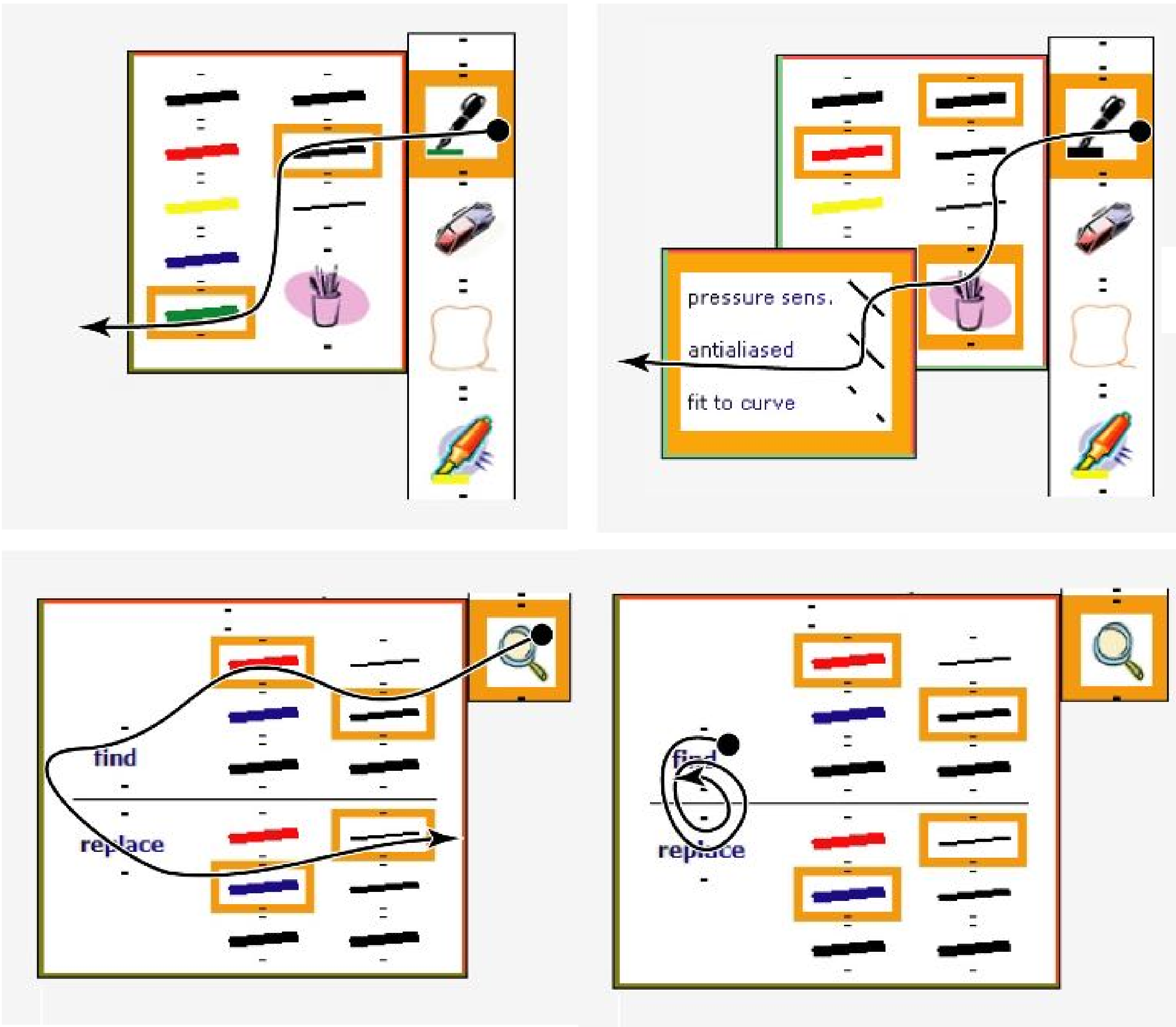

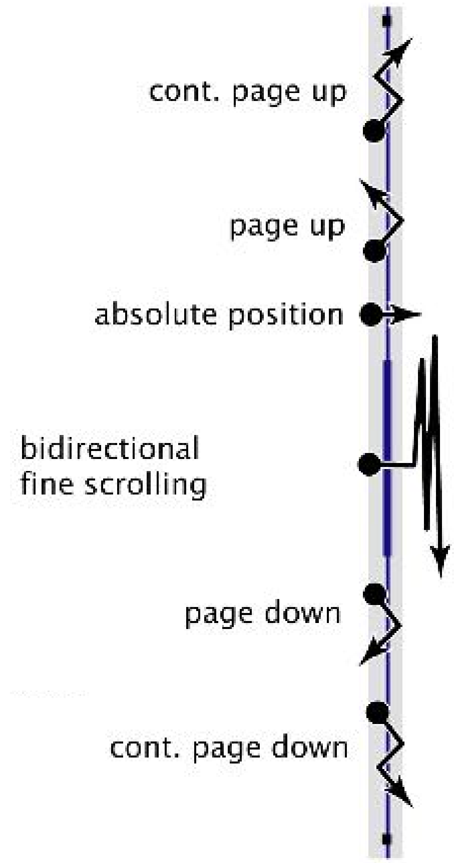

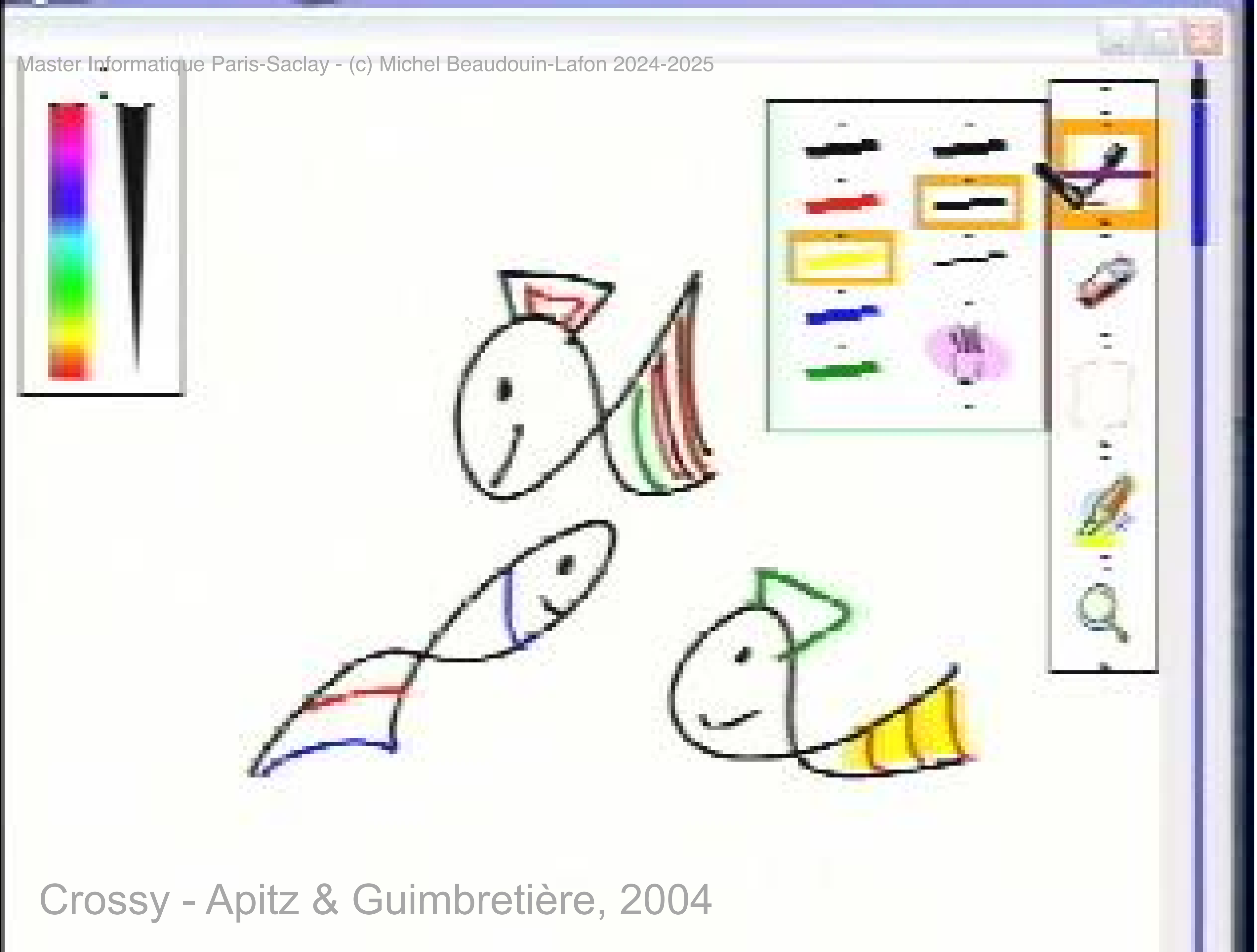

Crossy - Apitz & Guimbretière, 2004

Conclusion

Basic interactions such as pointing are still far from optimal

Fitts' law is a surprisingly robust law

Information is key:

- Information available in the display
- Information perceived by the user
- Information produced by the motor system
- Information captured by the system