WebcamPaperPen: A Low-Cost Graphics Tablet

Gustavo T. Pfeiffer, Ricardo G. Marroquim, Antonio A. F. Oliveira

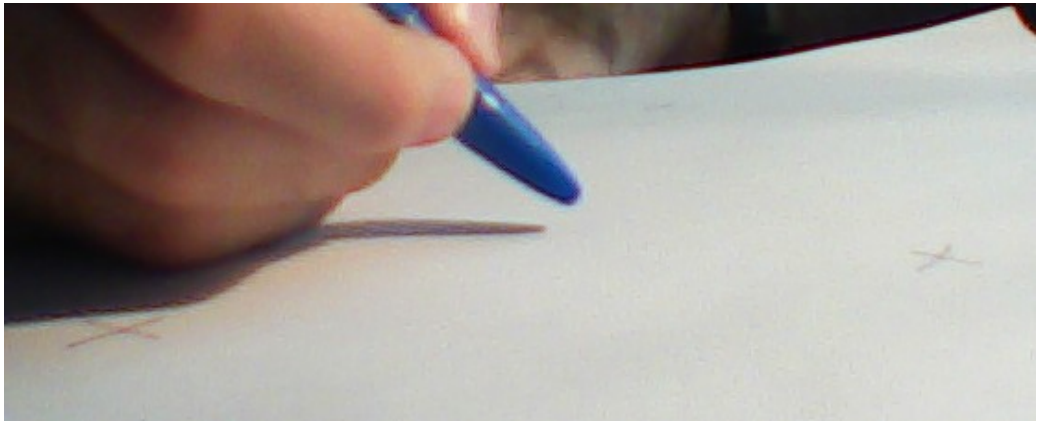
LCG-COPPE-UFRJ

WebcamPaperPen: A Low-Cost Graphics Tablet

Goal: Replace the **graphics tablet** by **webcam, paper and pen**

(http://en.wikipedia.org/wiki/File:Wacom_Bamboo_Capture_tablet_and_pen.jpg)

?



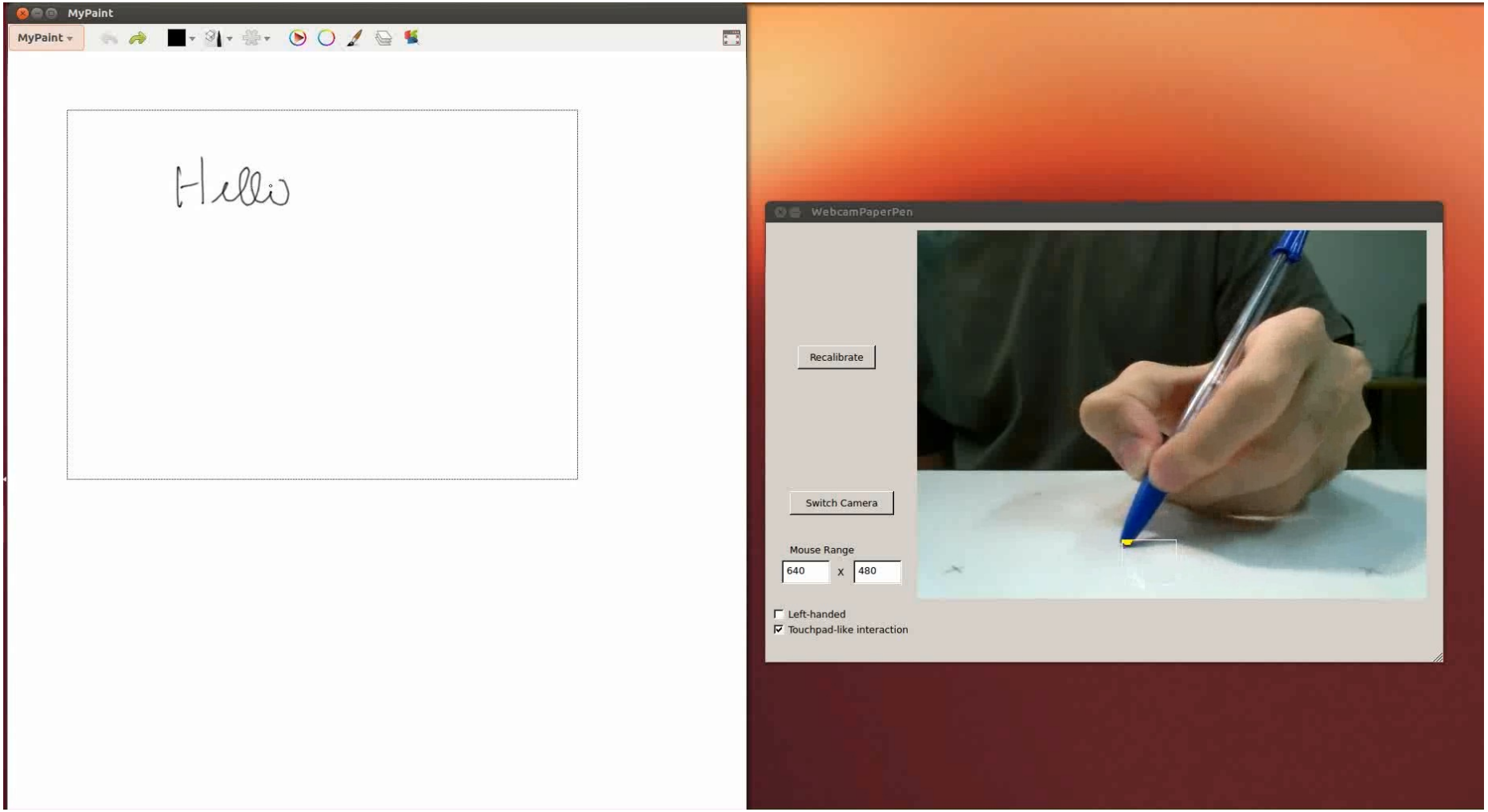
Graphics Tablet

- Device used to draw and handwrite
- Also controls the mouse cursor

WebcamPaperPen

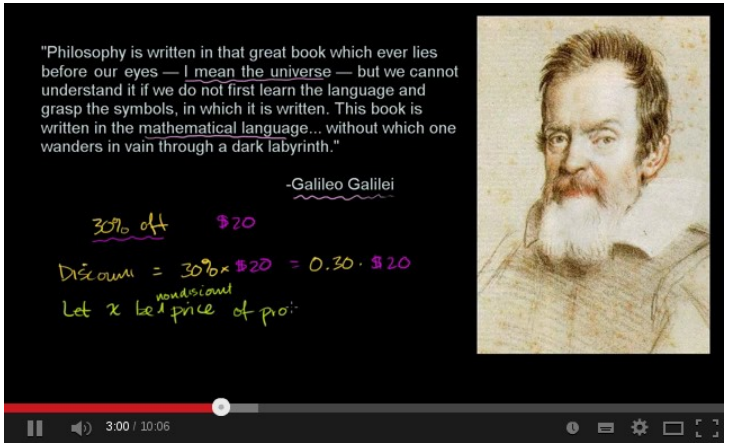
- improvisable vision-based HCI alternative
  - low-cost
  - practical
  - easy to set up

WebcamPaperPen in Action

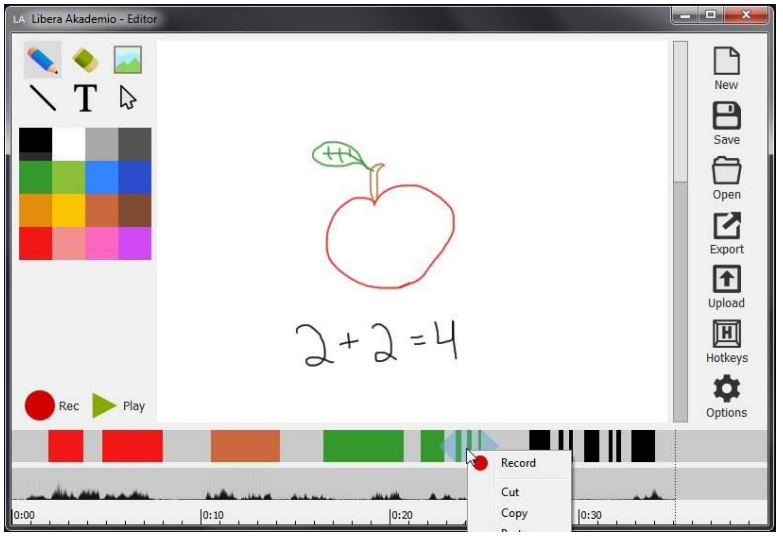


Motivation – Project *Libera Akademio*

- Video lectures to the masses
  - ➔ collaborative
  - ➔ extremely low-cost
  - ➔ similar to *Khan Academy* in style



Khan Academy video
(http://www.youtube.com/watch?v=kpCJyQ2usJ4)

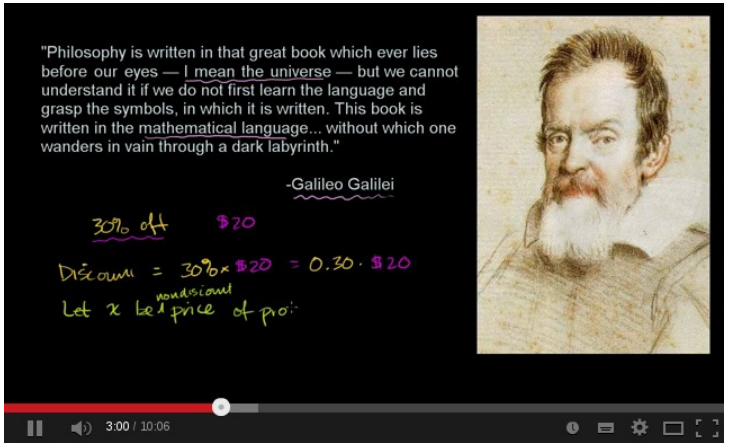


Libera Akademio Editor

Motivation – Project *Libera Akademio*

- Video lectures to the masses
  - ➔ collaborative
  - ➔ extremely low-cost
  - ➔ similar to *Khan Academy* in style

- But requires the **graphics tablet**
  - ➔ *Wouldn't webcam, paper and pen be much better?*



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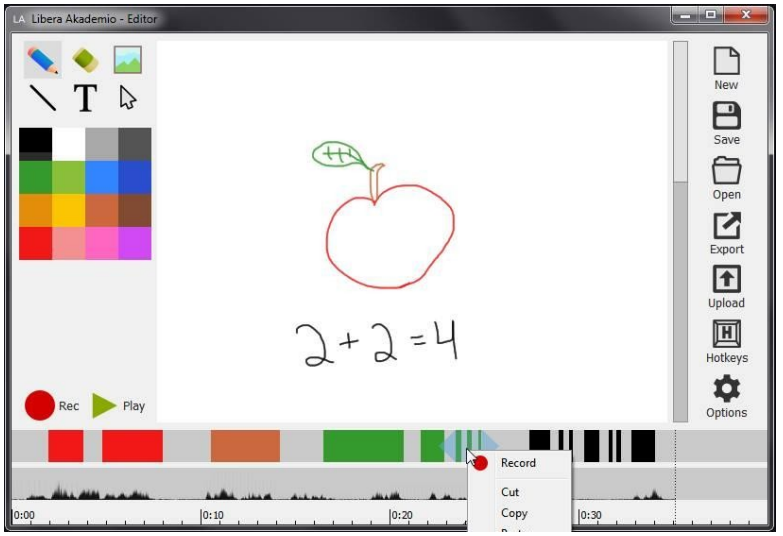
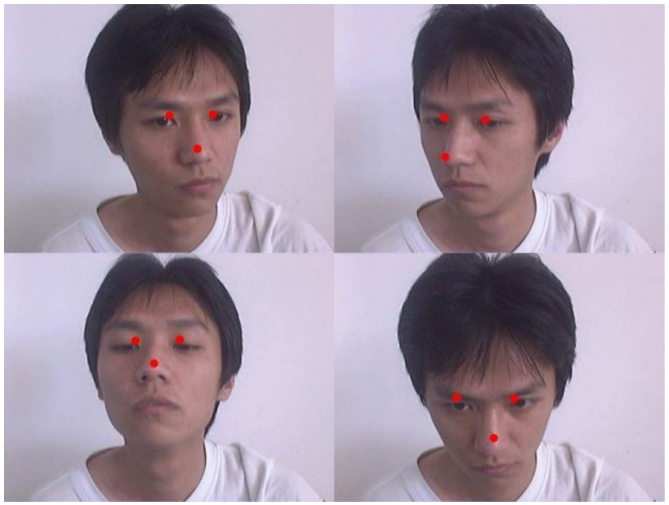


Libera Akademio Editor

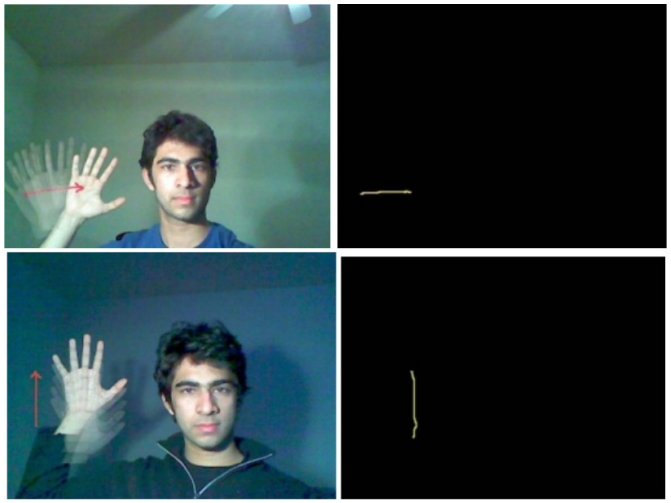
Related Work

Related Work

Body Parts Tracking



HAO and LEI, 2008



MANCHANDA and BING, 2010

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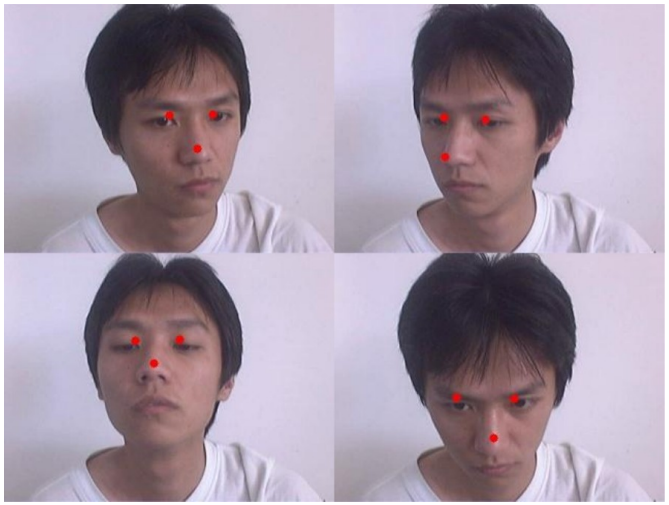

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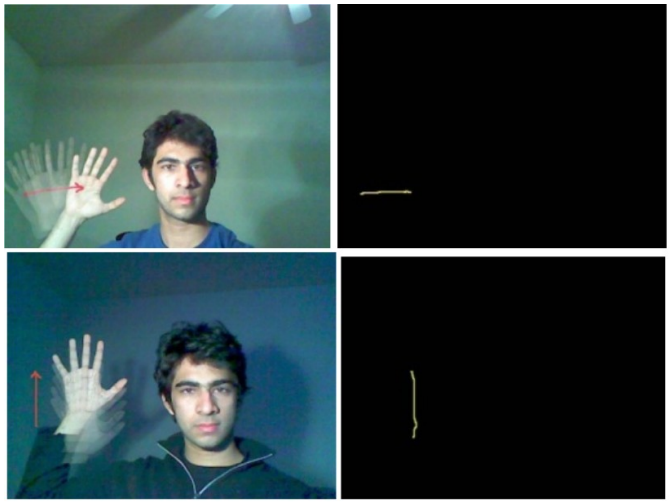
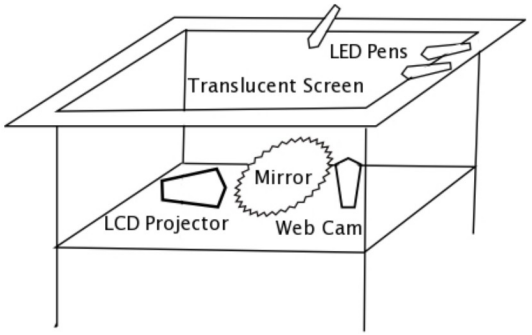
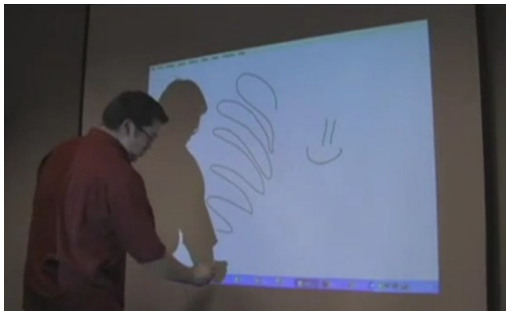


MANCHANDA and BING, 2010

Light Tracking



PIAZZA and FIELD, 2007



http://www.wiimoteproject.com/

http://laserinteraction.codeplex.com/

Related Work

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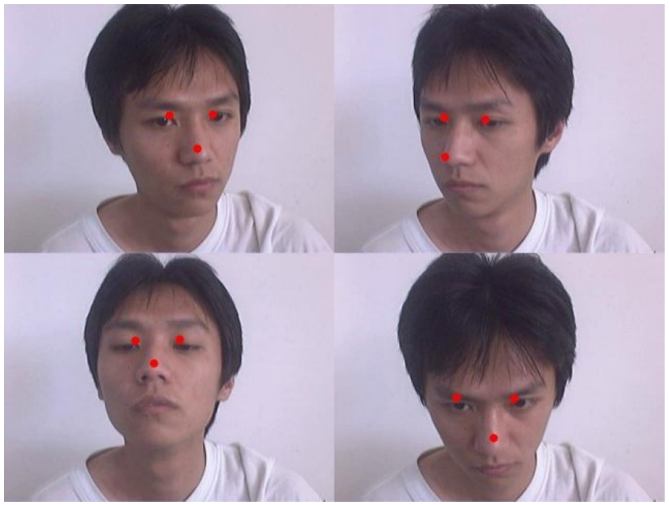

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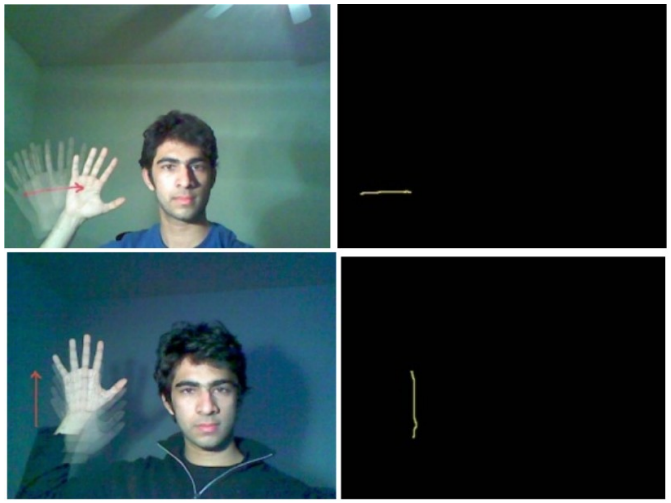

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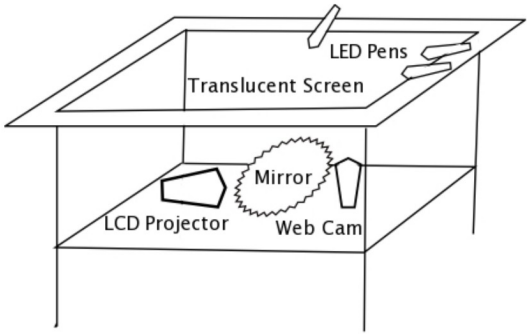

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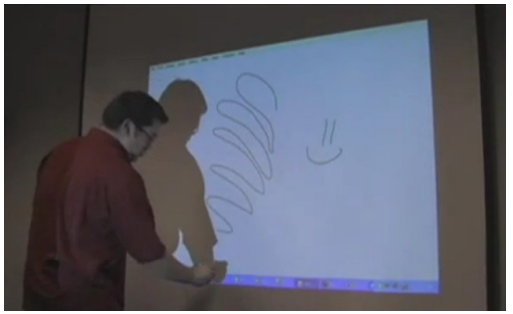

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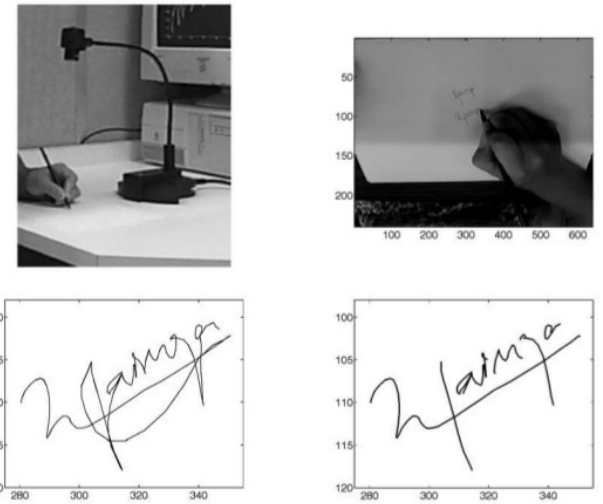
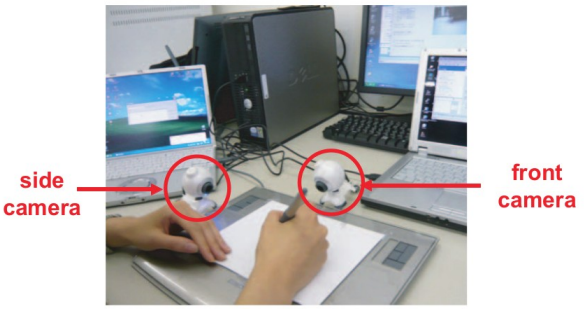
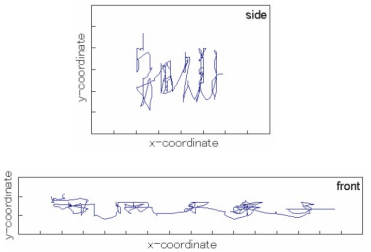
Pen Tip Tracking



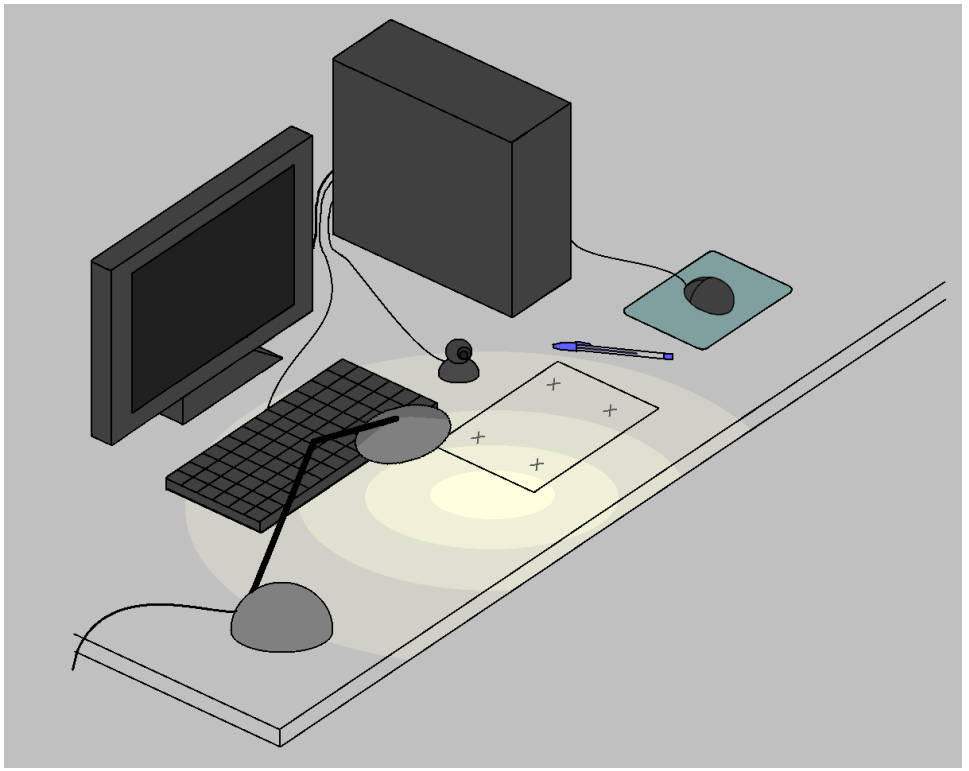
MUNICH and PERONA, 2002

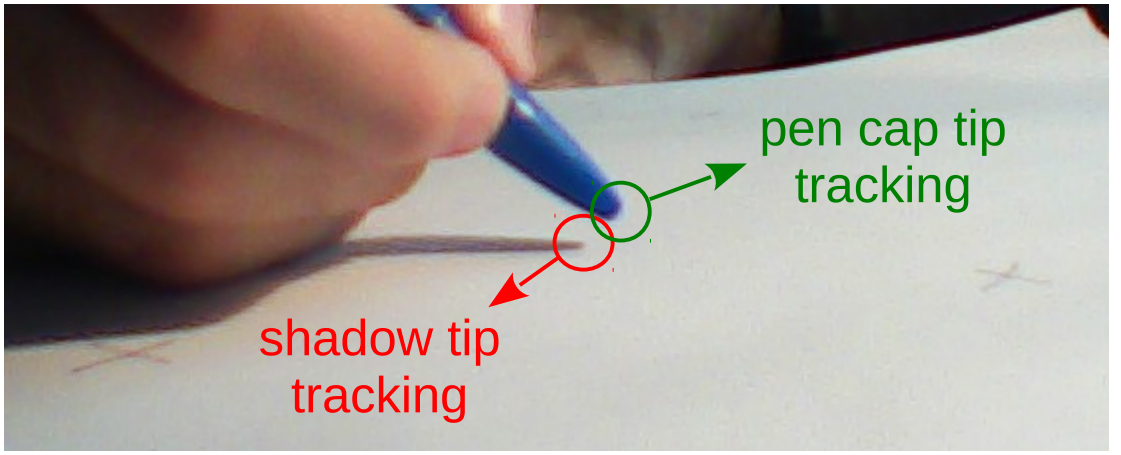


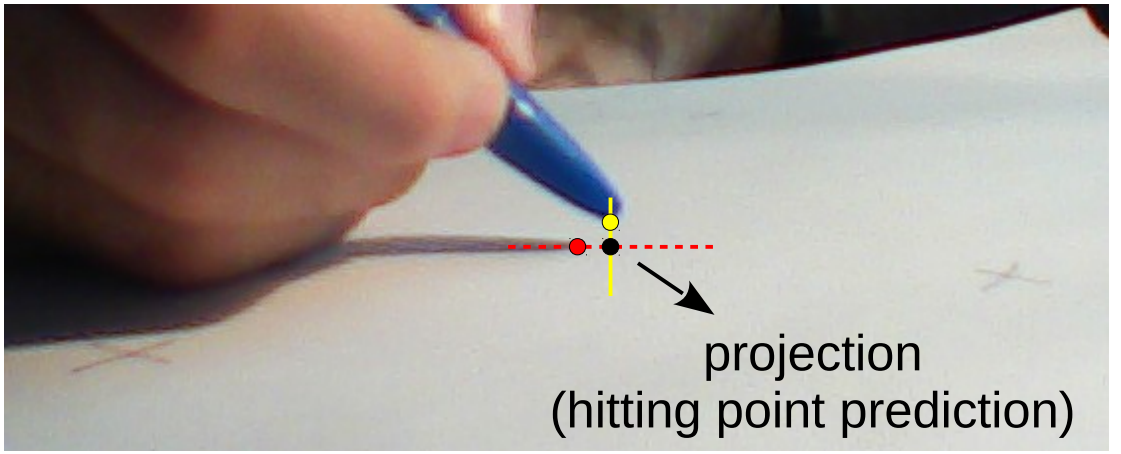


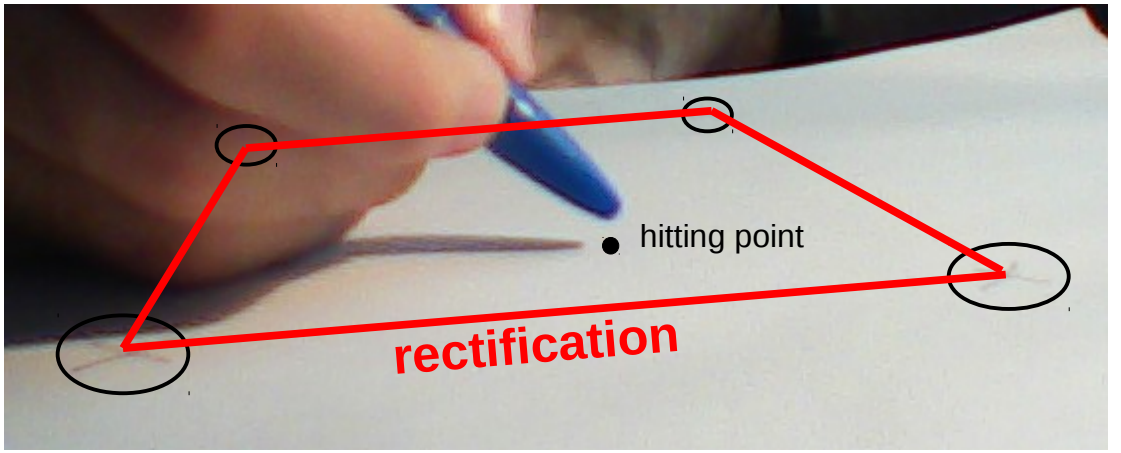
YASUDA et al., 2010

Fundamentals of WebcamPaperPen



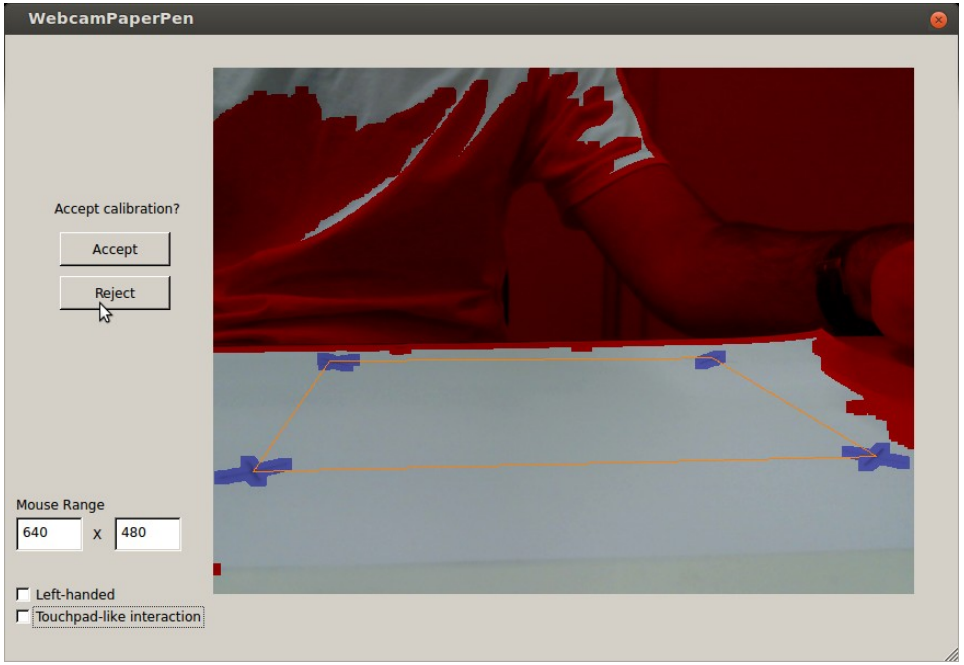


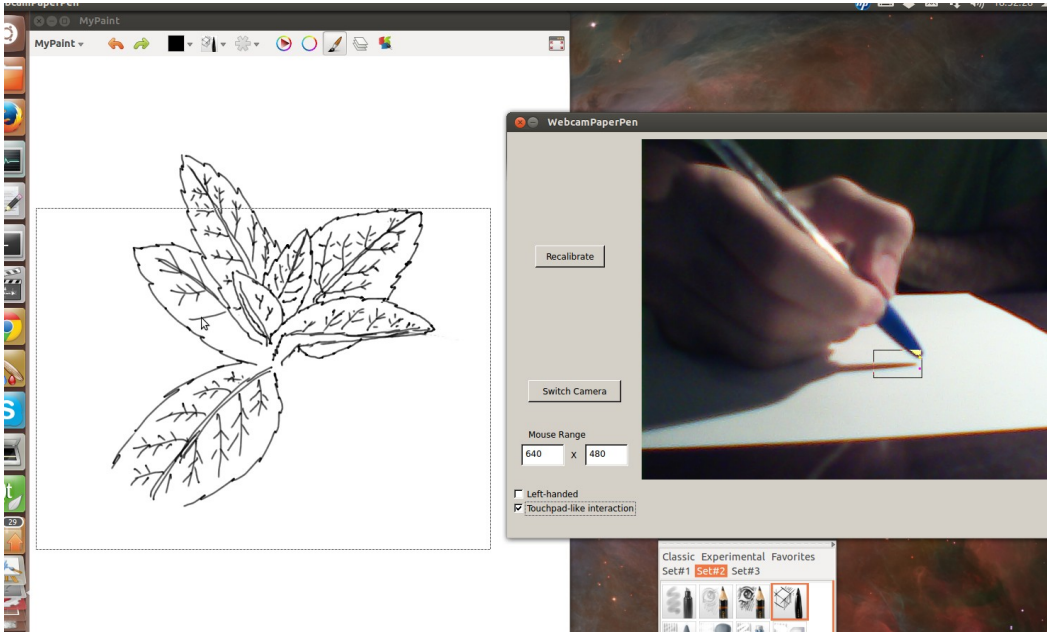




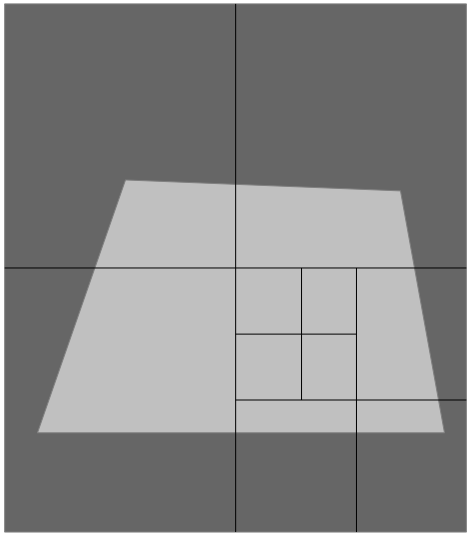
Calibration

Calibration Step ⟶ Drawing Step



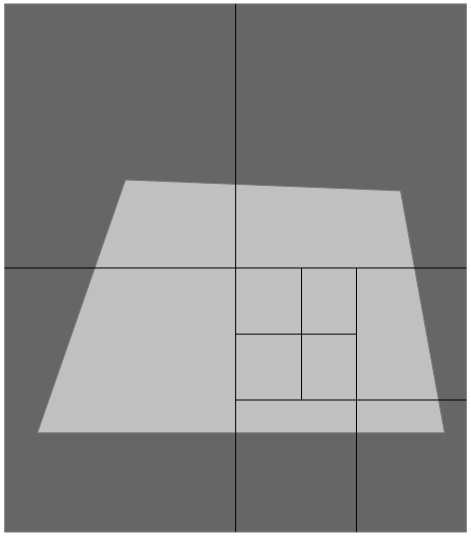


Method – Calibration



1. Search the paper, get mean intensity

Method – Calibration



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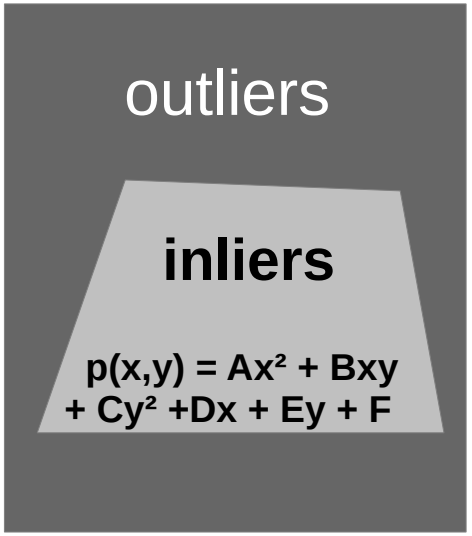

2. fit intensity to a quadratic function

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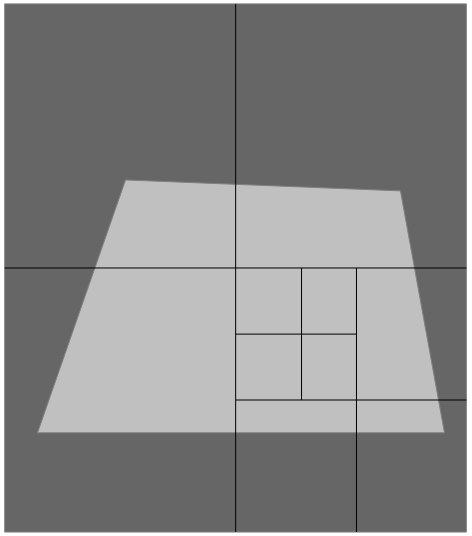

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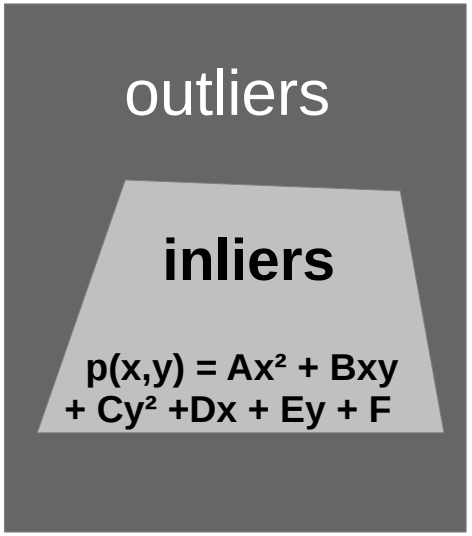

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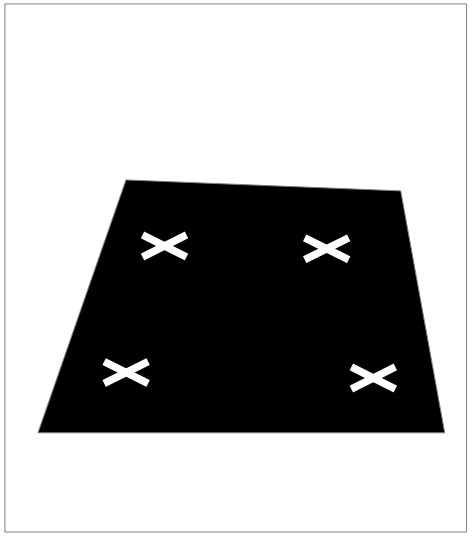
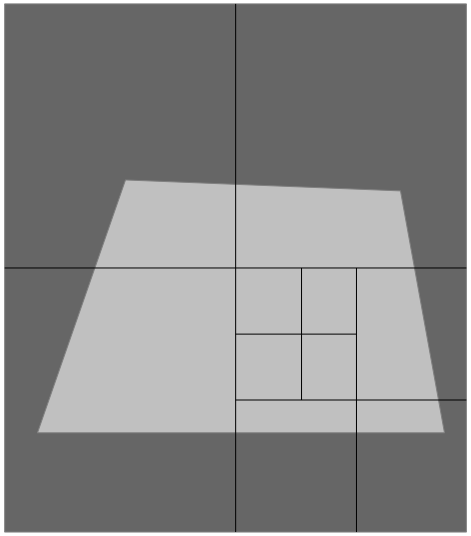


3. Compare pixelwise to fitted function

Method – Calibration



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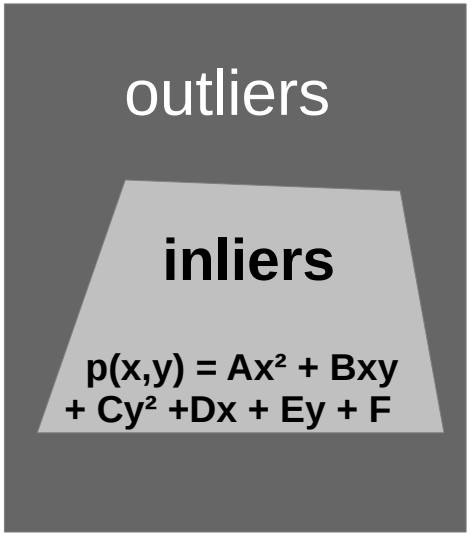

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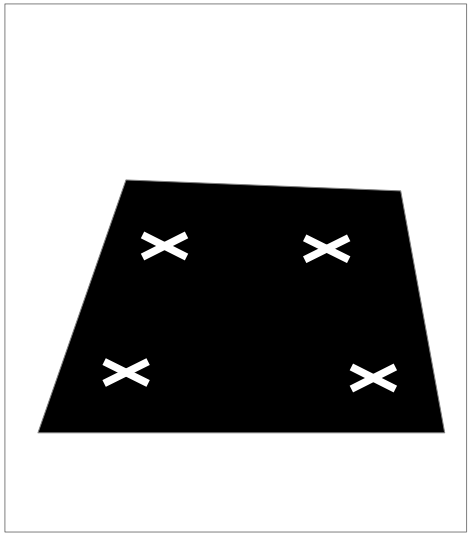

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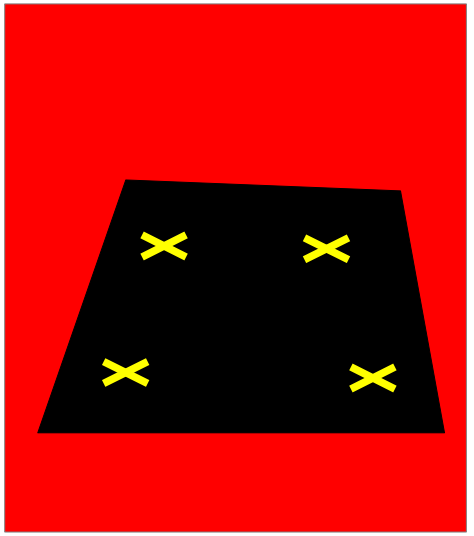
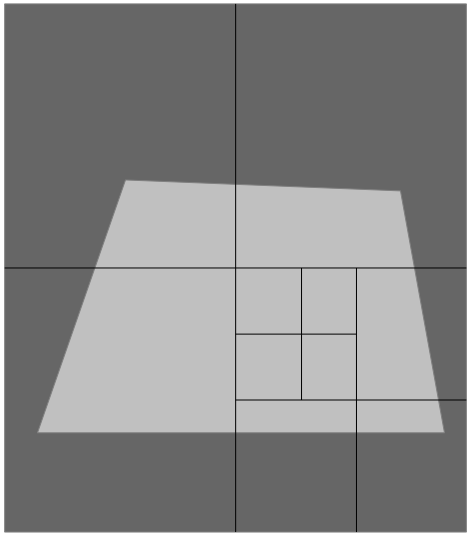


4. Classify connected components

Method – Calibration



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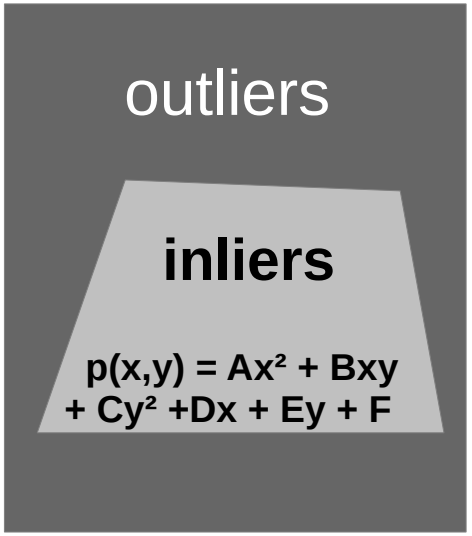

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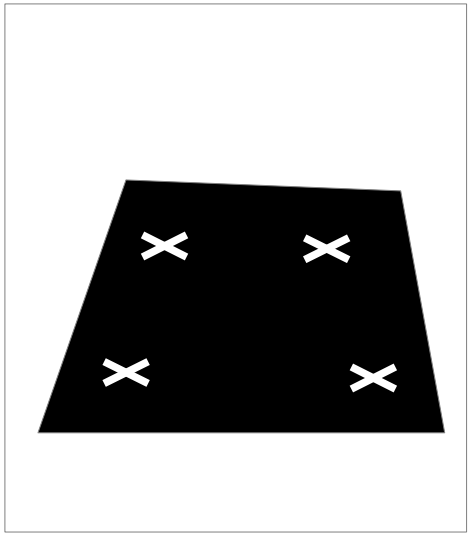

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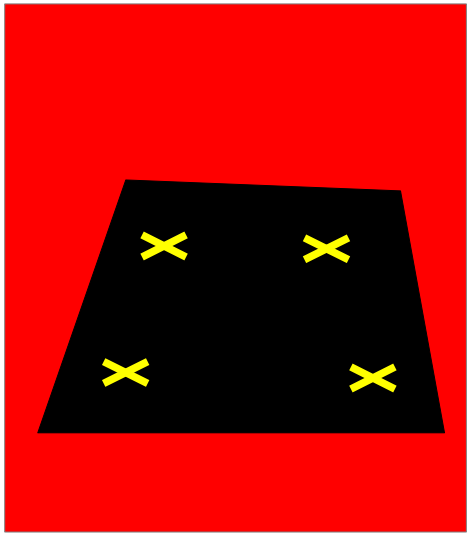

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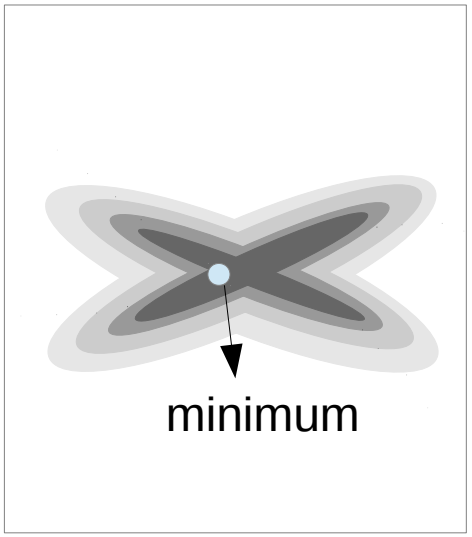
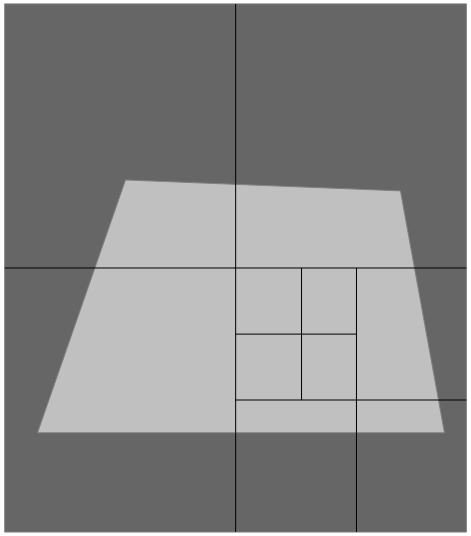


5. minimum intensity after blur

Method – Calibration



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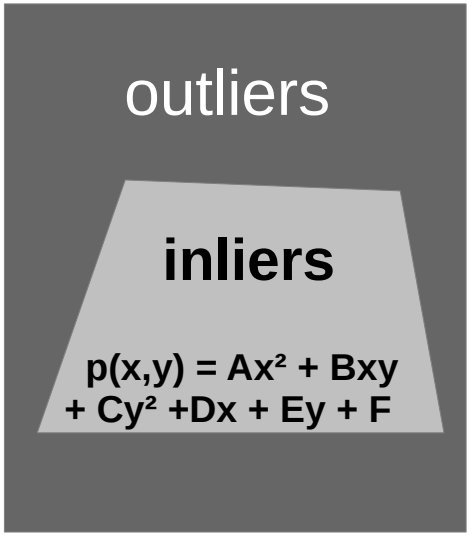

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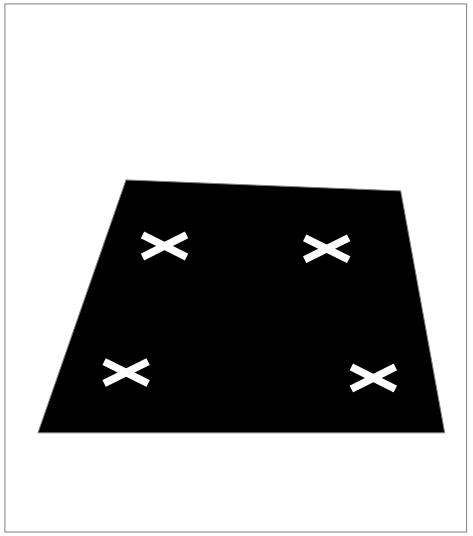
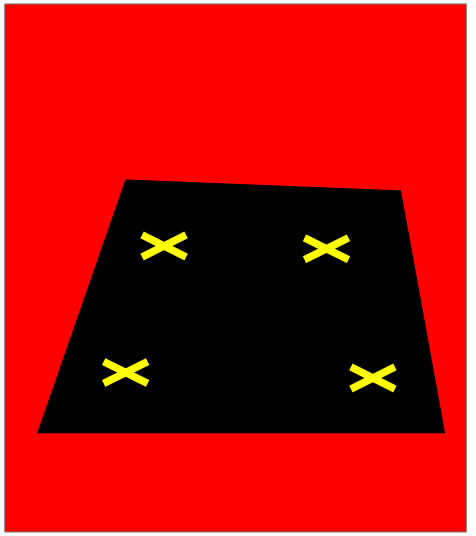


3. Compare pixelwise to fitted function



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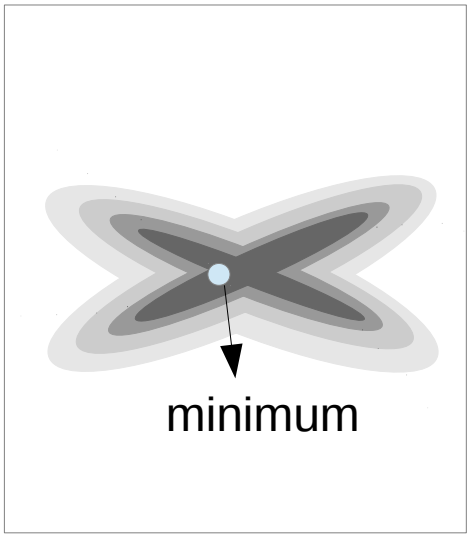

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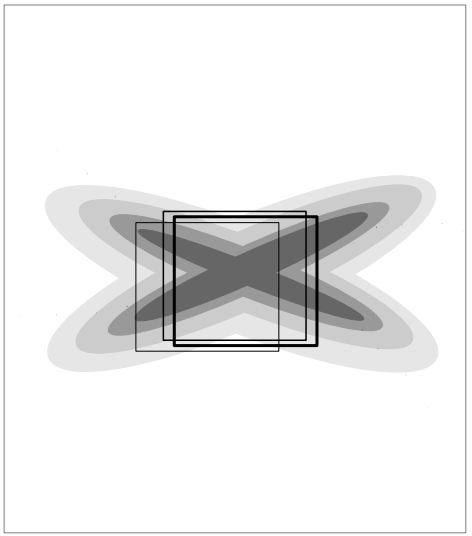
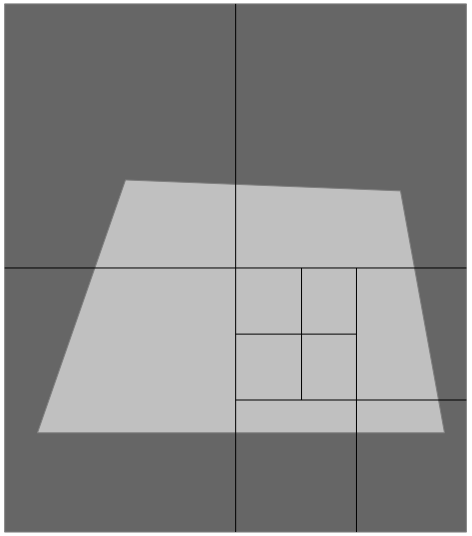


6. update using quadratic fit

Method – Calibration



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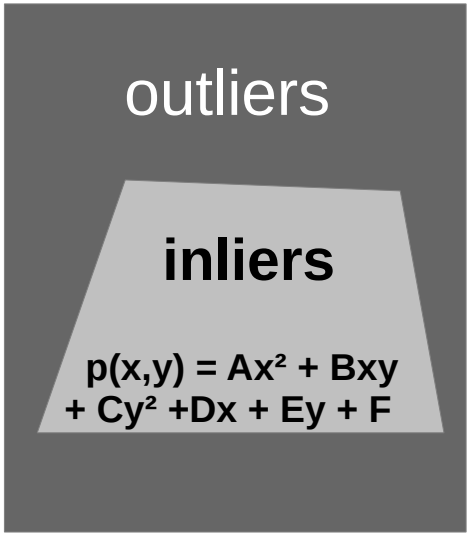
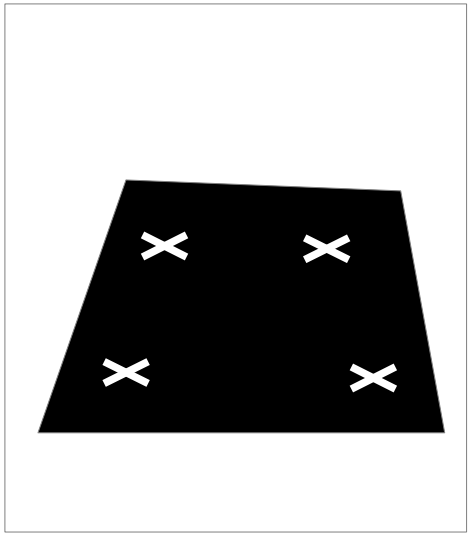


2. fit intensity to a quadratic function



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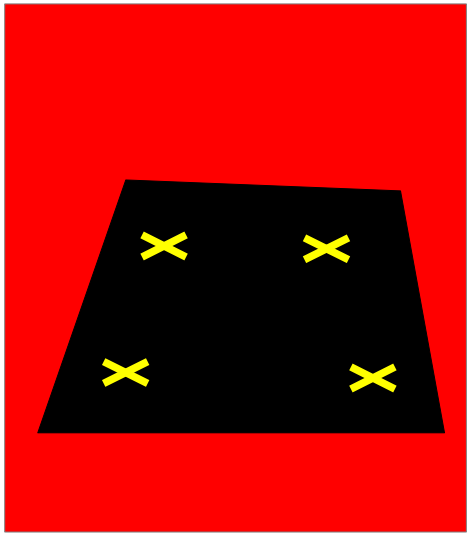

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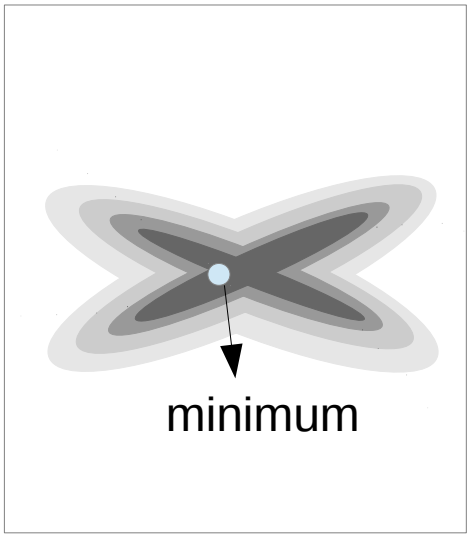
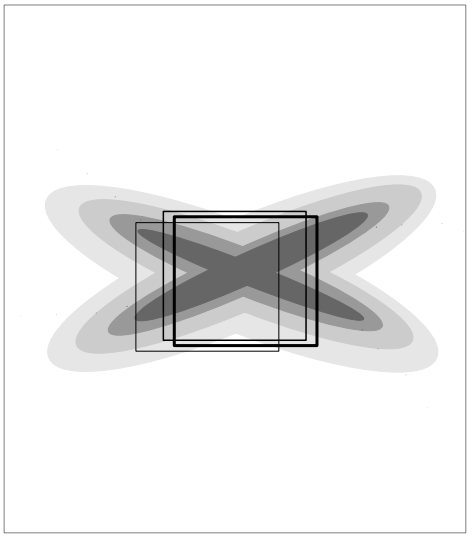
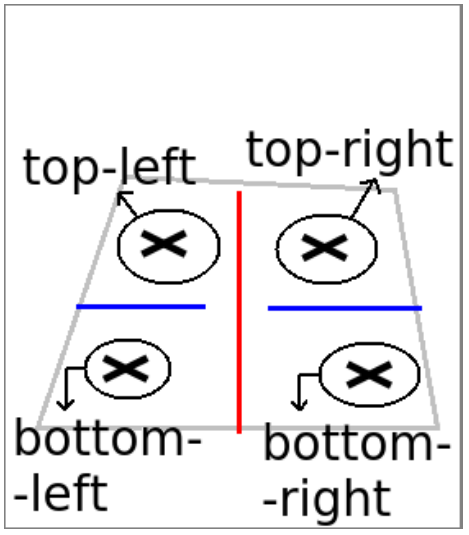


5. minimum intensity after blur

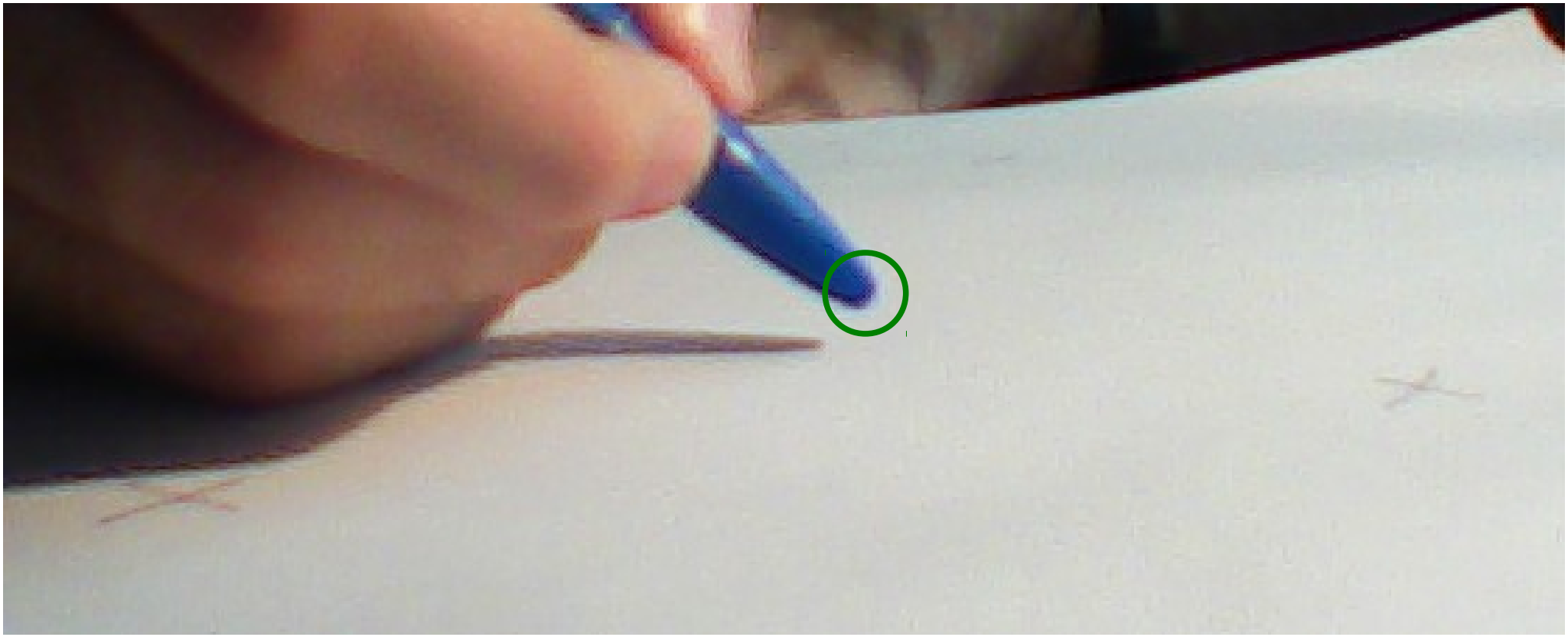


6. update using quadratic fit

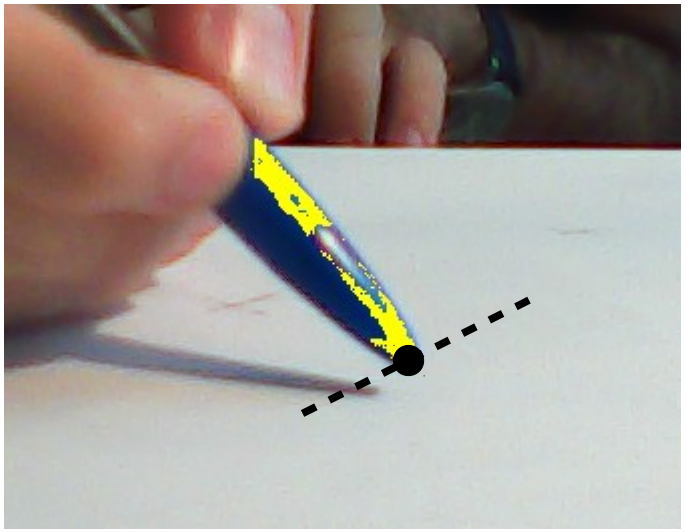


7. Classify crosses

Pen Cap Tip Tracking

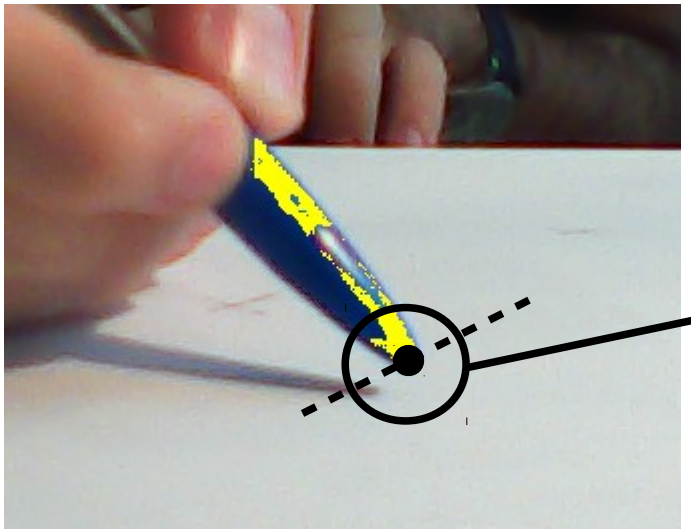


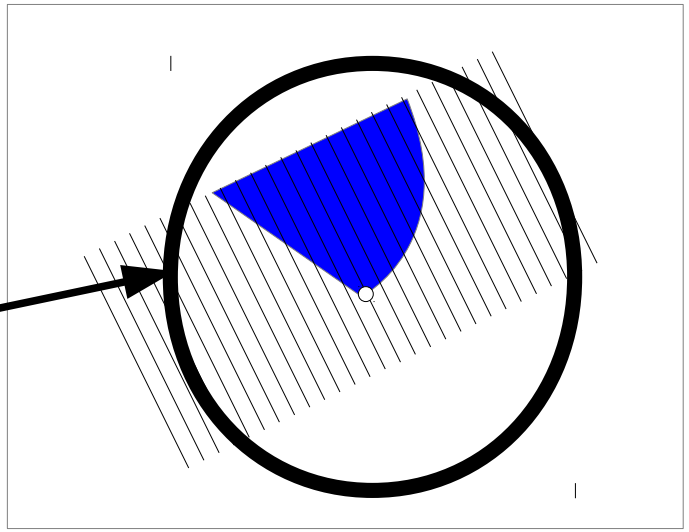
Method – Pen Cap Tip Tracking



1. Apply blue filter and maximize 2y+x

Method – Pen Cap Tip Tracking

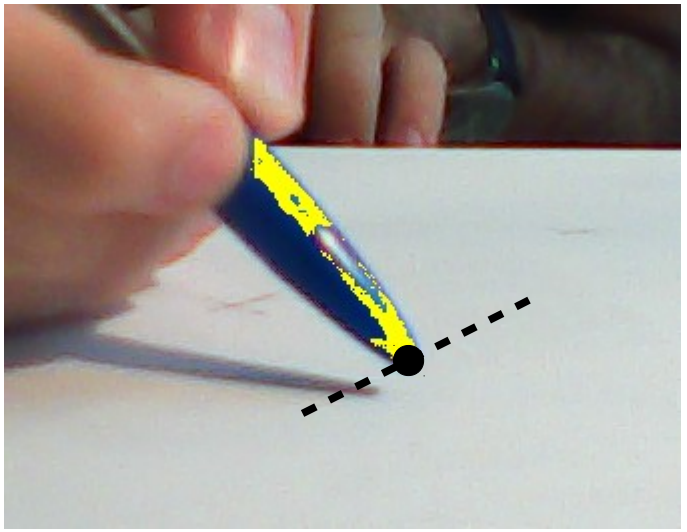




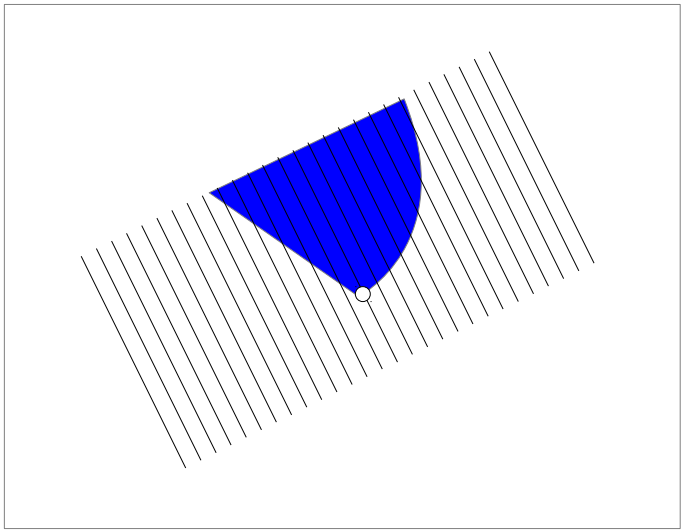
1. Apply blue filter and maximize 2y+x

2. Minimize sum (hor.) Maximize Sobel (ver.)

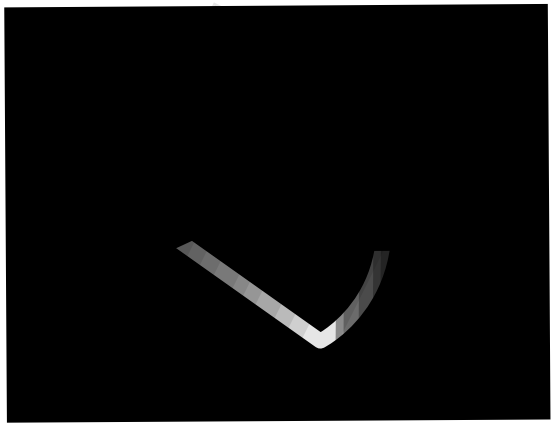
Method – Pen Cap Tip Tracking



1. Apply blue filter and maximize 2y+x

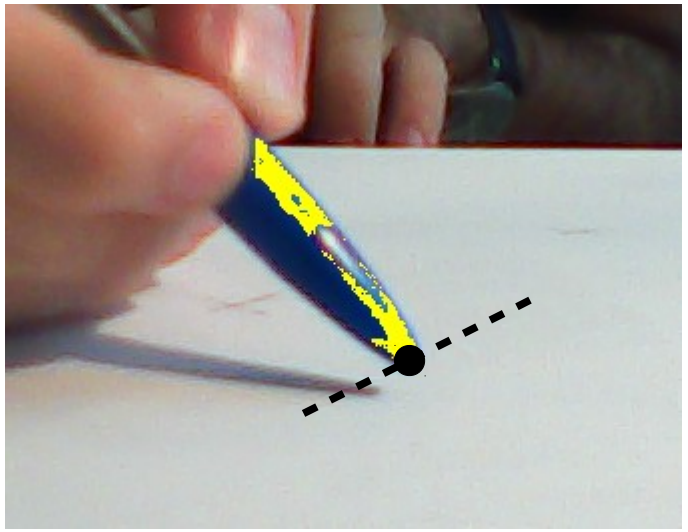


2. Minimize sum (hor.) Maximize Sobel (ver.)

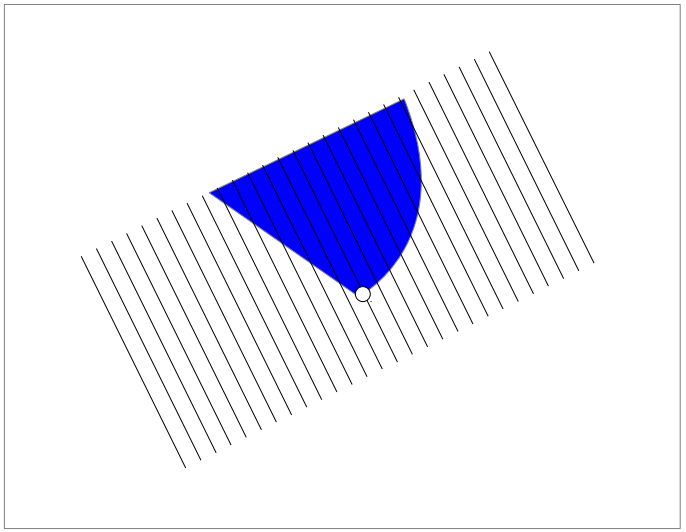


3. Search pixel that maximizes objective function

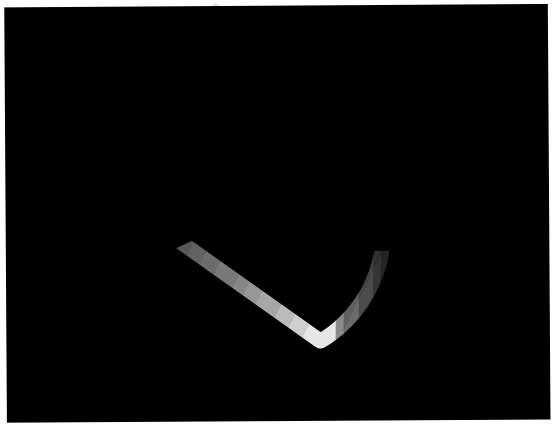
Method – Pen Cap Tip Tracking



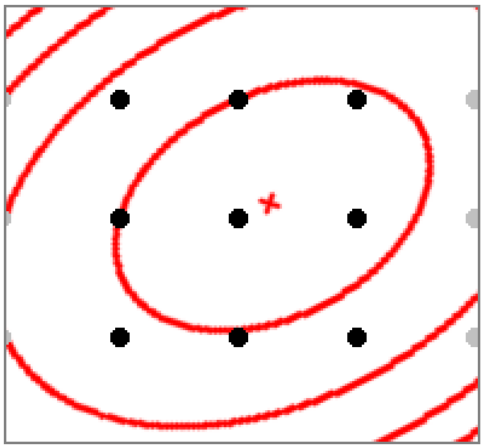
1. Apply blue filter and maximize 2y+x



2. Minimize sum (hor.) Maximize Sobel (ver.)

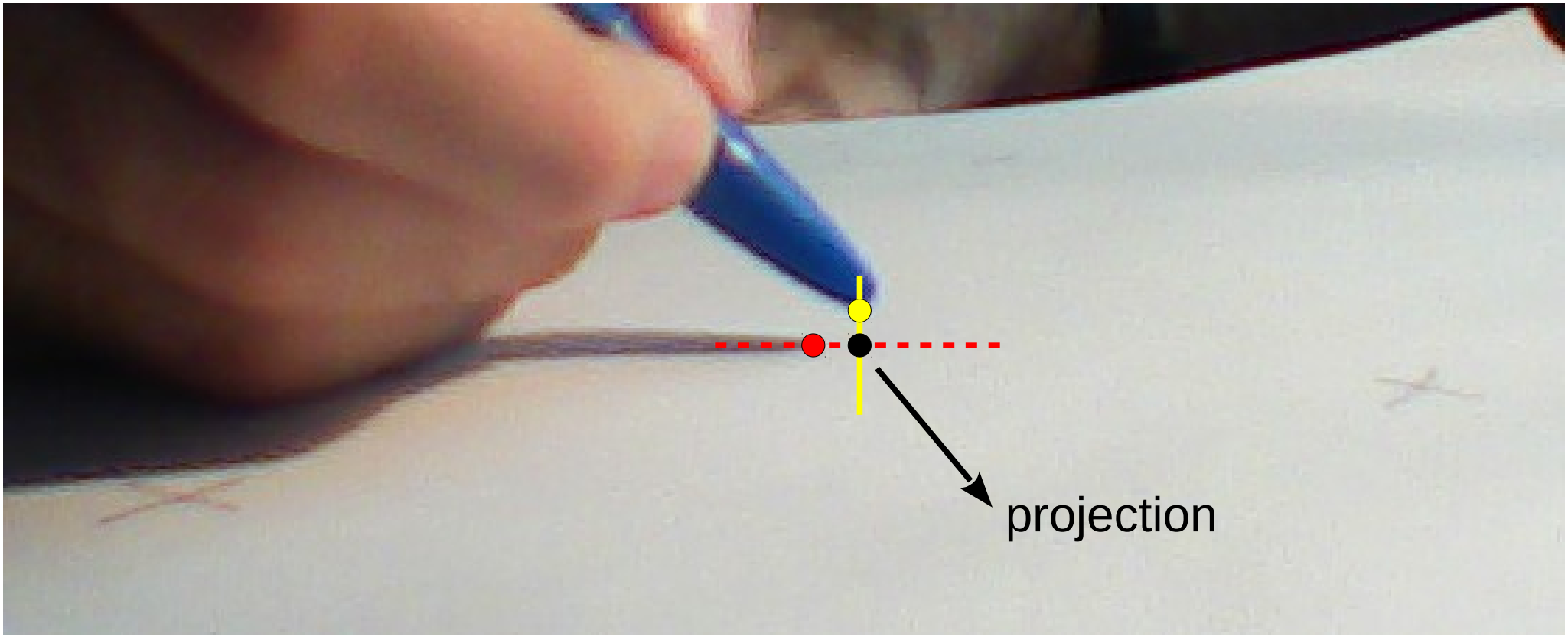


3. Search pixel that maximizes objective function

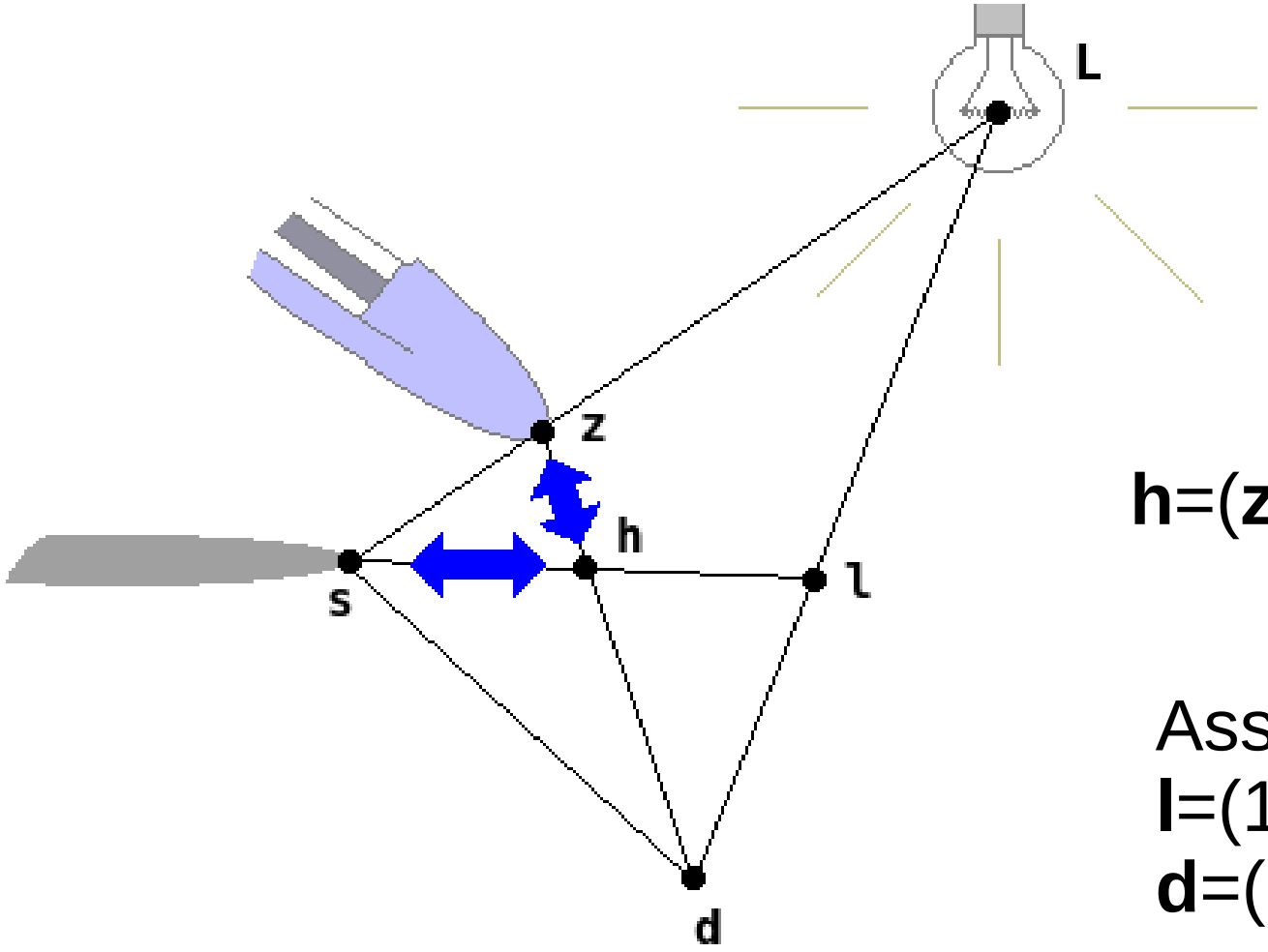


4. Subpixel estimation using quadratic fit

Hitting Point Prediction



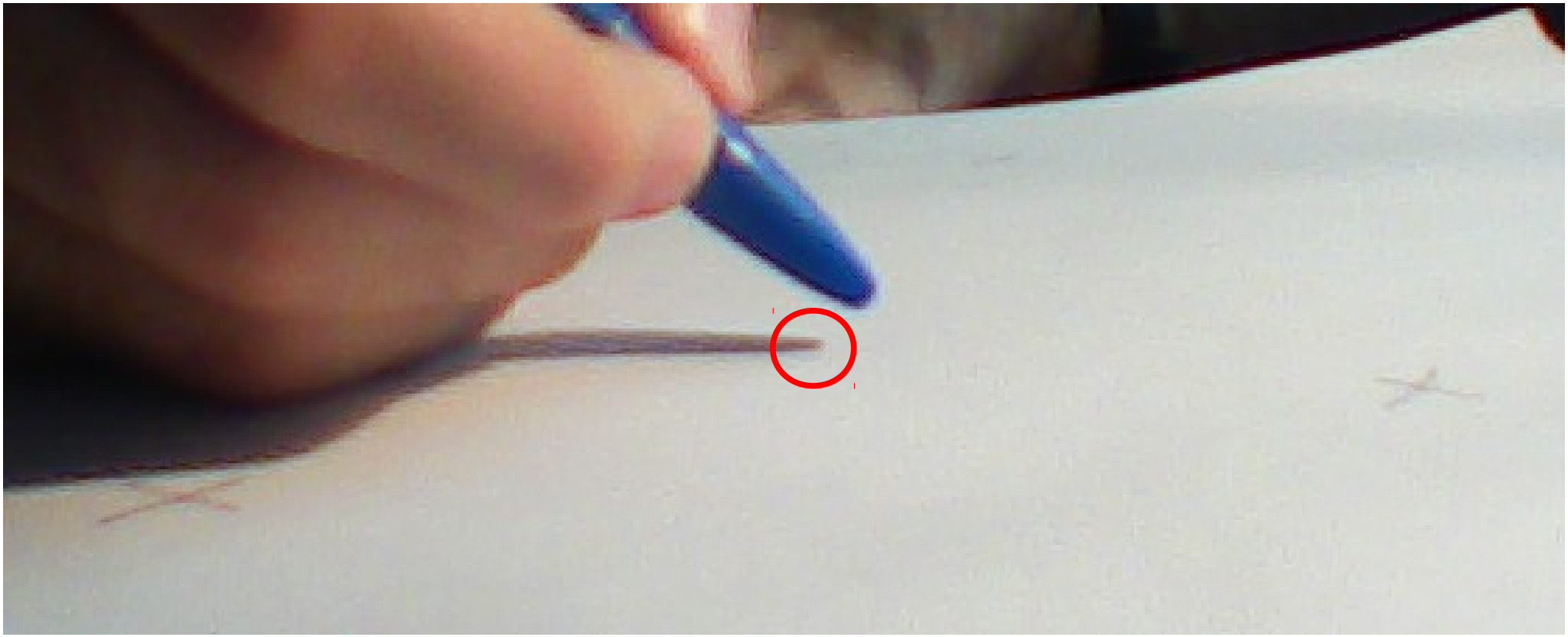
Theory - Hitting Point Prediction



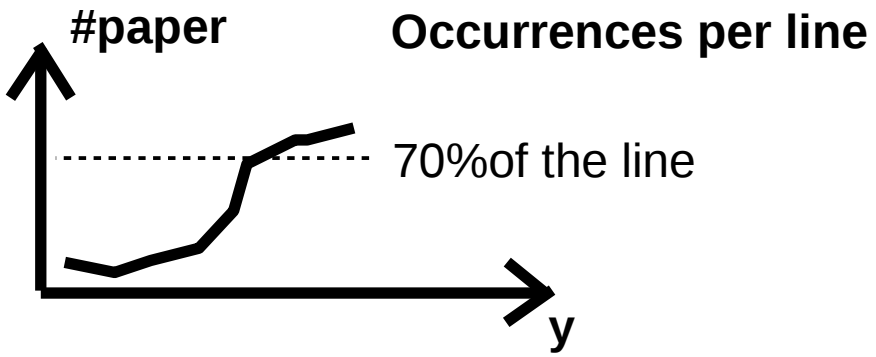
$$\mathbf{h}=(\mathbf{z}\times\mathbf{d})\times(\mathbf{l}\times\mathbf{s})$$

Assumption:
$\mathbf{l}=(1,0,0)$
$\mathbf{d}=(0,1,0)$

Shadow Tip Tracking

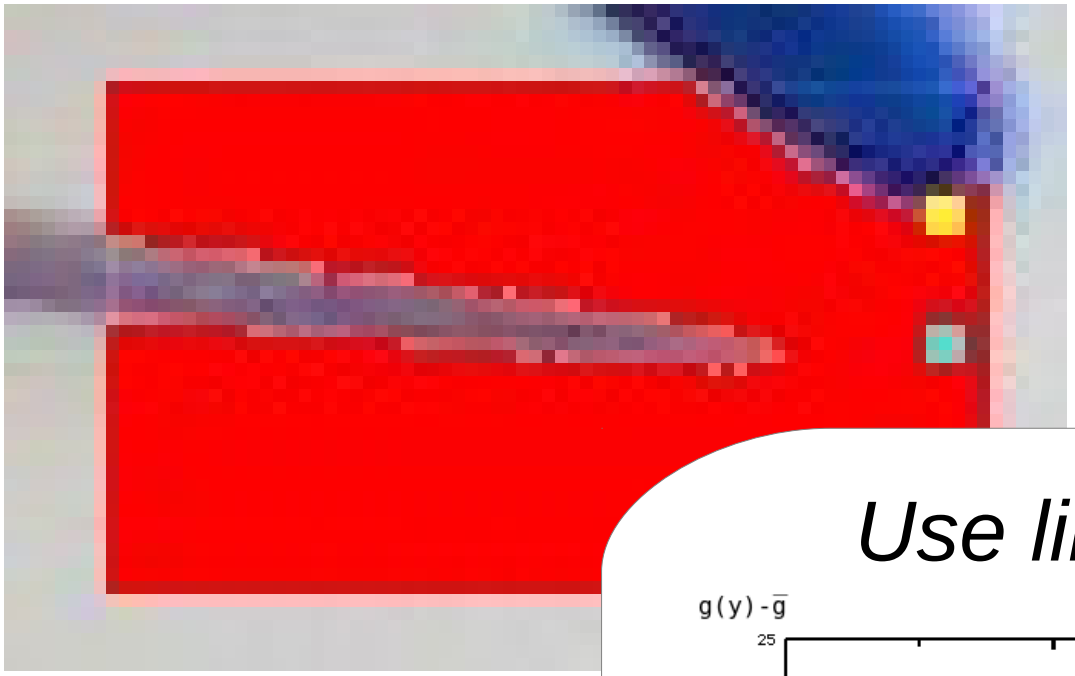


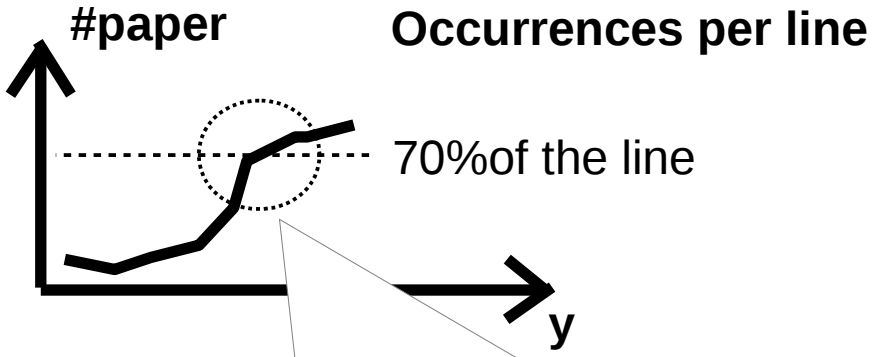
Method – Shadow Tracking



Threshold: 75% of paper intensity

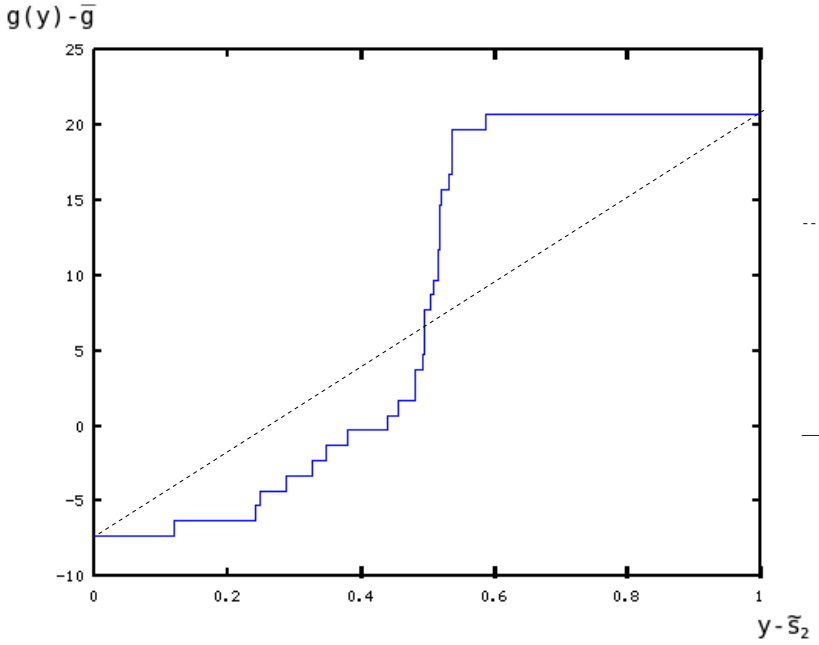
Method – Shadow Tracking





Threshold: 75% of pap

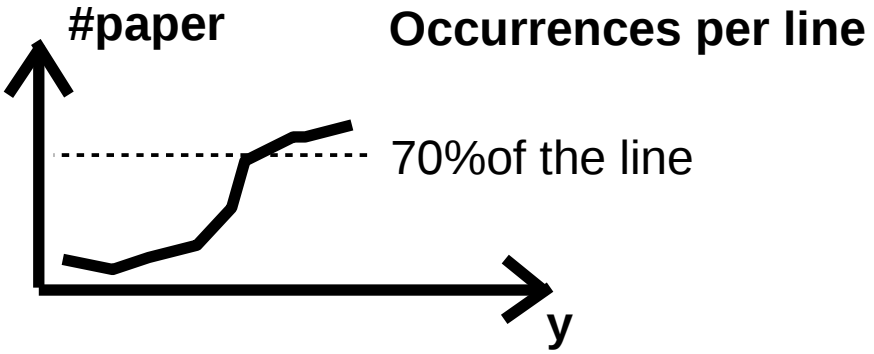
Use linear interpolation?



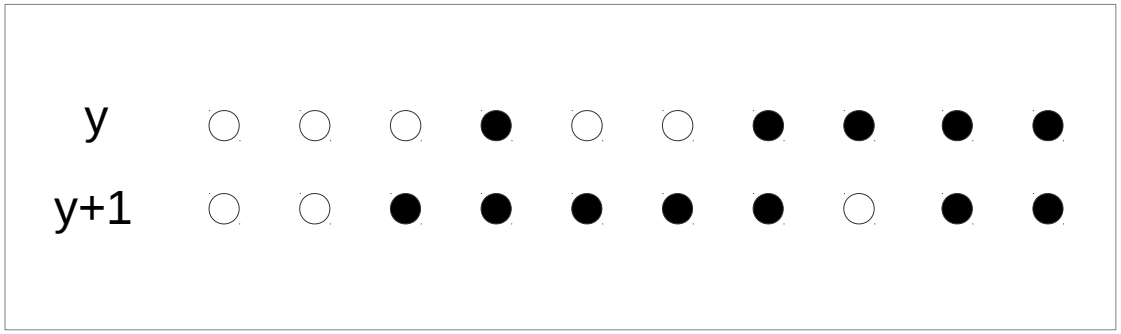
Linear interpolation

Actual (?) curve

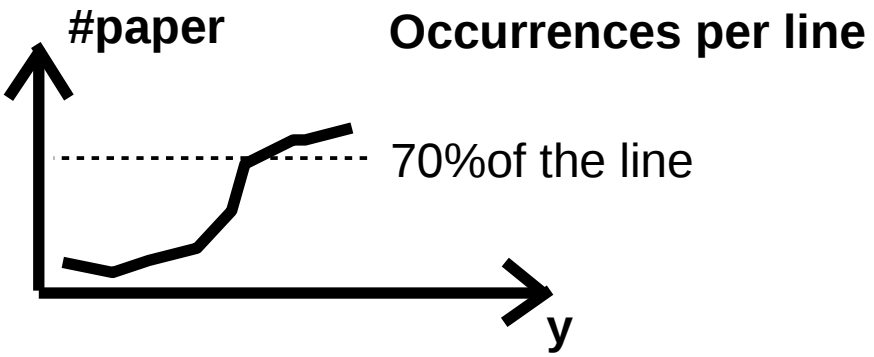
Method – Shadow Tracking



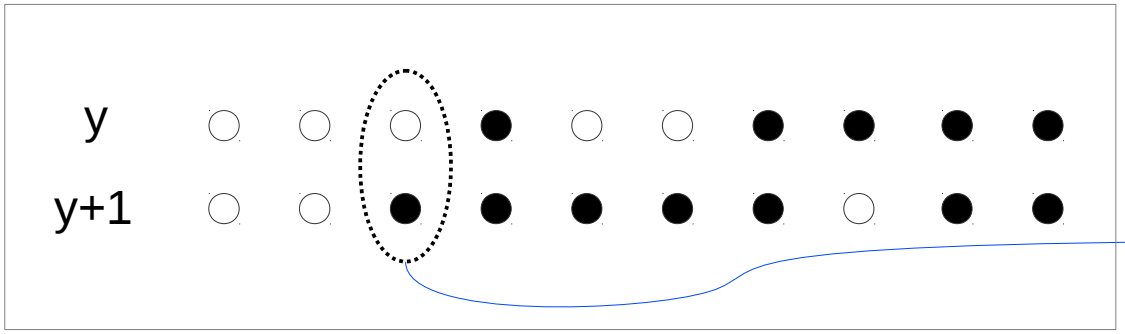
Threshold: 75% of paper intensity

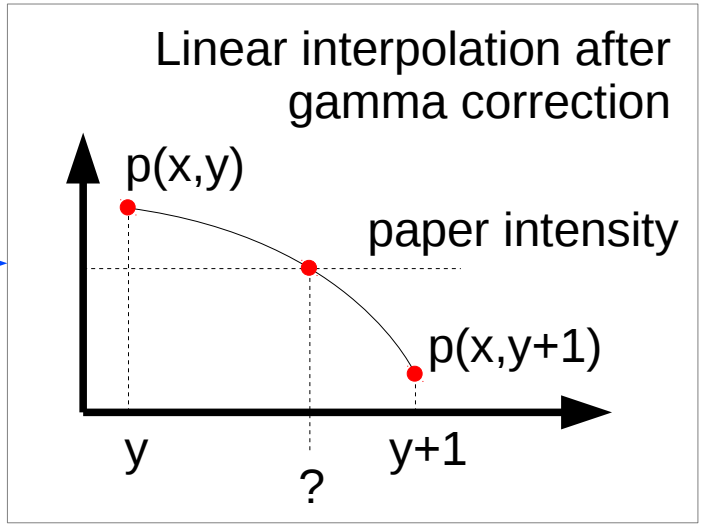


Method – Shadow Tracking

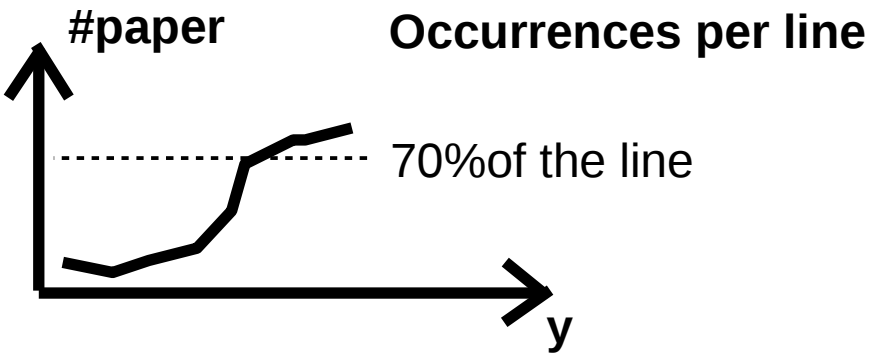


Threshold: 75% of paper intensity





Method – Shadow Tracking



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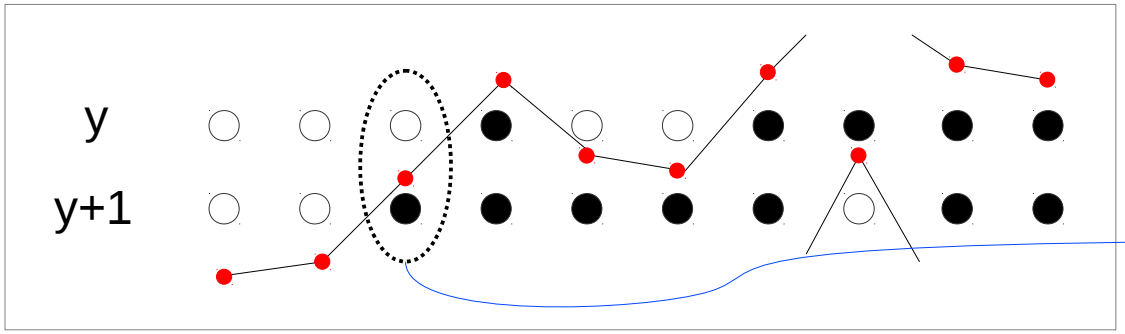
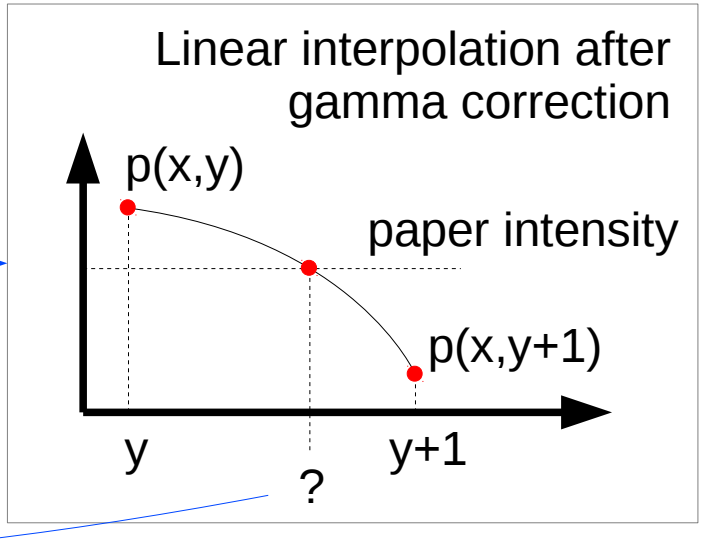
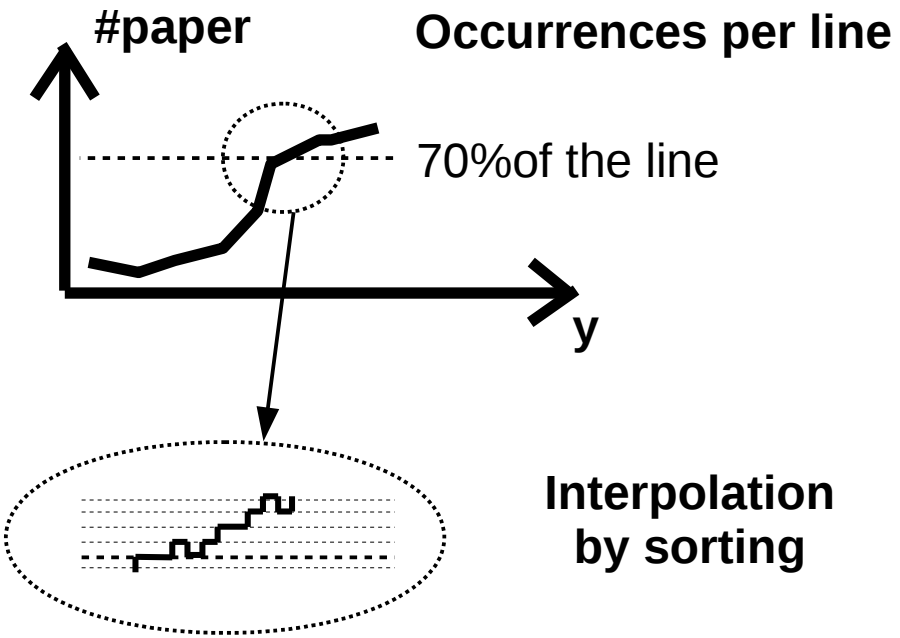
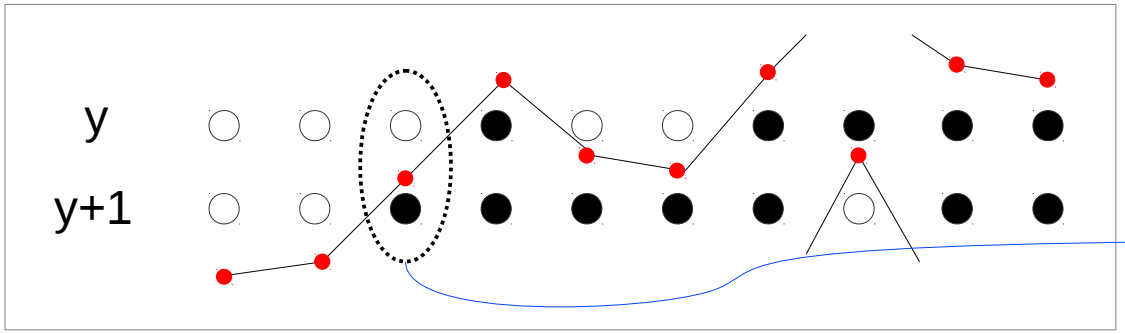


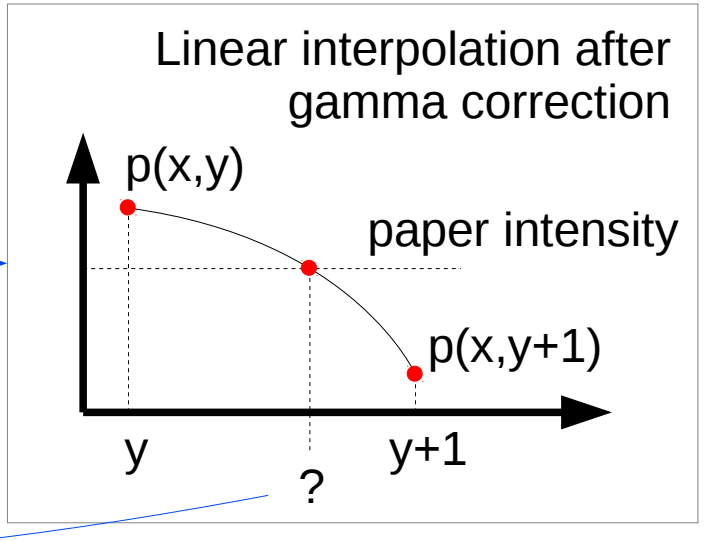


Method – Shadow Tracking

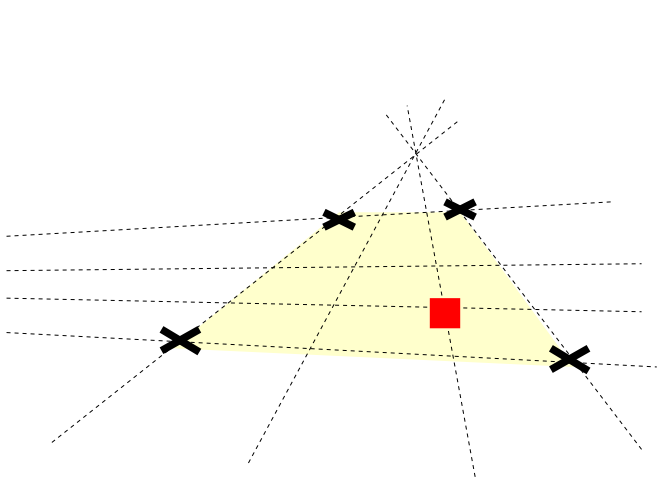


Threshold: 75% of paper intensity



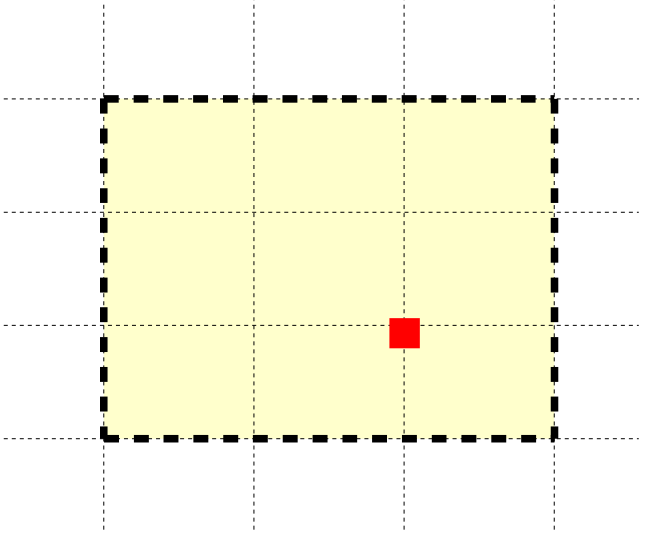


Method – Mouse Motion



four crosses' convex hull

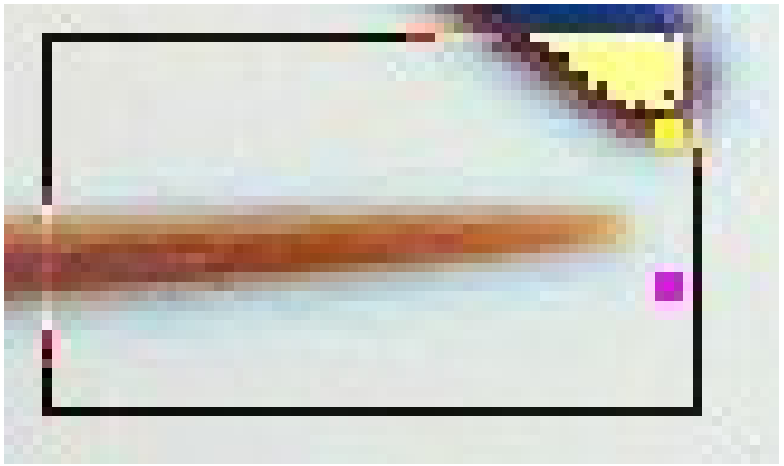
Rectification
(homography)



mouse range window

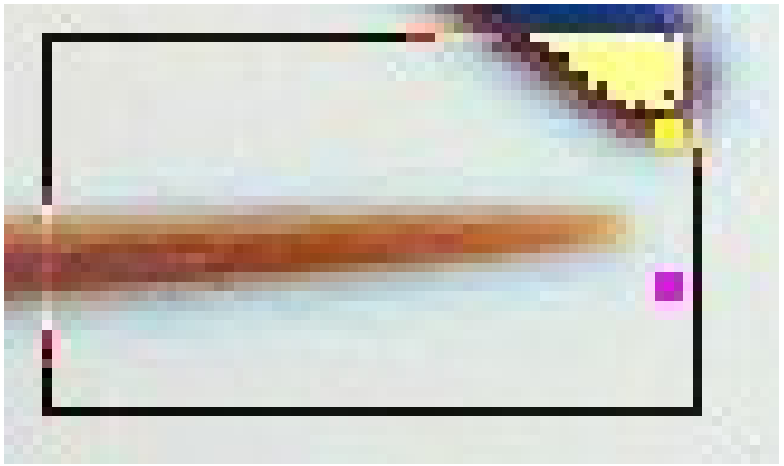
- Rounded off using hysteresis technique

Method - Conditions for Mouse Click



1. Pen and shadow must be near each other

Method - Conditions for Mouse Click



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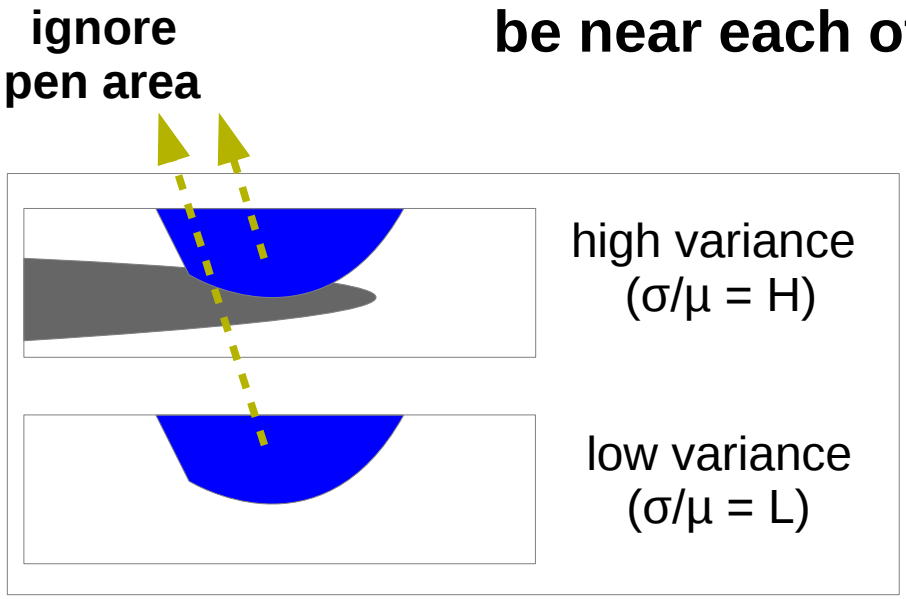
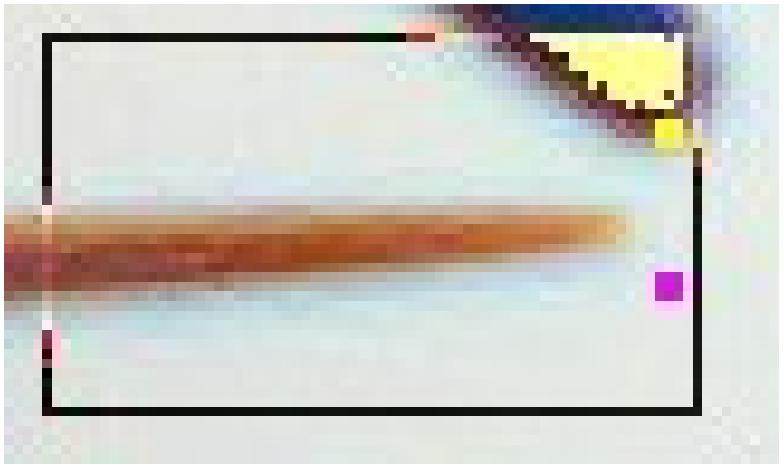


2. Variance must be high

Method - Conditions for Mouse Click



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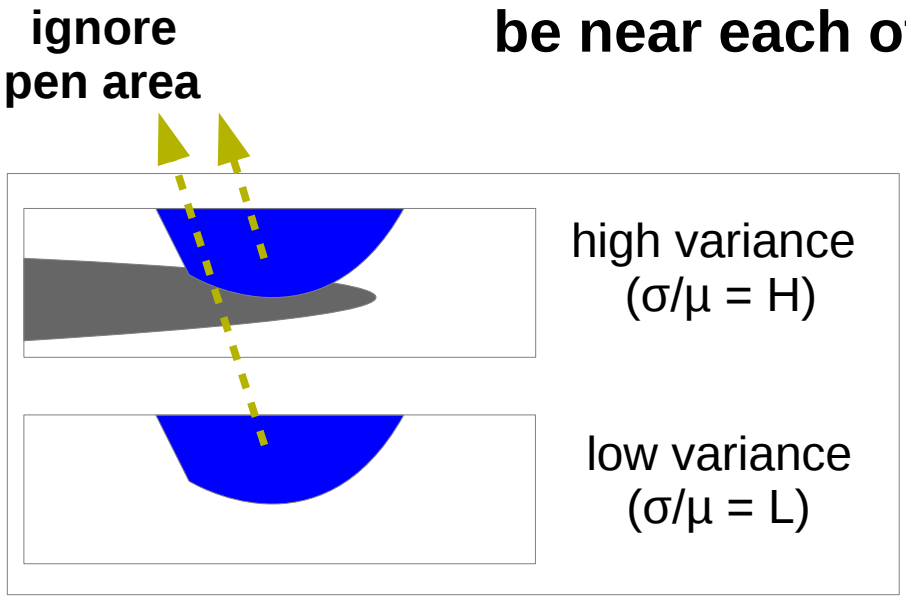

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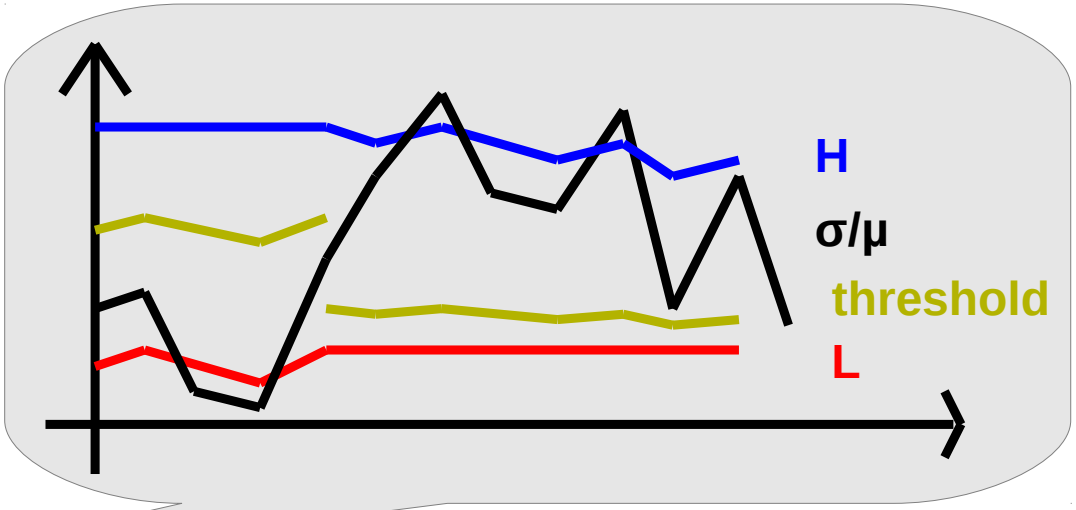
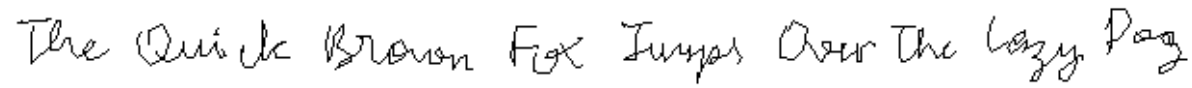
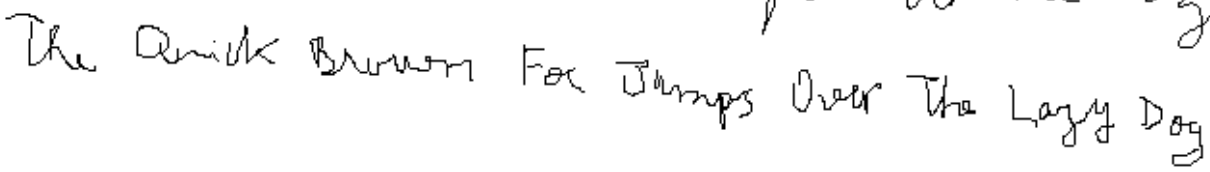
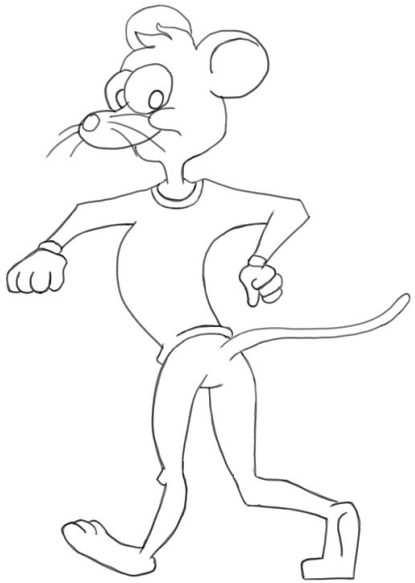


Adaptive Threshold and Hysteresis

Results: Comparisons with Graphics Tablet

Interface	Drawing Time	Output
Webcam-PaperPen	23.82s	
Graphics Tablet	22.72s	
Mouse	62.21s	

Pencil and Paper



Graphics Tablet

Our Method

Precision Detail

Graphics Tablet

Our Method

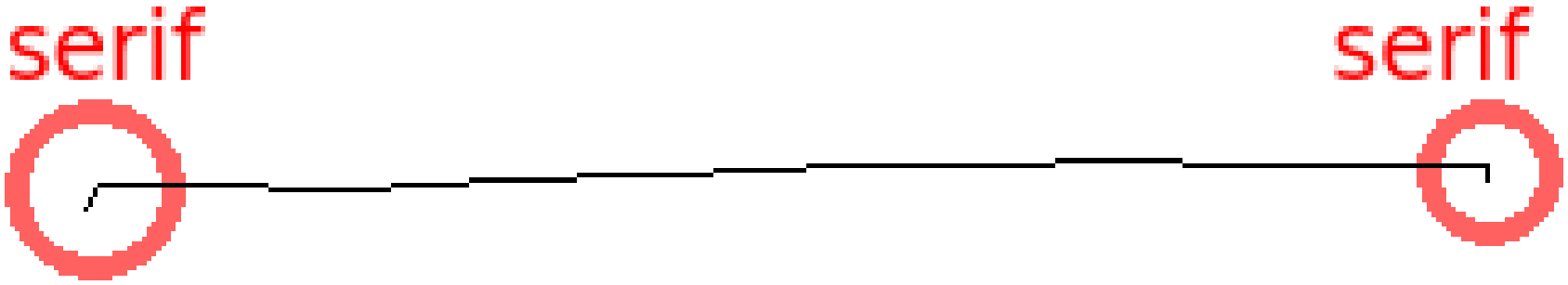
Limitations

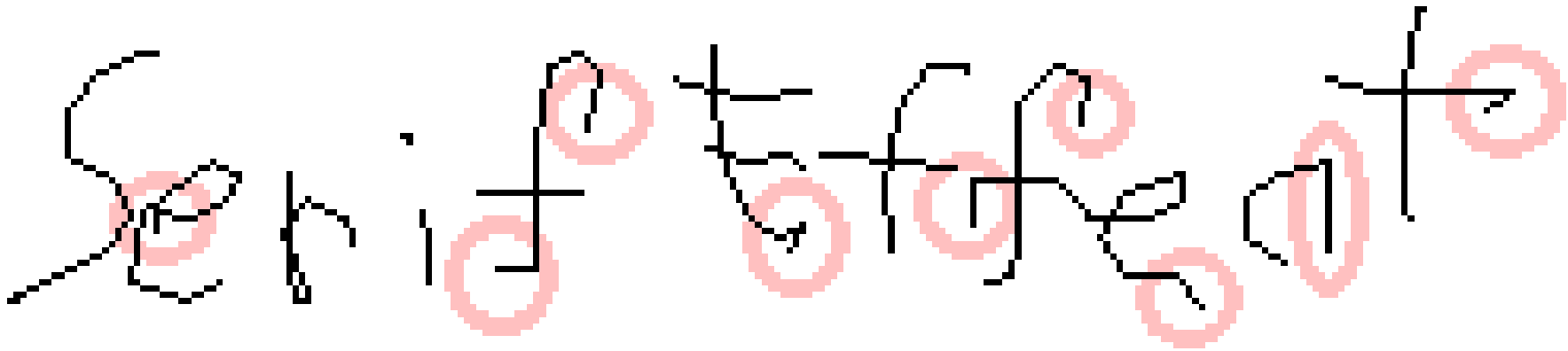
- Restrictions in illumination, webcam, way of holding the pen, etc.

Limitations

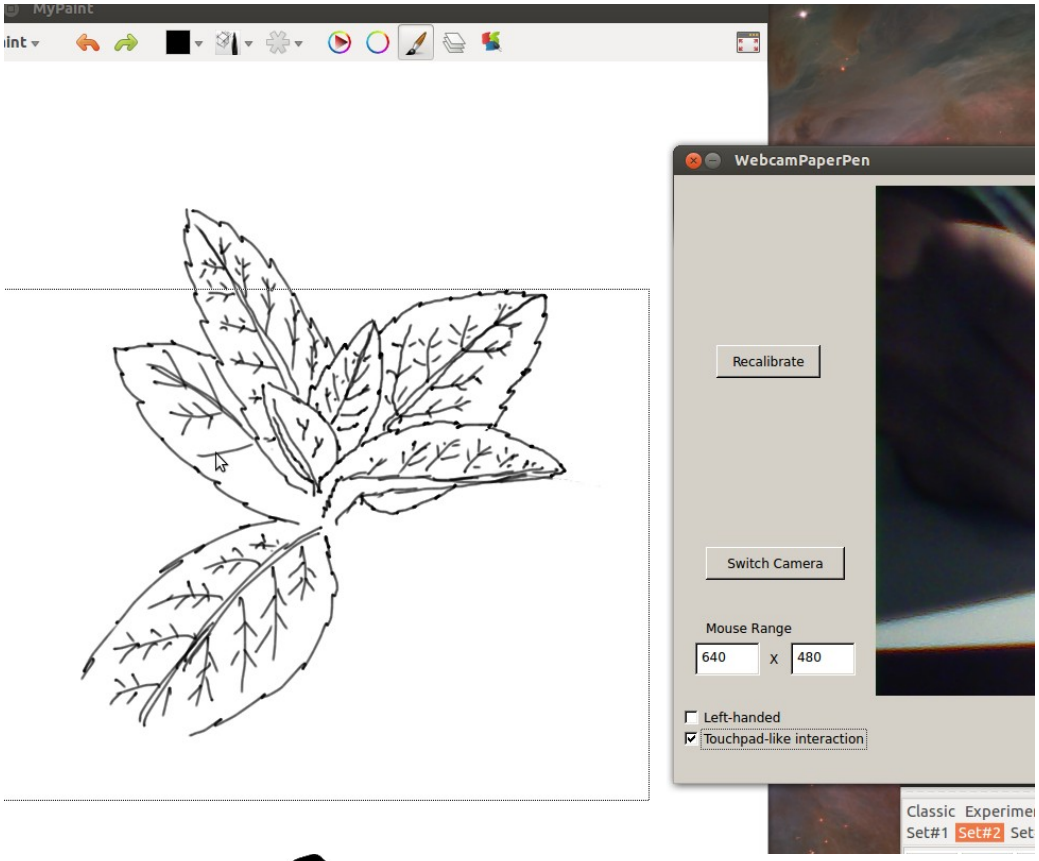
- Restrictions in illumination, webcam, way of holding the pen, etc.

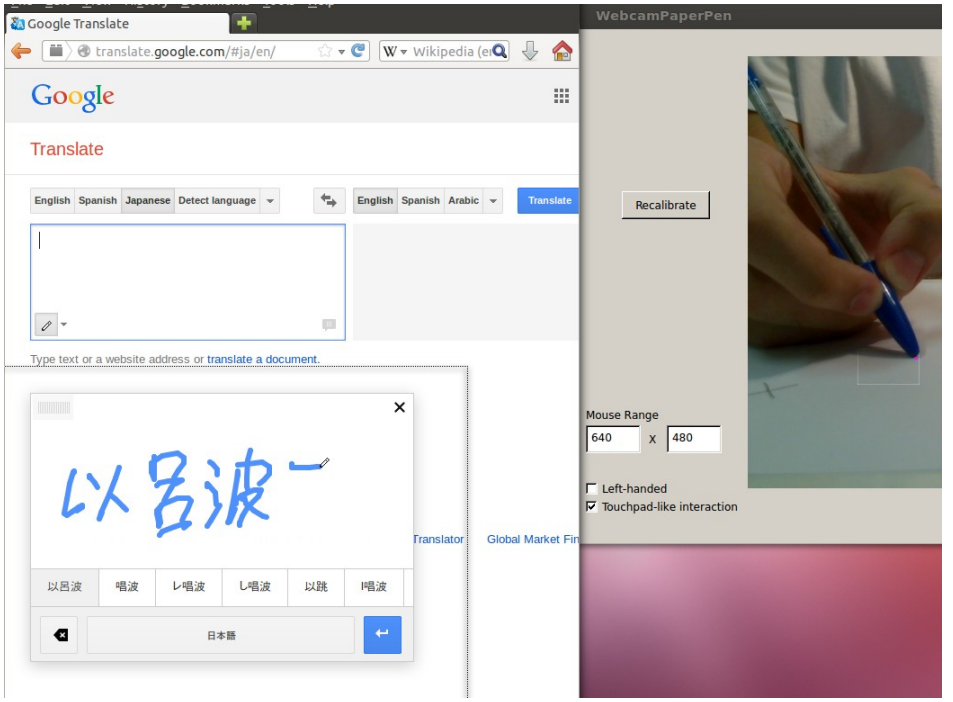
- “Serif” effect:





More Results





Supplementary Video

WebcamPaperPen:
A Low-Cost
Graphics Tablet

SIBGRAPI 2014

Conclusions

- Our system is
  - low-cost
  - practical
  - easy to set up
  - modestly precise
- Good for handwriting and simple drawings
  - But not enough for more artistic purposes

Future Work

- Increase flexibility and stability
  - Less setup restrictions
- Try something with the 3D position of the pen
  - can be easily calculated using the shadow

Thank you for your attention!

Downloads, source code, etc.:

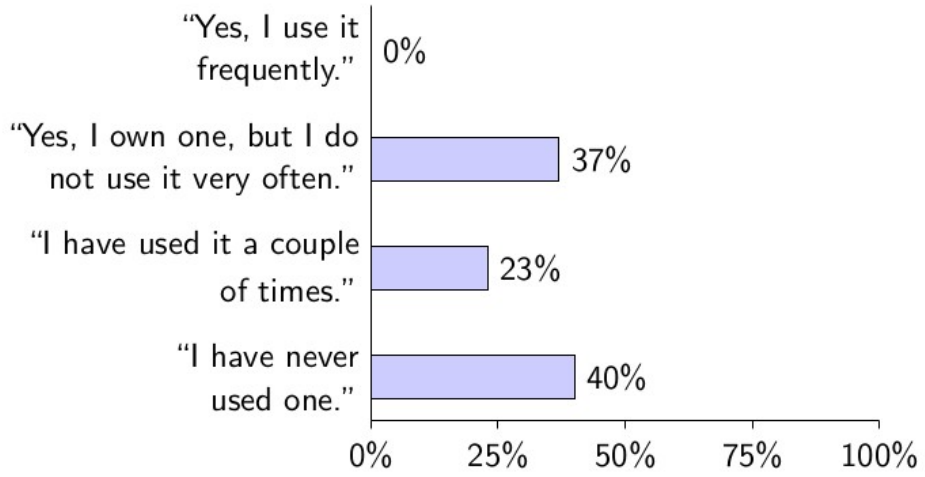
- http://www.lcg.ufrj.br/Members/gustavopfeiffer/WPP/en.html

Questions?

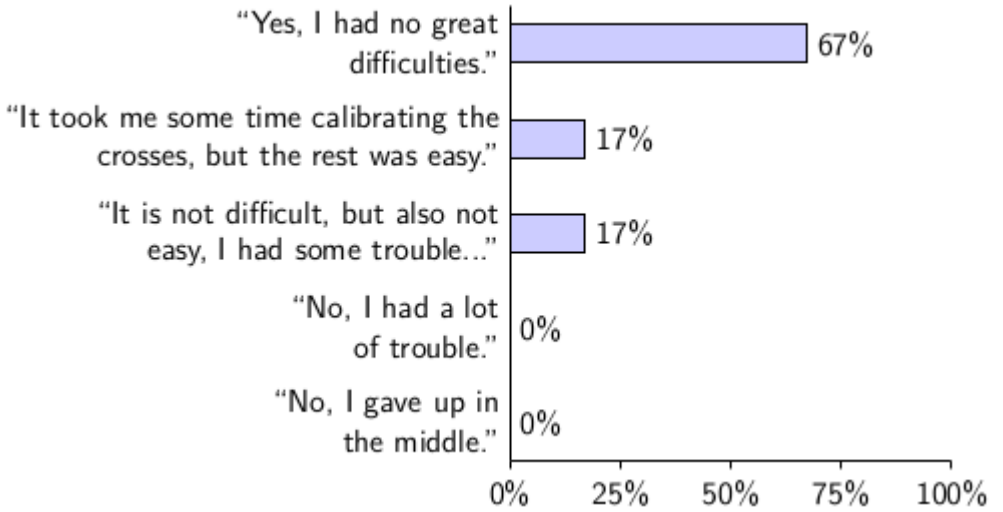
Comments?

Survey

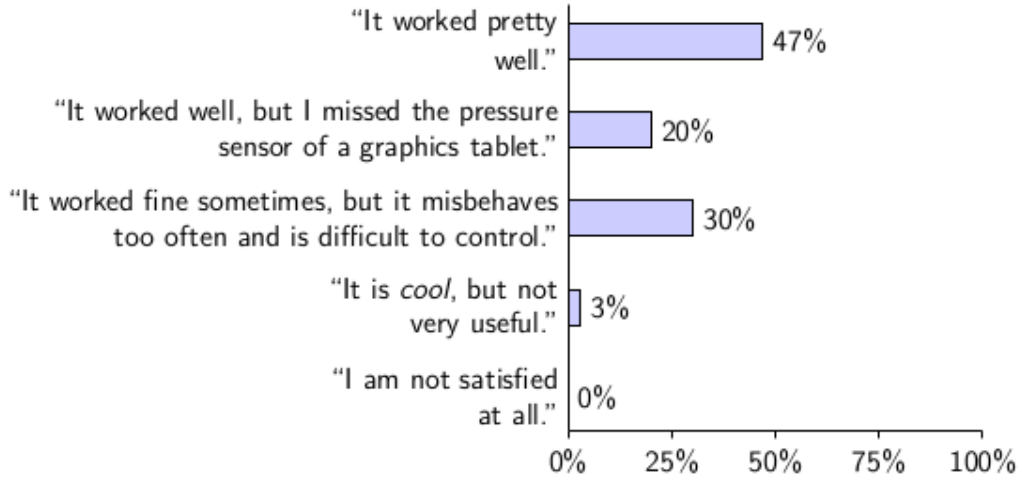
Familiarity with graphics tablets



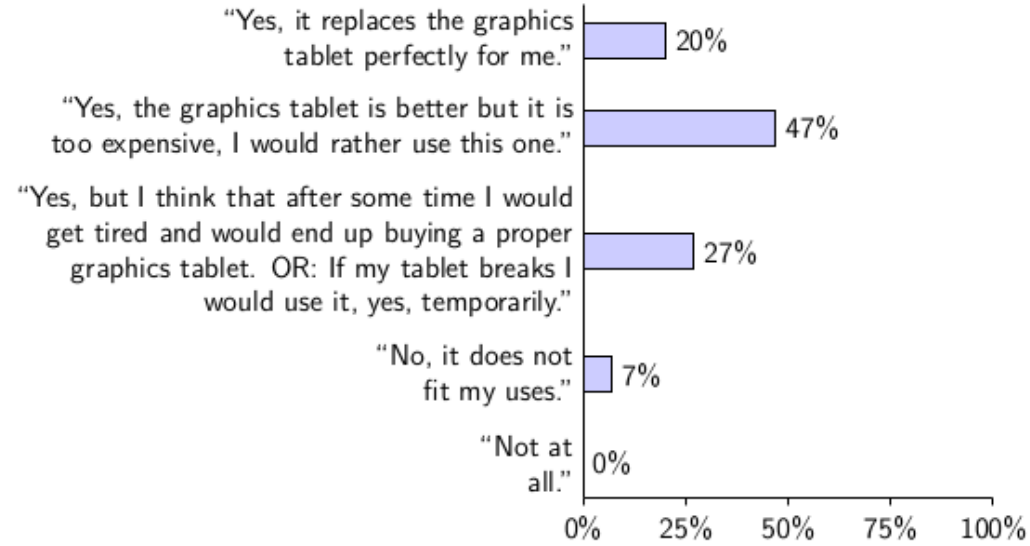
Ease of setup



Control Quality



"Would you use it?"

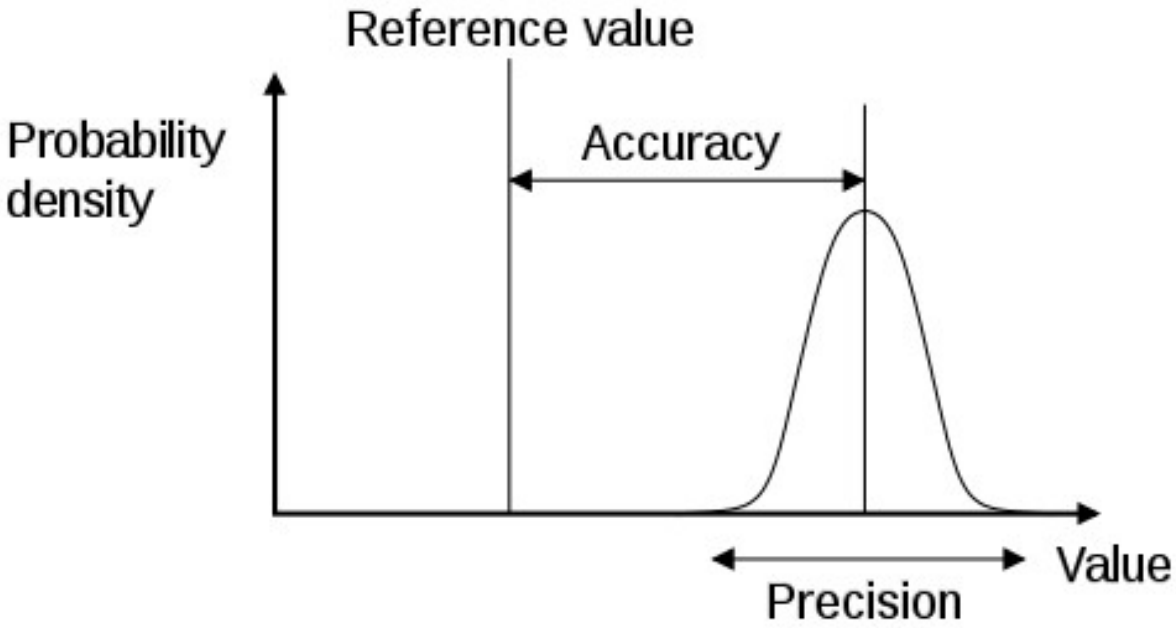


- **Most reported problems:** undesired click (47%), "serif" effect (40%)

Quantitative Precision Measurement

- Asked a user to hold the pen still in some positions and poses

- Estimated σ using |f(t) – f(t-1)|



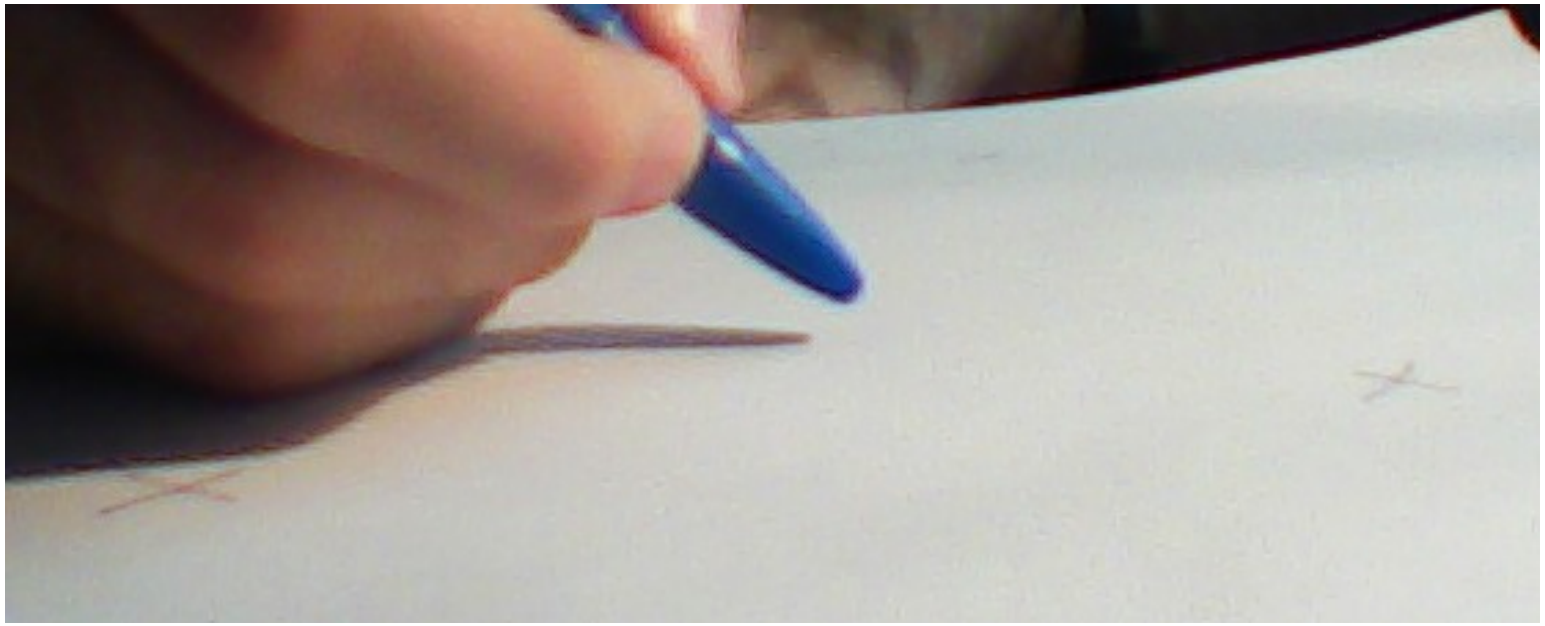
(http://en.wikipedia.org/wiki/Accuracy_and_precision)

- Discarded values above 0.5, corresponding to
  - ➔ 12.0% of the values for hor. pen tip
  - ➔ 9.8% of the values for ver. pen tip
  - ➔ 2.1% of the values for shadow tip

- Obtained
  - ➔ **σ=0.116** for hor. pen tip
  - ➔ **σ=0.103** for ver. pen tip
  - ➔ **σ=0.095** for shadow tip

Why use the cap shut?

- Easier to track
- Users won't look at the paper, but at the monitor
- More applications
  - ➔ If you can look at the paper, you need no online processing
- Less paper is consumed



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