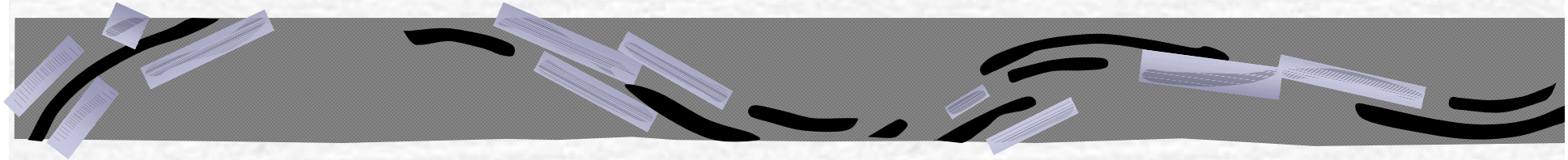
SSIP 2005, Szeged



Character Recognition Internals

Dr. István Marosi

Scansoft-Recognita, Inc., Hungary

OCR Internals

- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
  - Text recognition
  - User assisted correction
  - Result exportation

OCR Internals

- Main tasks of an OCR system:
  - Image acquisition
    - Get image
      - B/W Scanning
      - Gray Scanning
      - Color Scanning
      - Load from image file
    - Preprocess image
  - Layout recognition
  - Text recognition
  - User assisted correction
  - Result exportation

OCR Internals

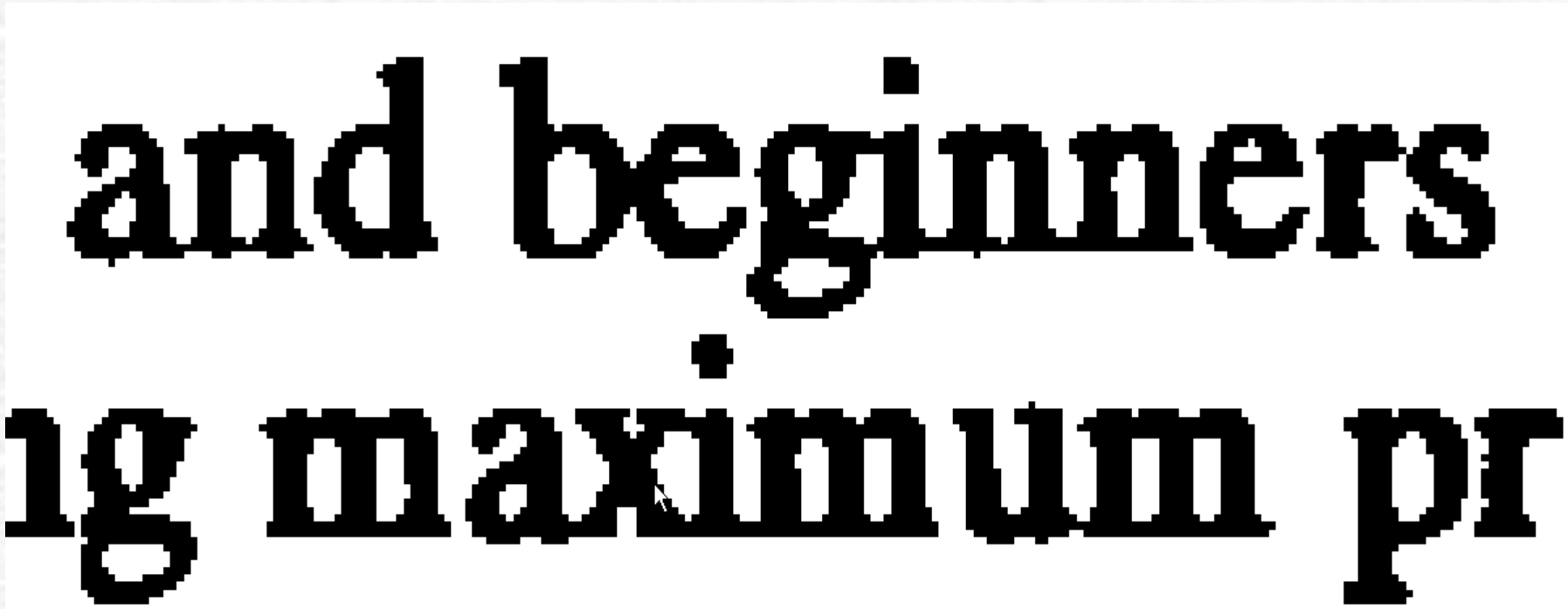
- Main tasks of an OCR system:
  - Image acquisition
    - Get image
    - Preprocess image
      - Color separation
      - Thresholding
      - Despeckling
      - Rotation
      - Deskewing
  - Layout recognition
  - Text recognition
  - User assisted correction
  - Result exportation

Color Separation

De-speckle, de-skew

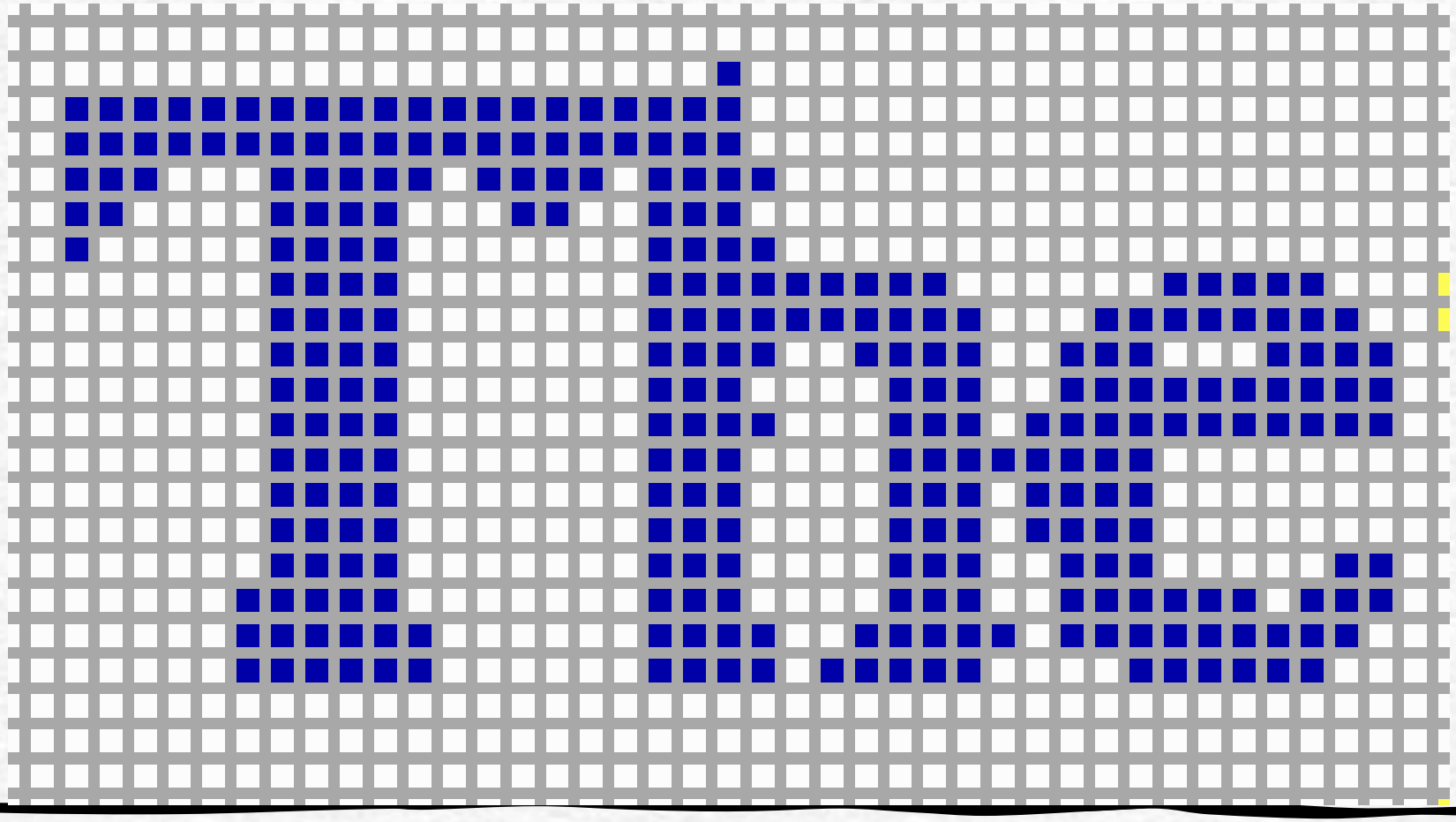
The Preprocessed Image

Joined chars



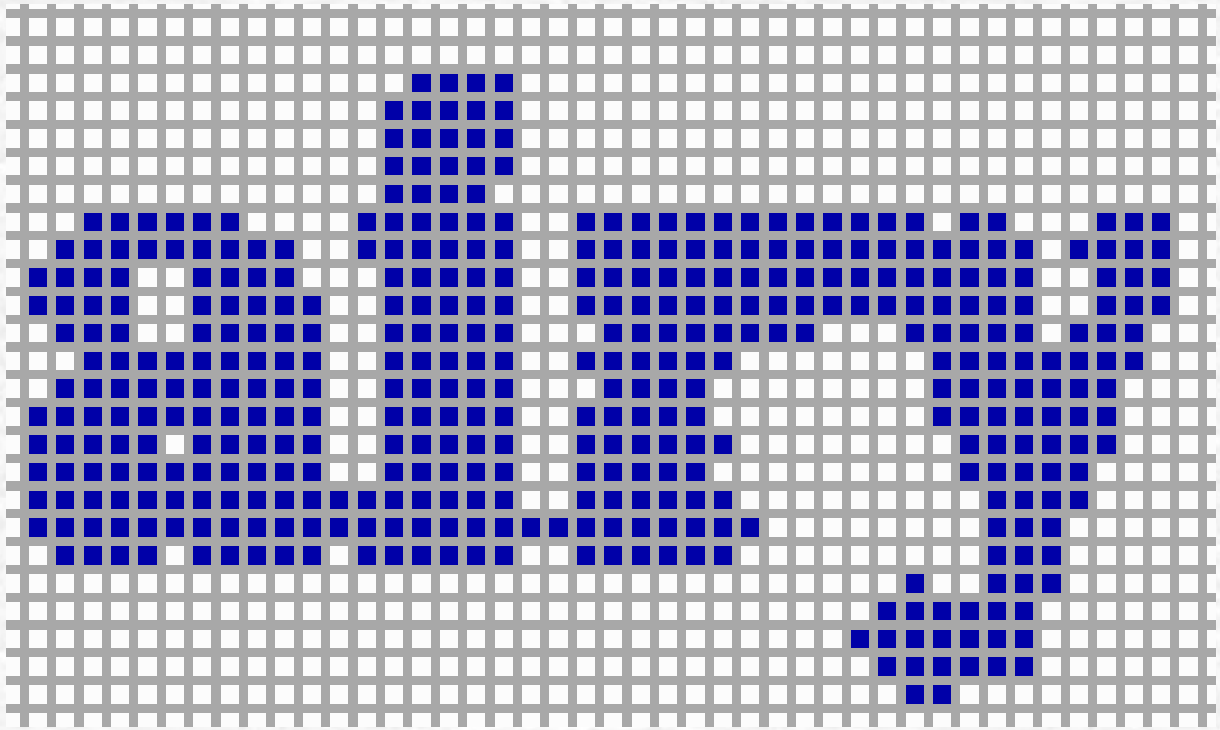
The Preprocessed Image

Joined chars



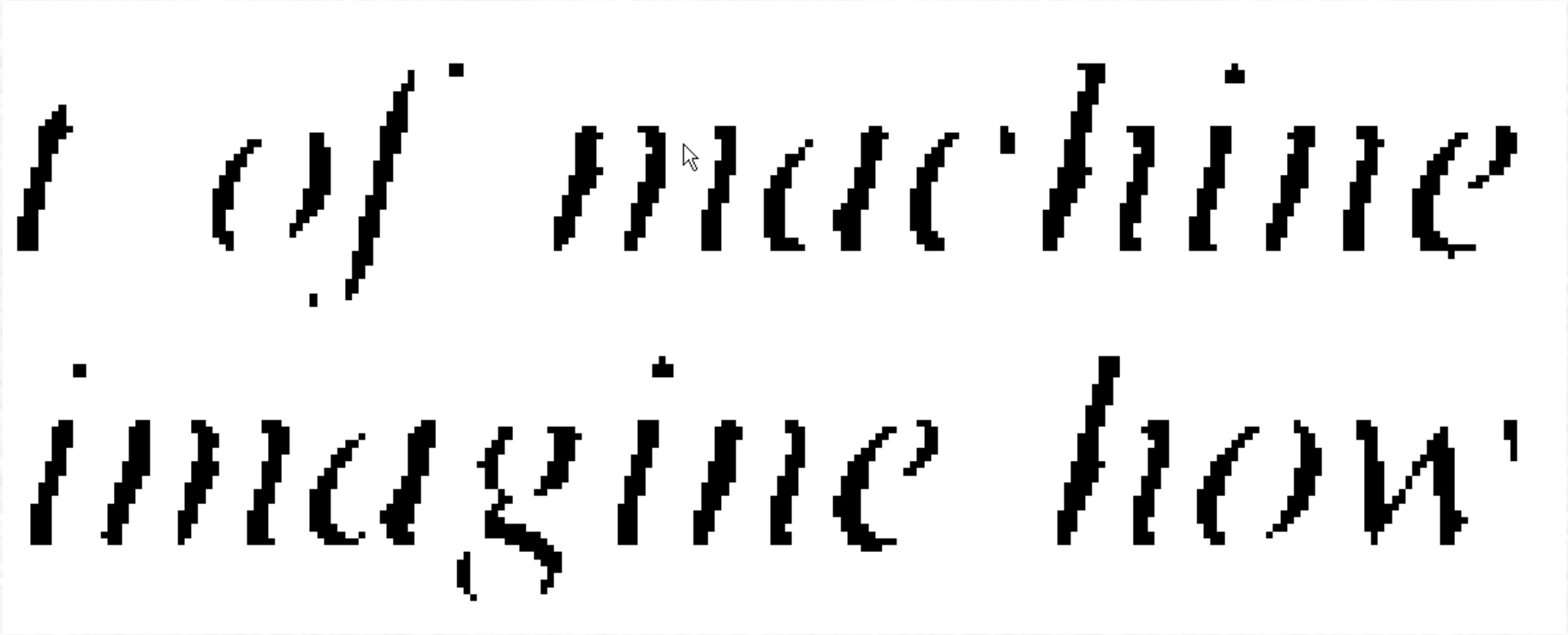
The Preprocessed Image

Joined chars



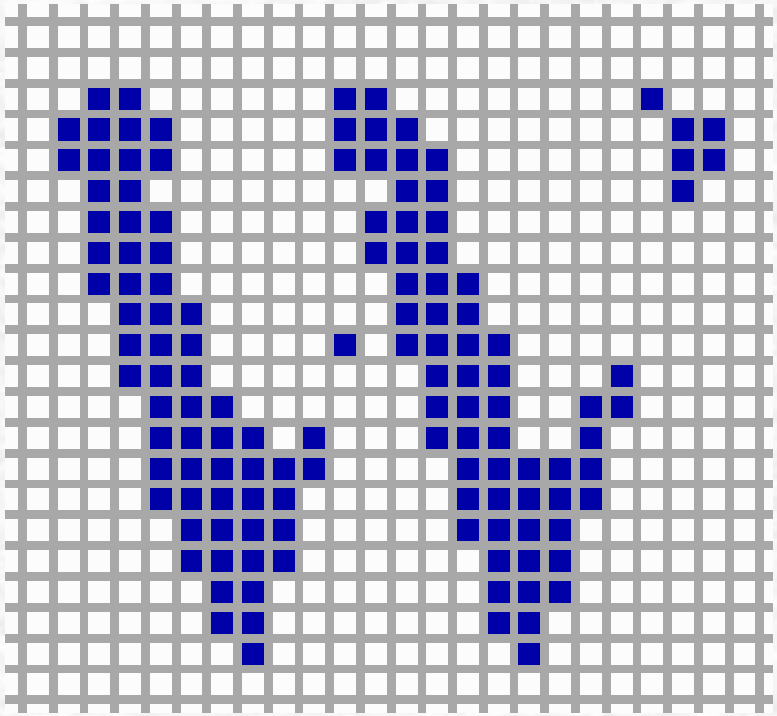
The Preprocessed Image

Broken chars



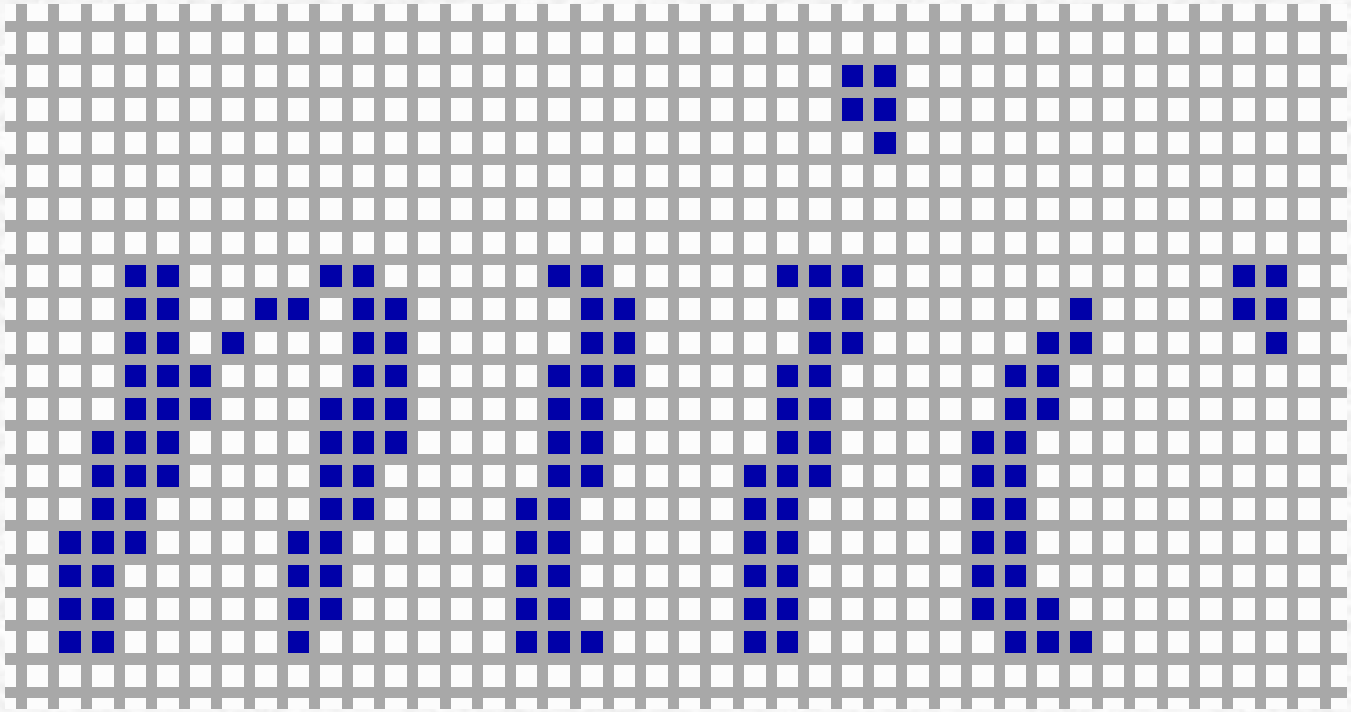
The Preprocessed Image

Broken chars



The Preprocessed Image

Broken chars

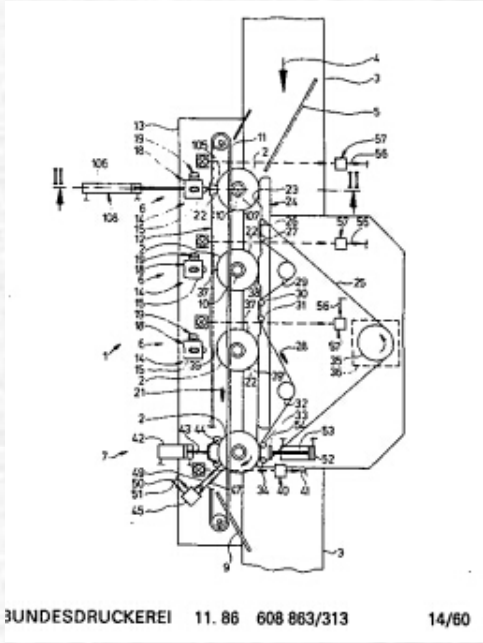


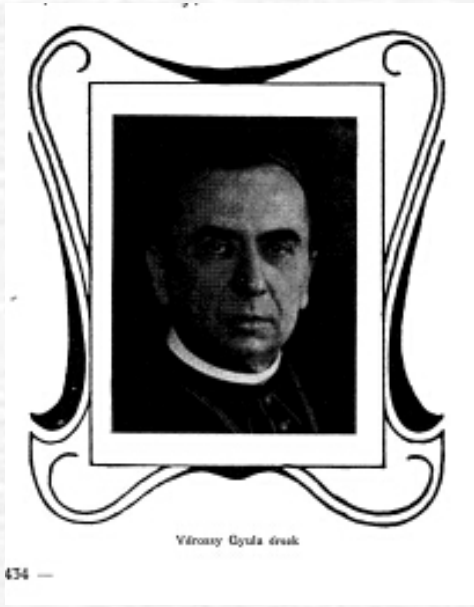
OCR Internals

- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
    - Text zones
      - Columns of flowed text
      - Tables
      - Inverse text
    - Graphic zones
  - Text recognition
  - User assisted correction
  - Result exportation

OCR Internals

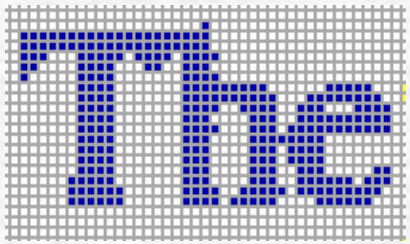
- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
    - Text zones
    - Graphic zones
      - Line Art
      - Photo
  - Text recognition
  - User assisted correction
  - Result exportation

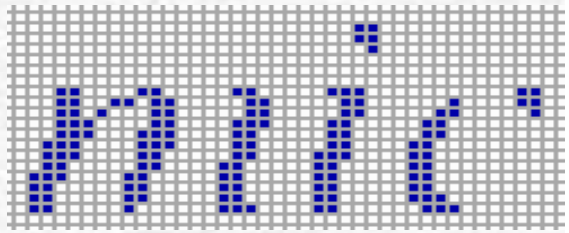




OCR Internals

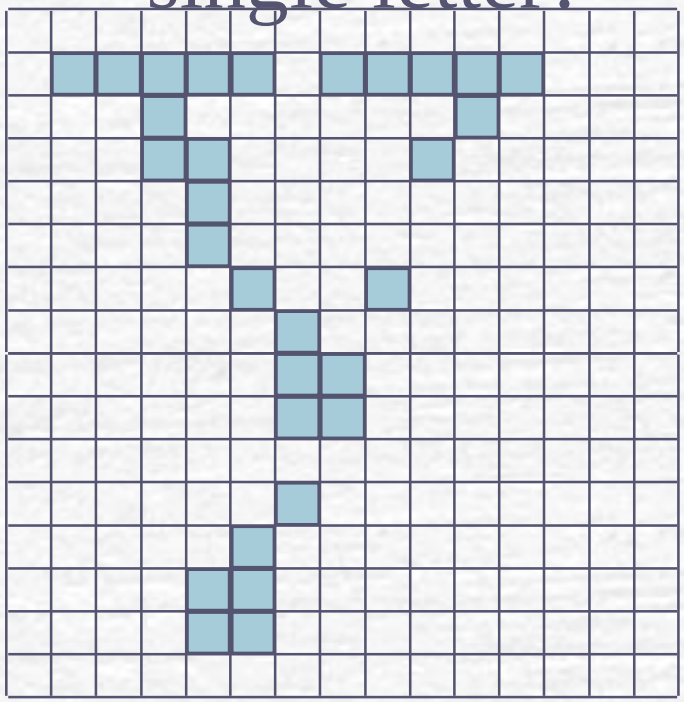
- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
  - Text recognition
    - *Segmentation*
    - *Calculation of Feature Vector Elements*
    - *Classification*
    - *Language Analysis*
    - *Voting*
  - User assisted correction
  - Result exportation





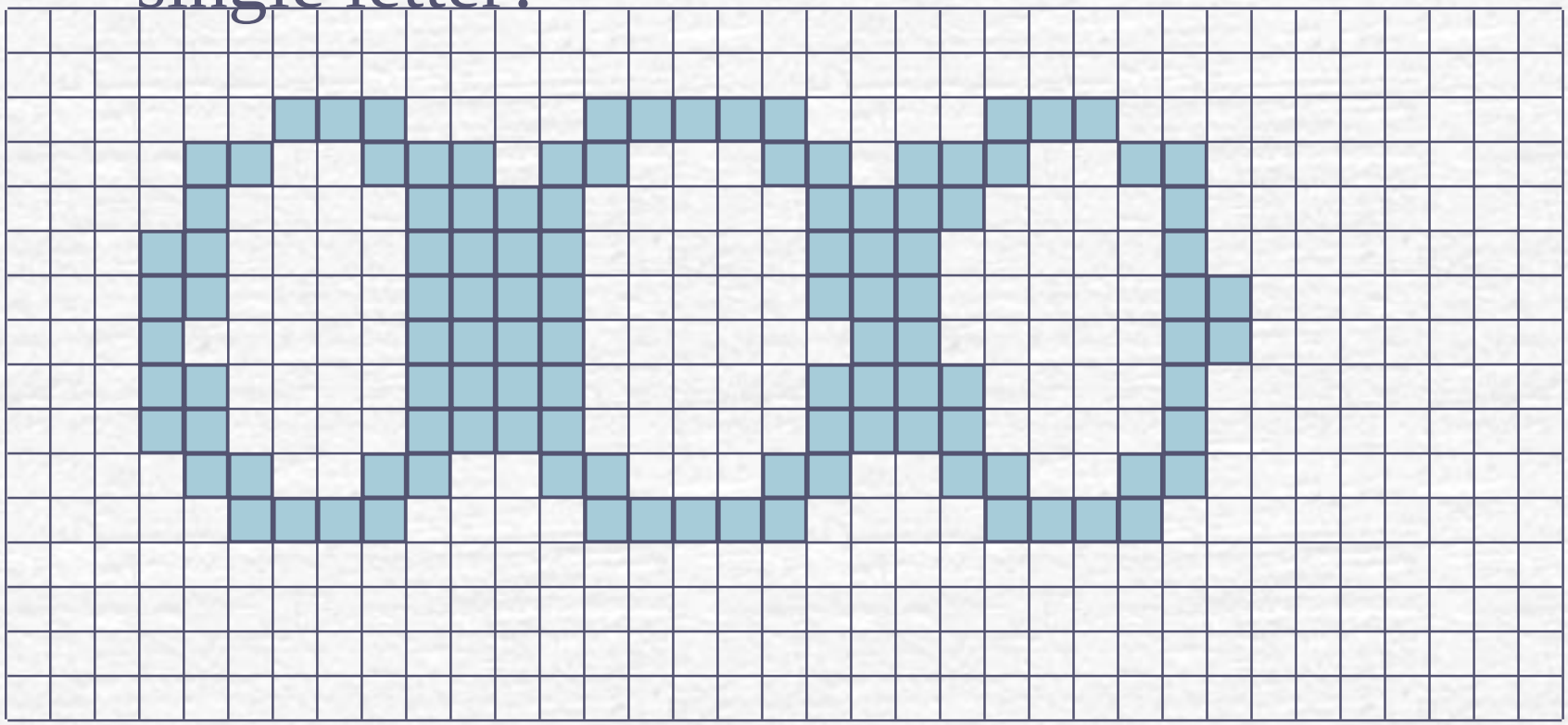
Segmentation

- What are those pixel groups belonging to a single letter?



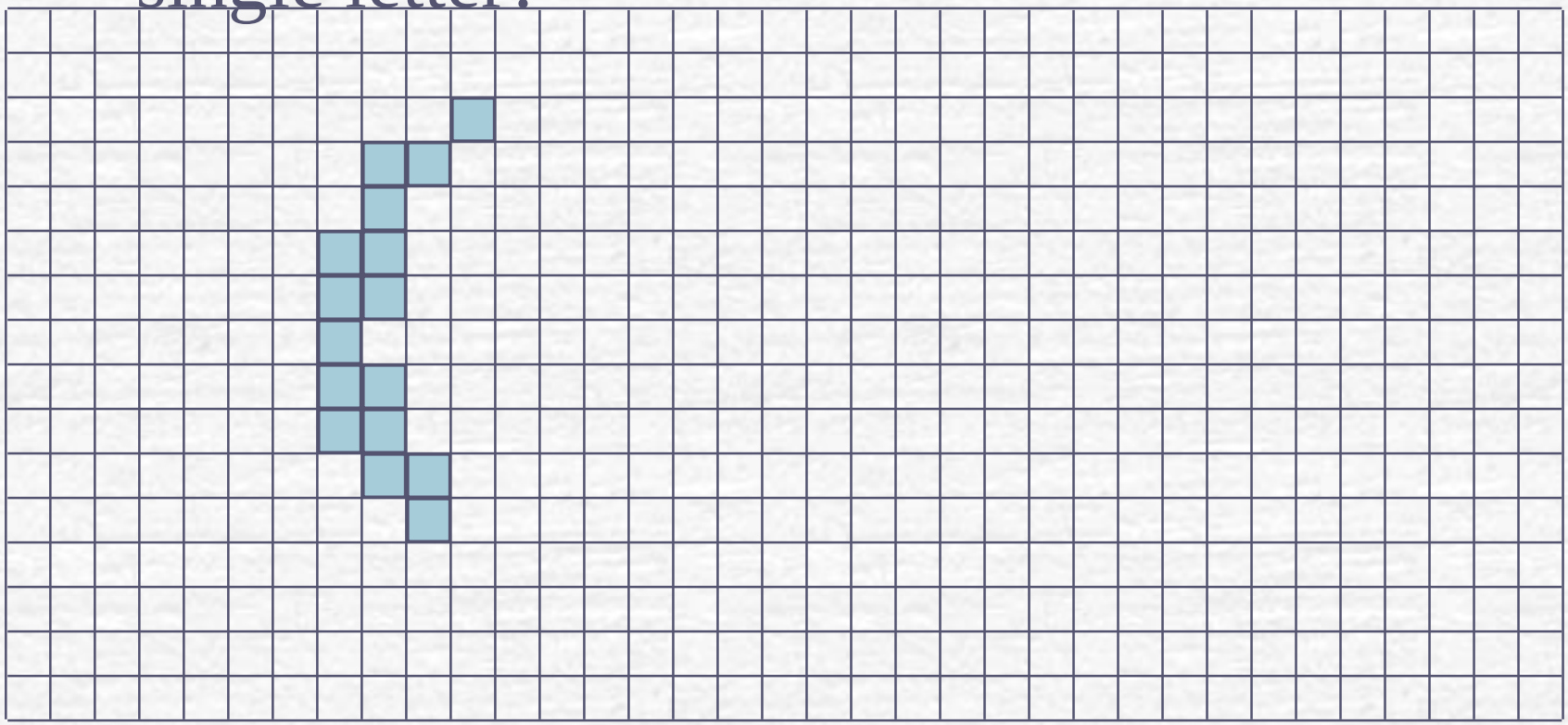
Segmentation

- What are those pixel groups belonging to a single letter?



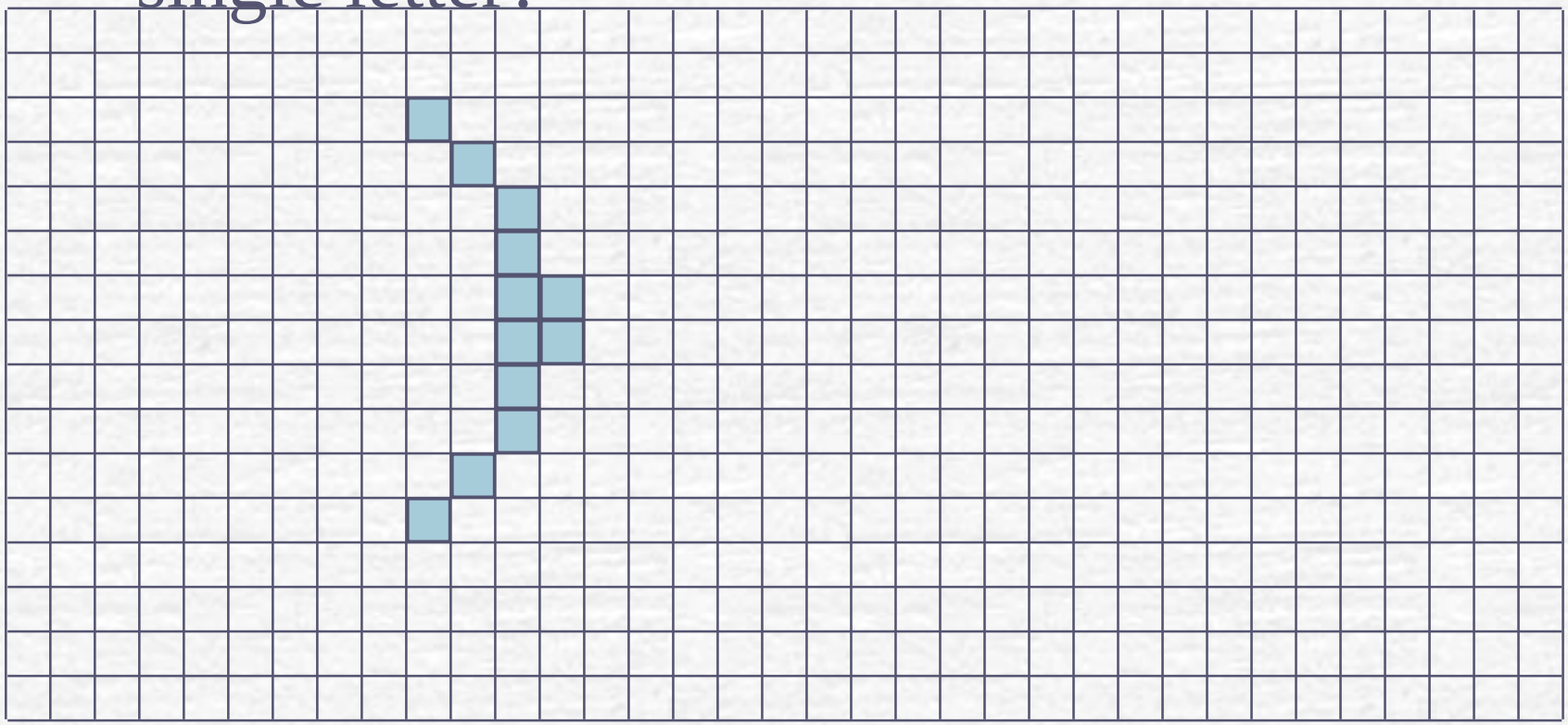
Segmentation

- What are those pixel groups belonging to a single letter?



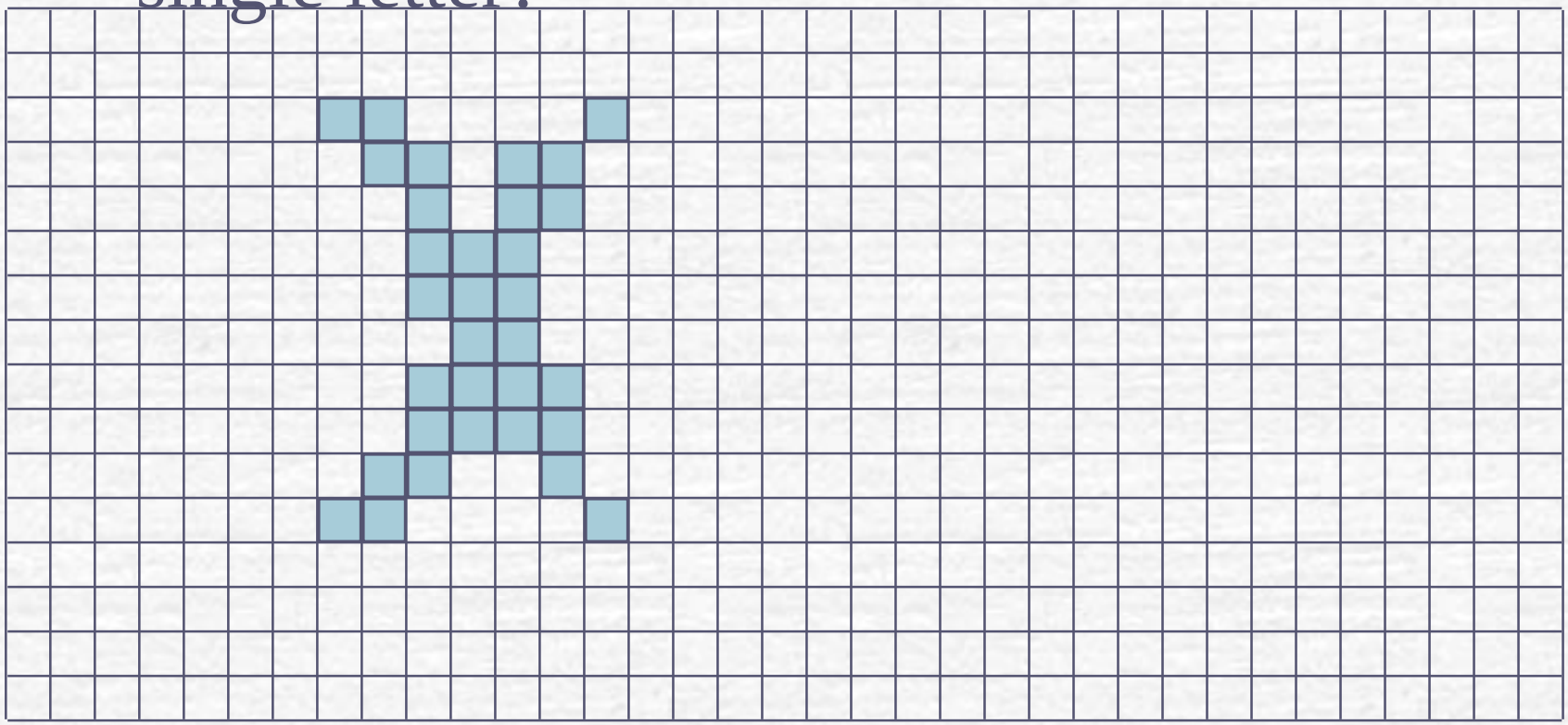
Segmentation

- What are those pixel groups belonging to a single letter?



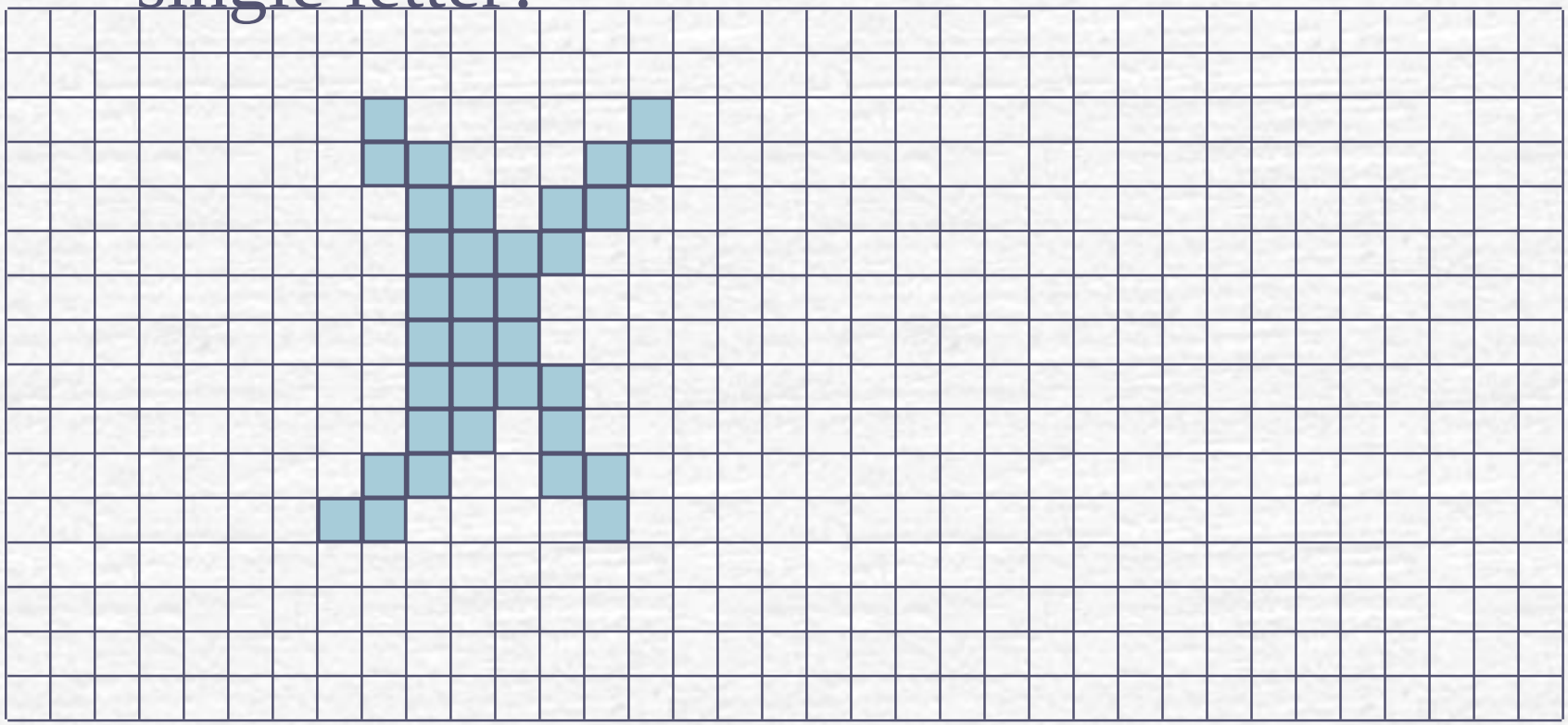
Segmentation

- What are those pixel groups belonging to a single letter?



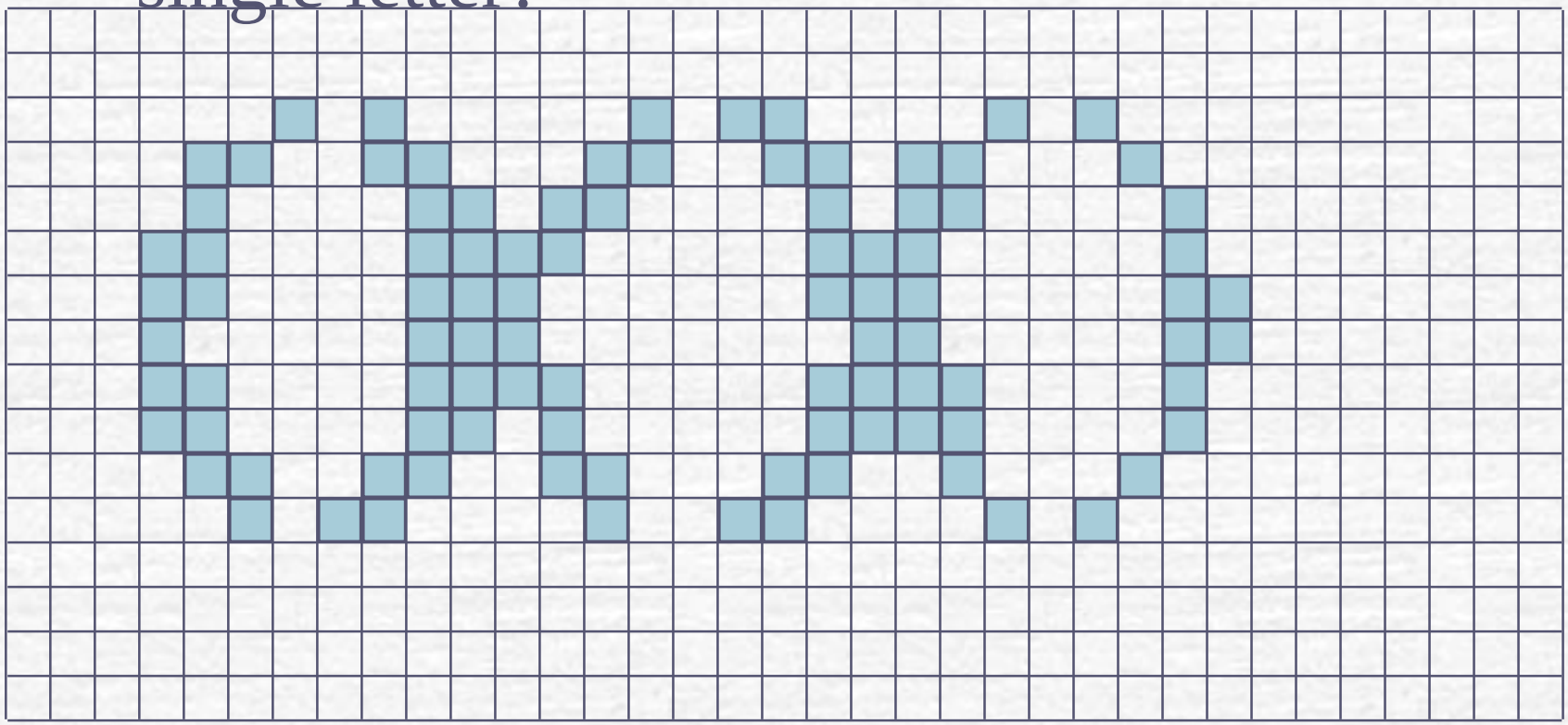
Segmentation

- What are those pixel groups belonging to a single letter?



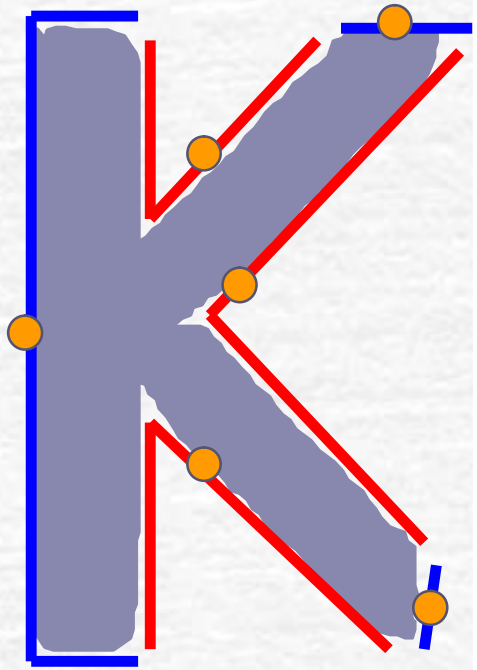
Segmentation

- What are those pixel groups belonging to a single letter?



OCR Internals

- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
  - Text recognition
    - *Segmentation*
    - *Calculation of Feature Vector Elements*
    - *Classification*
    - *Language Analysis*
    - *Voting*
  - User assisted correction
  - Result exportation

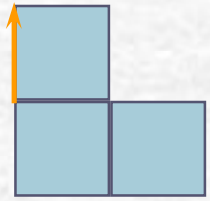


Calculation of FV Elements: Contour Tracing

- Find a (new) white-black transition
- Follow the “edge” of the pixels using the MIN or MAX rule
- Administrate the already traced white-black transitions
- Collect information while going around
- And repeat the process on new shapes ...

Contour Tracing

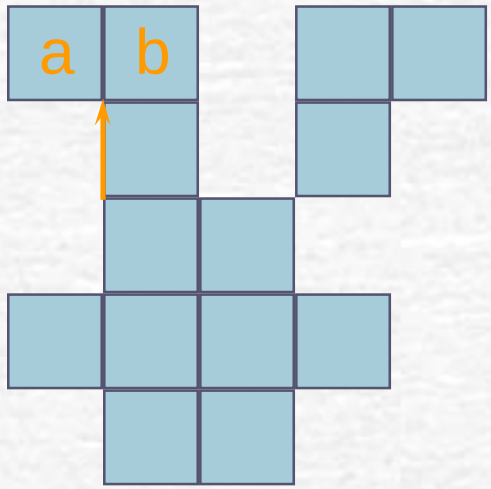
- Find a (new) white-black transition



- Follow the “edge” of the pixels using the MIN or MAX rule
- Administrate the already traced white-black transitions
- Collect information while going around
- And repeat the process on new shapes ...

Contour Tracing

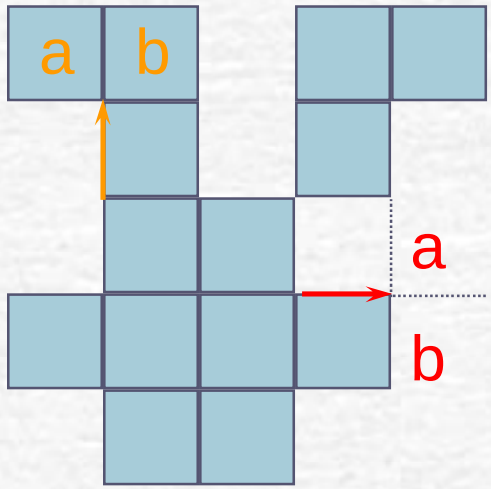
- Find a (new) white-black transition
- Follow the “edge” of the pixels using the MIN or MAX rule



if black(a) then turn(ccw)
else if black(b) then forward
else turn(cw)

Contour Tracing

- Find a (new) white-black transition
- Follow the “edge” of the pixels using the MIN or MAX rule



if black(a) then turn(ccw)
else if black(b) then forward
else turn(cw)

if white(b) then turn(cw)
else if white(a) then forward
else turn(ccw)

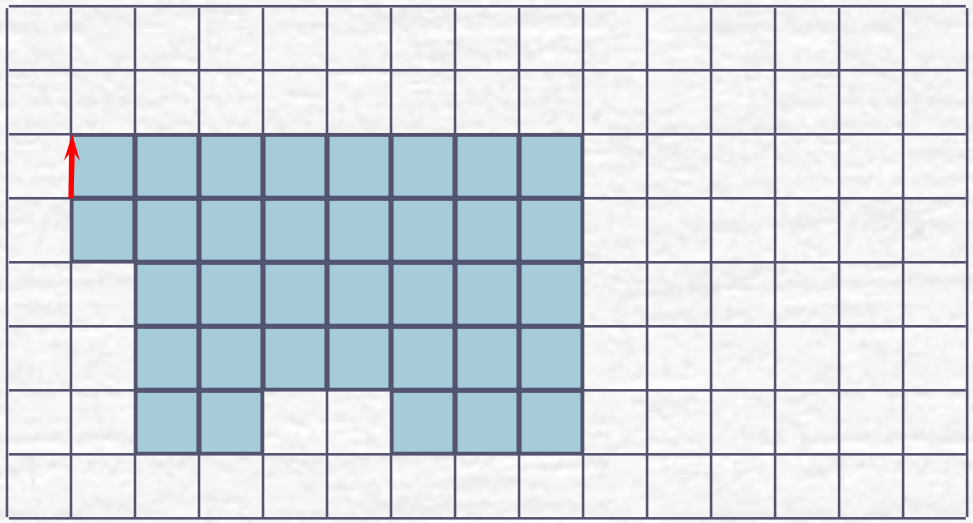
Contour Tracing

- Find a (new) white-black transition
- Follow the “edge” of the pixels using the MIN or MAX rule
- Administrate the already traced white-black transitions

- Collect information while going around
- And repeat the process on new shapes ...

Some Easily Calculatable Data

- Problem #1



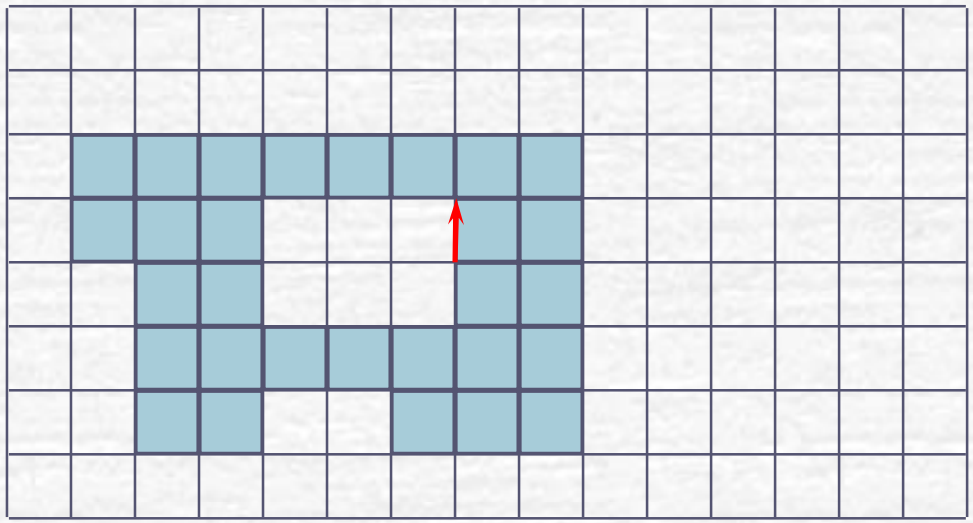
Turning CW: $I_n=I_{n-1}+1$

Turning CCW: $I_n=I_{n-1}-1$

Going Forward: $I_n=I_{n-1}$

Some Easily Calculatable Data

- Problem #2



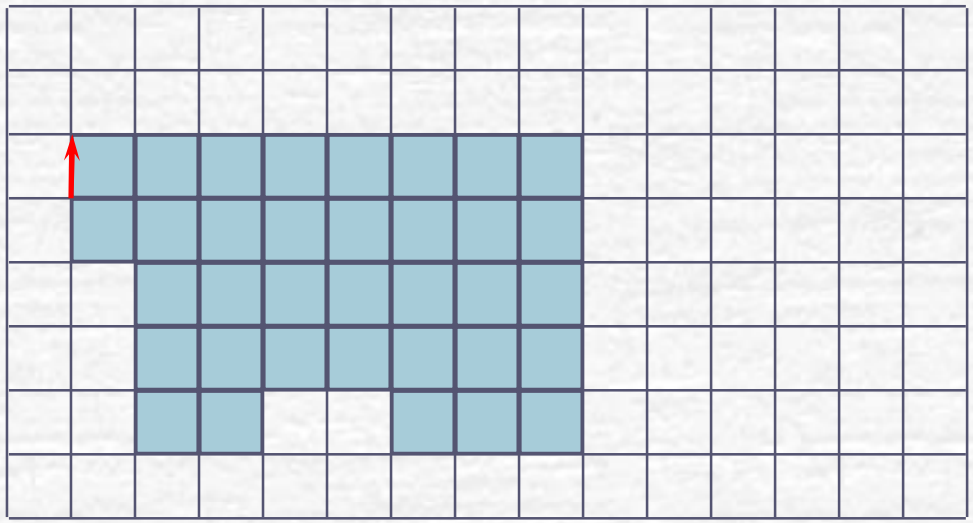
Turning CW: $I_n=I_{n-1}+1$

Turning CCW: $I_n=I_{n-1}-1$

Going Forward: $I_n=I_{n-1}$

Some Easily Calculatable Data

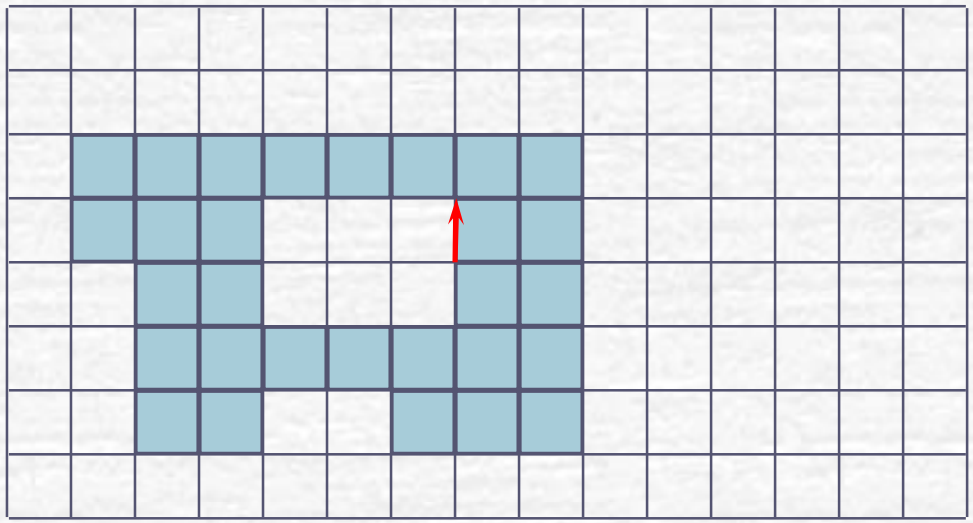
- Problem #3



Going Up: $I_n=I_{n-1}-X_n$
Going Down: $I_n=I_{n-1}+X_n$
Going Right: $I_n=I_{n-1}$
Going Left: $I_n=I_{n-1}$

Some Easily Calculatable Data

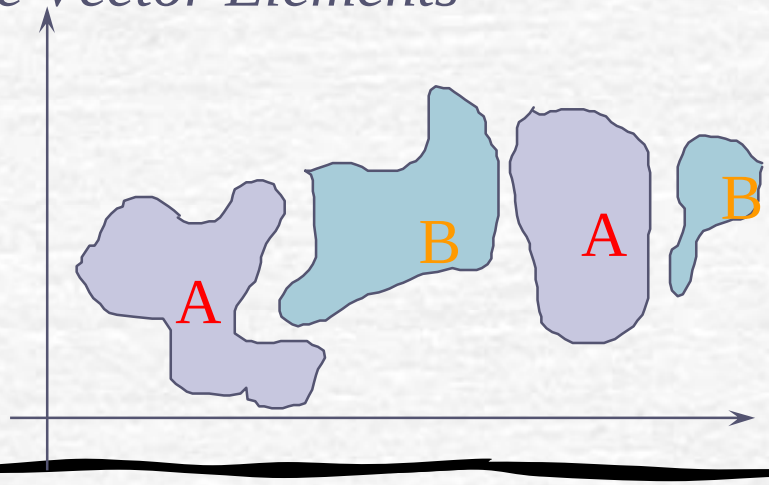
- Problem #4



Going Up: $I_n=I_{n-1}-X_n$
Going Down: $I_n=I_{n-1}+X_n$
Going Right: $I_n=I_{n-1}$
Going Left: $I_n=I_{n-1}$

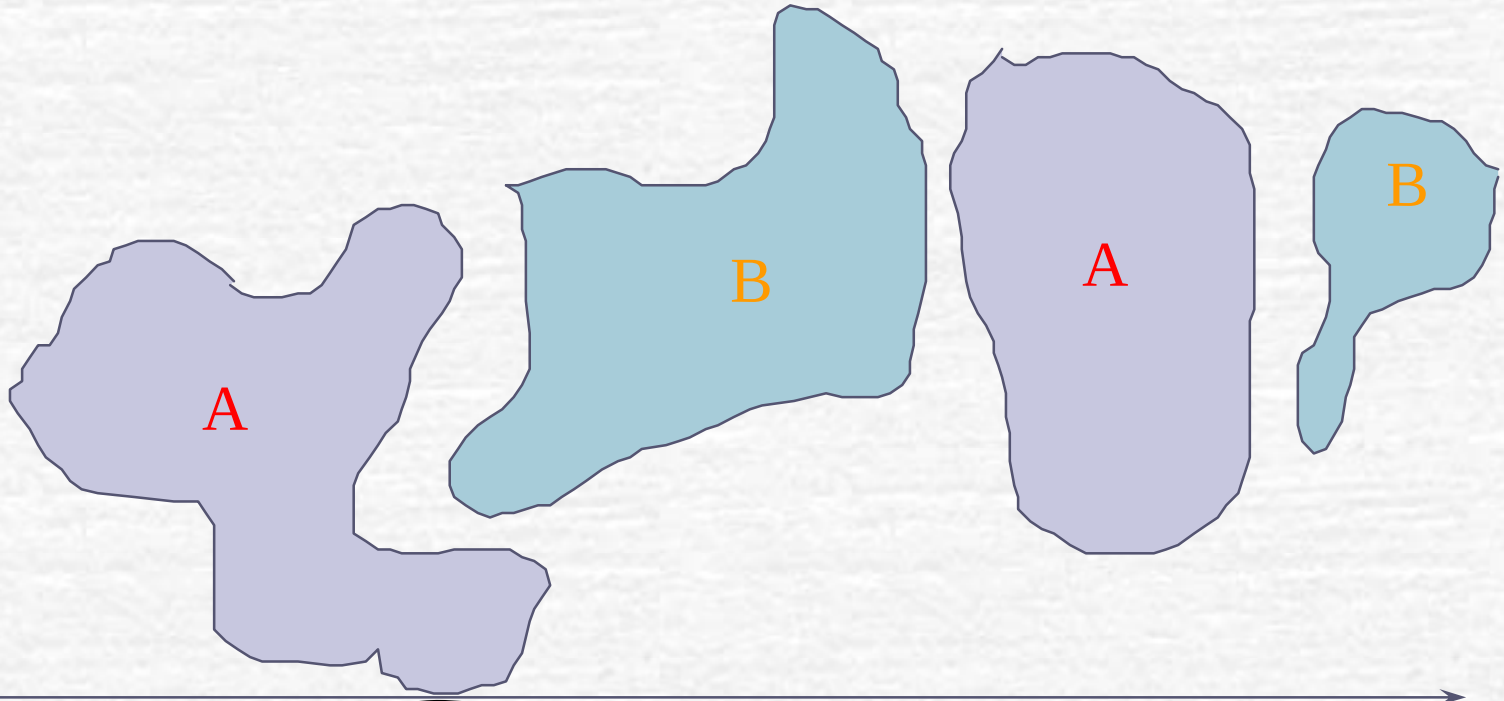
OCR Internals

- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
  - Text recognition
    - *Segmentation*
    - *Calculation of Feature Vector Elements*
    - *Classification*
    - *Language Analysis*
    - *Voting*
  - User assisted correction
  - Result exportation



Classification; Training models

- Restricted Coulomb Energy (RCE) Network (Dr. Leon Cooper, Dr. Charles Elbaum)



Classification; Training models

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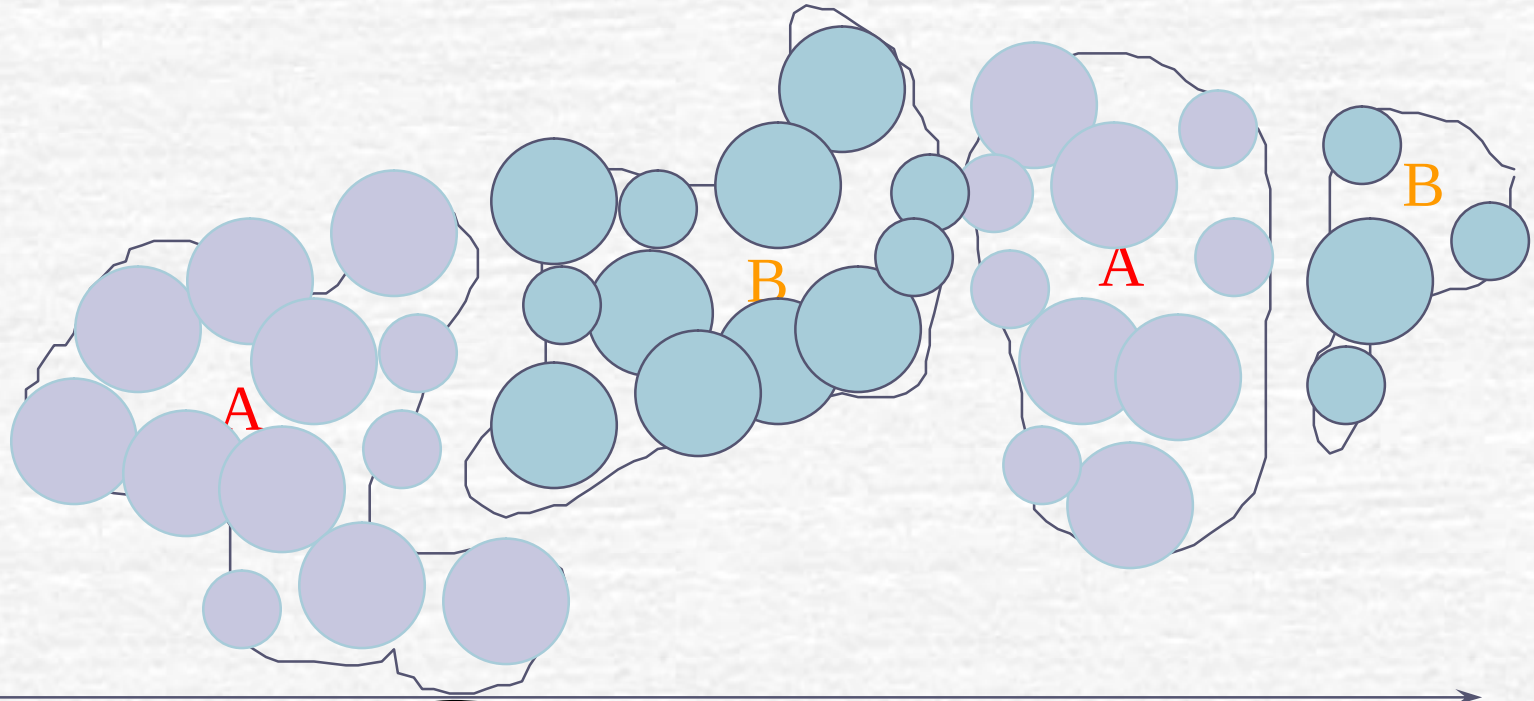
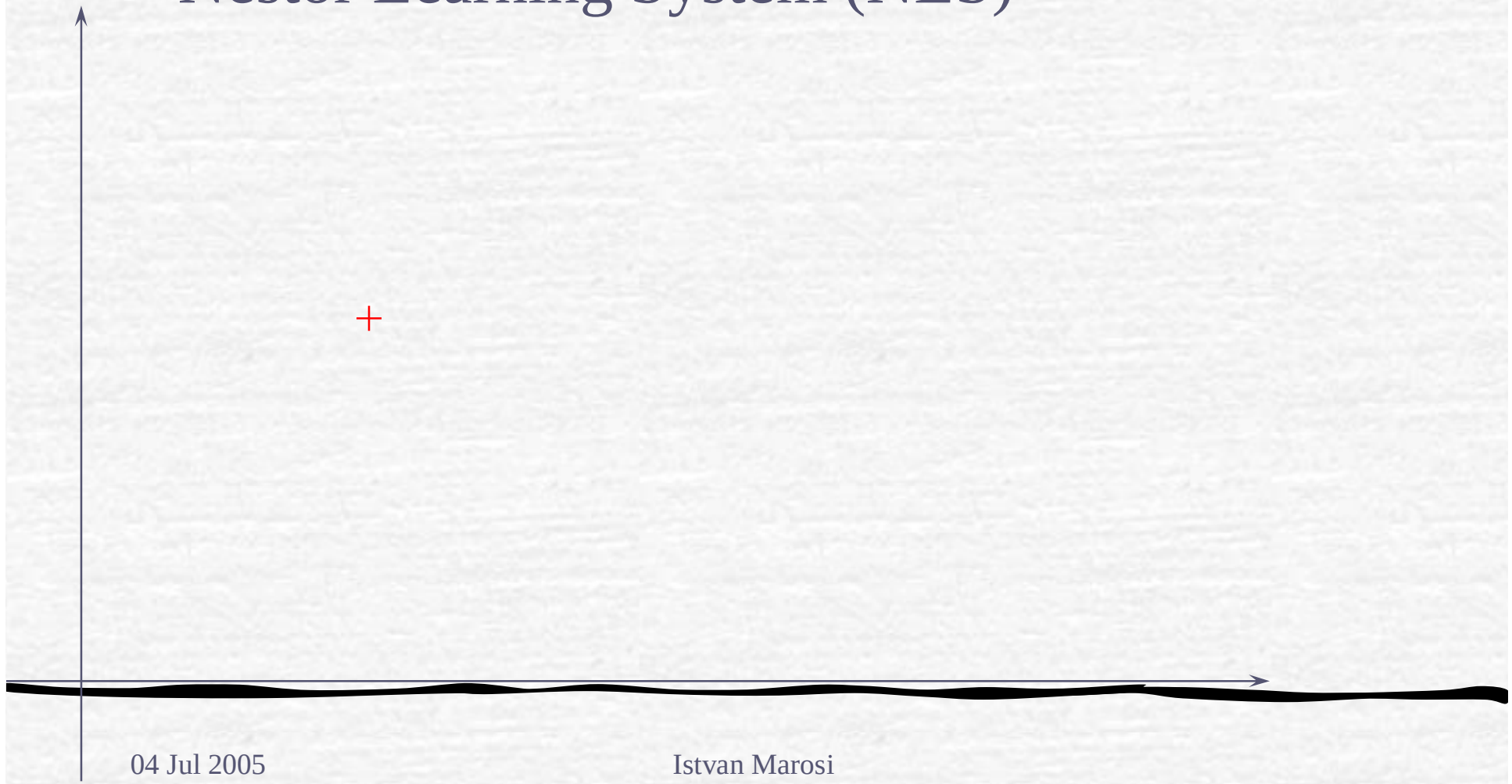


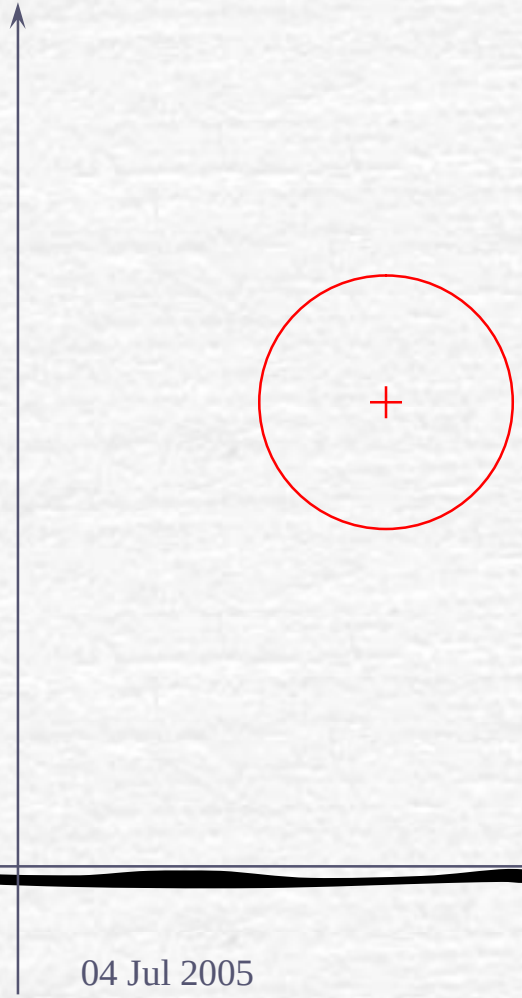
Classification; Training models

- Nestor Learning System (NLS)



Classification; Training models

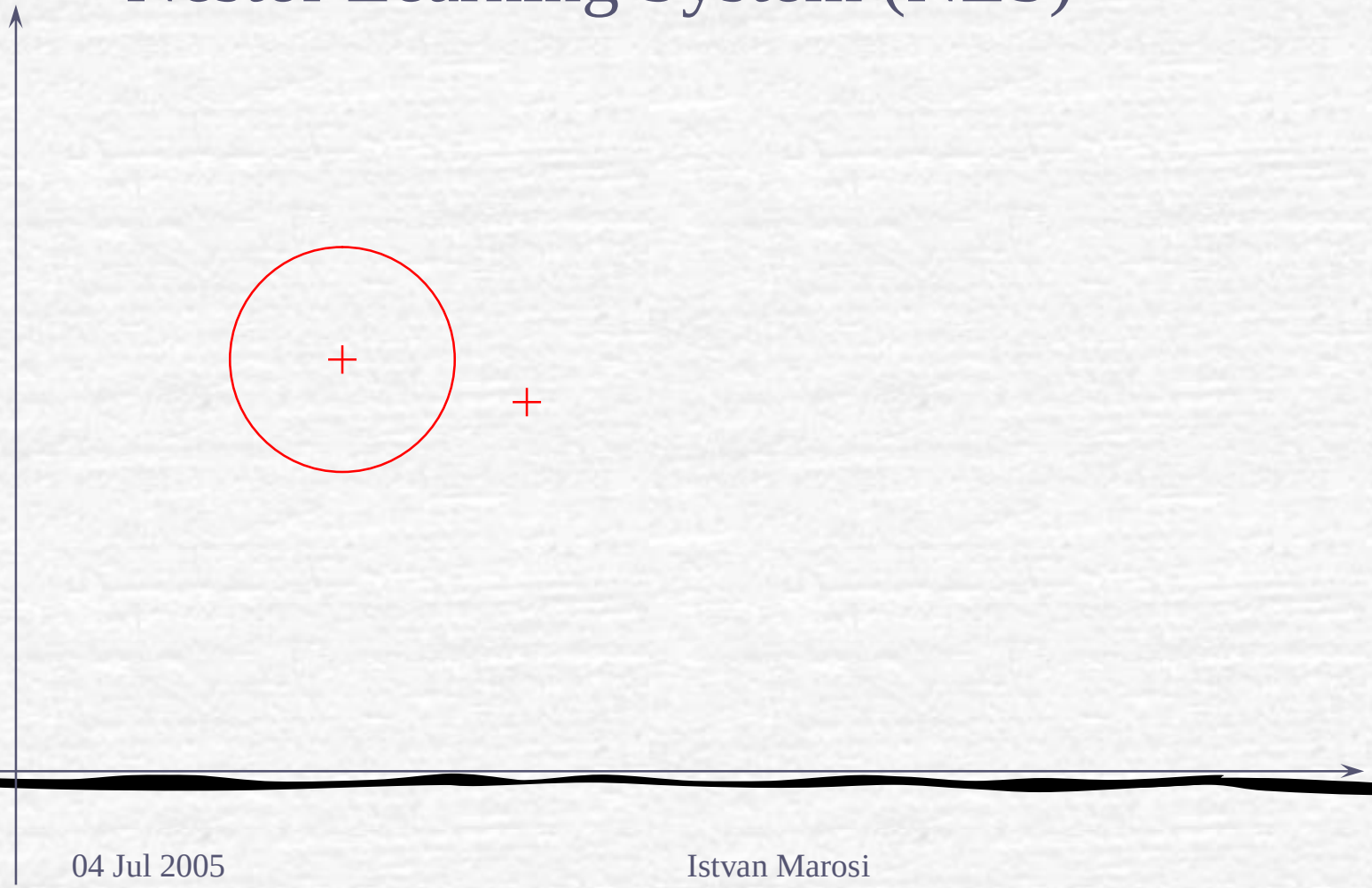
- Nestor Learning System (NLS)



Default radius R_{max}

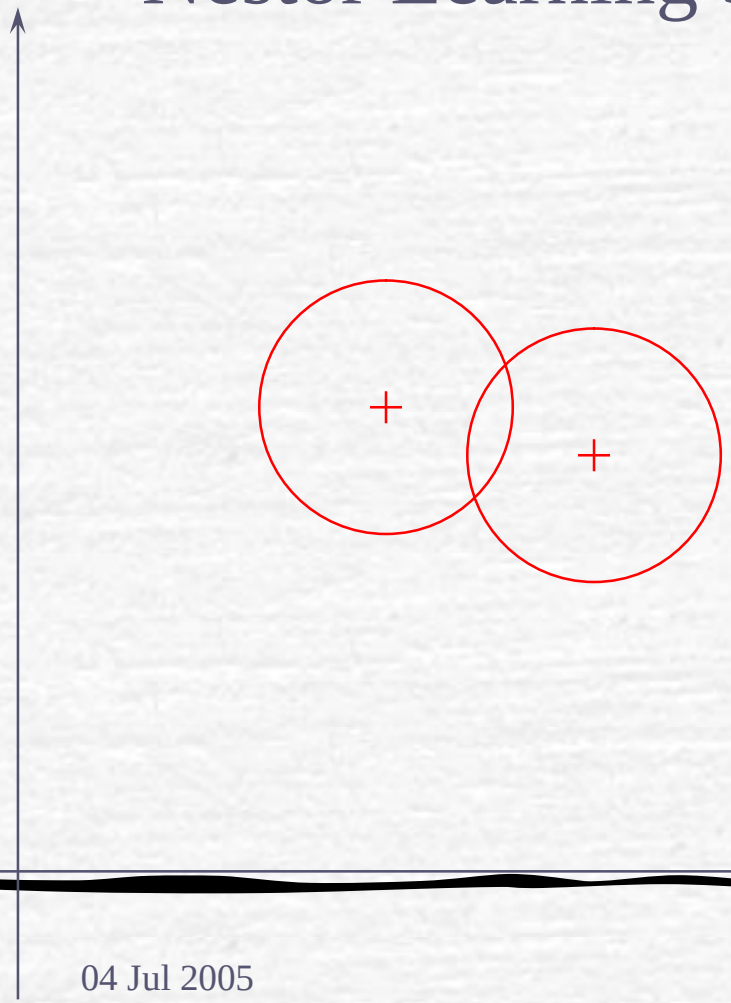
Classification; Training models

- Nestor Learning System (NLS)



Classification; Training models

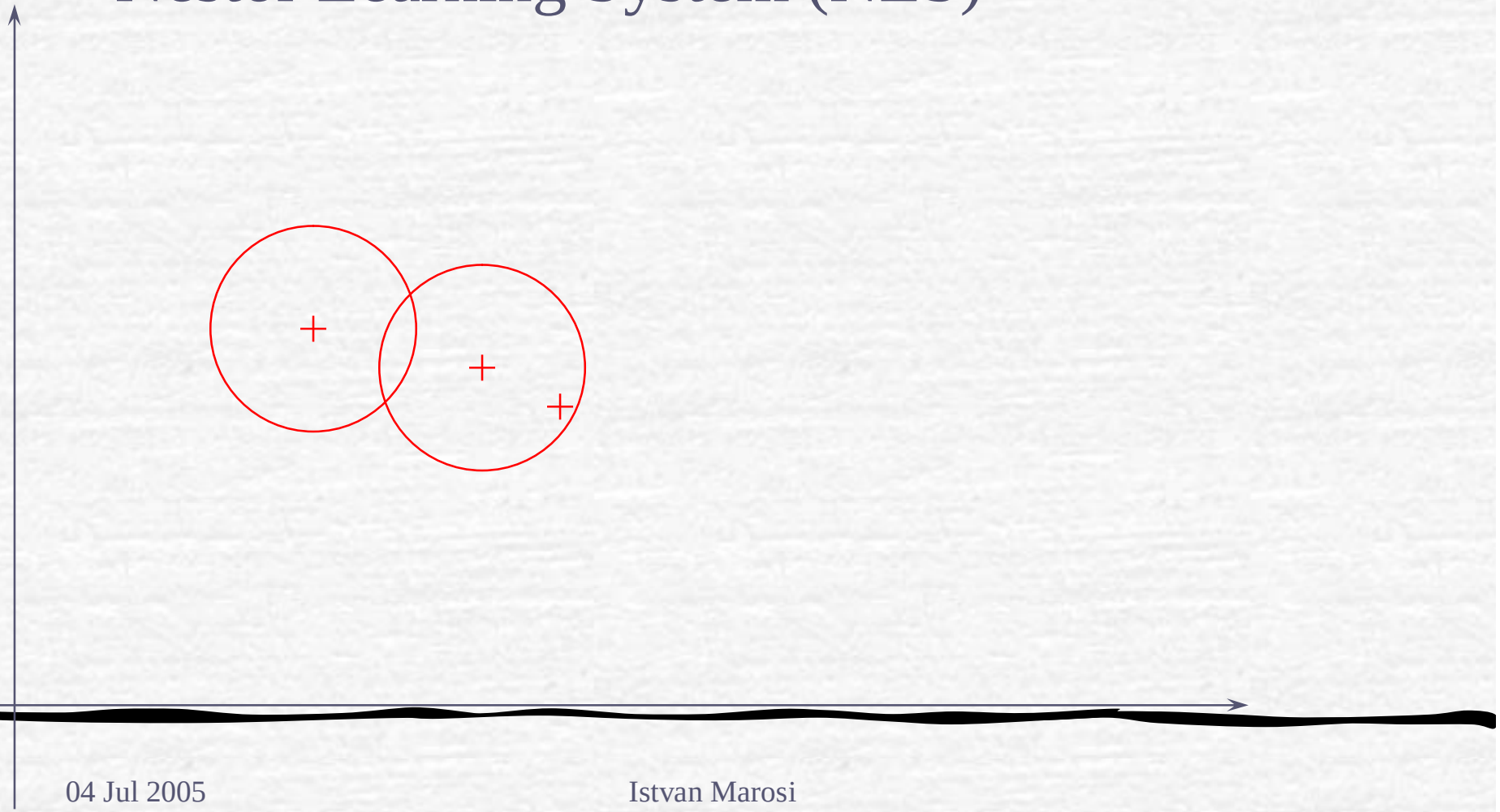
- Nestor Learning System (NLS)



Default radius R_{max}

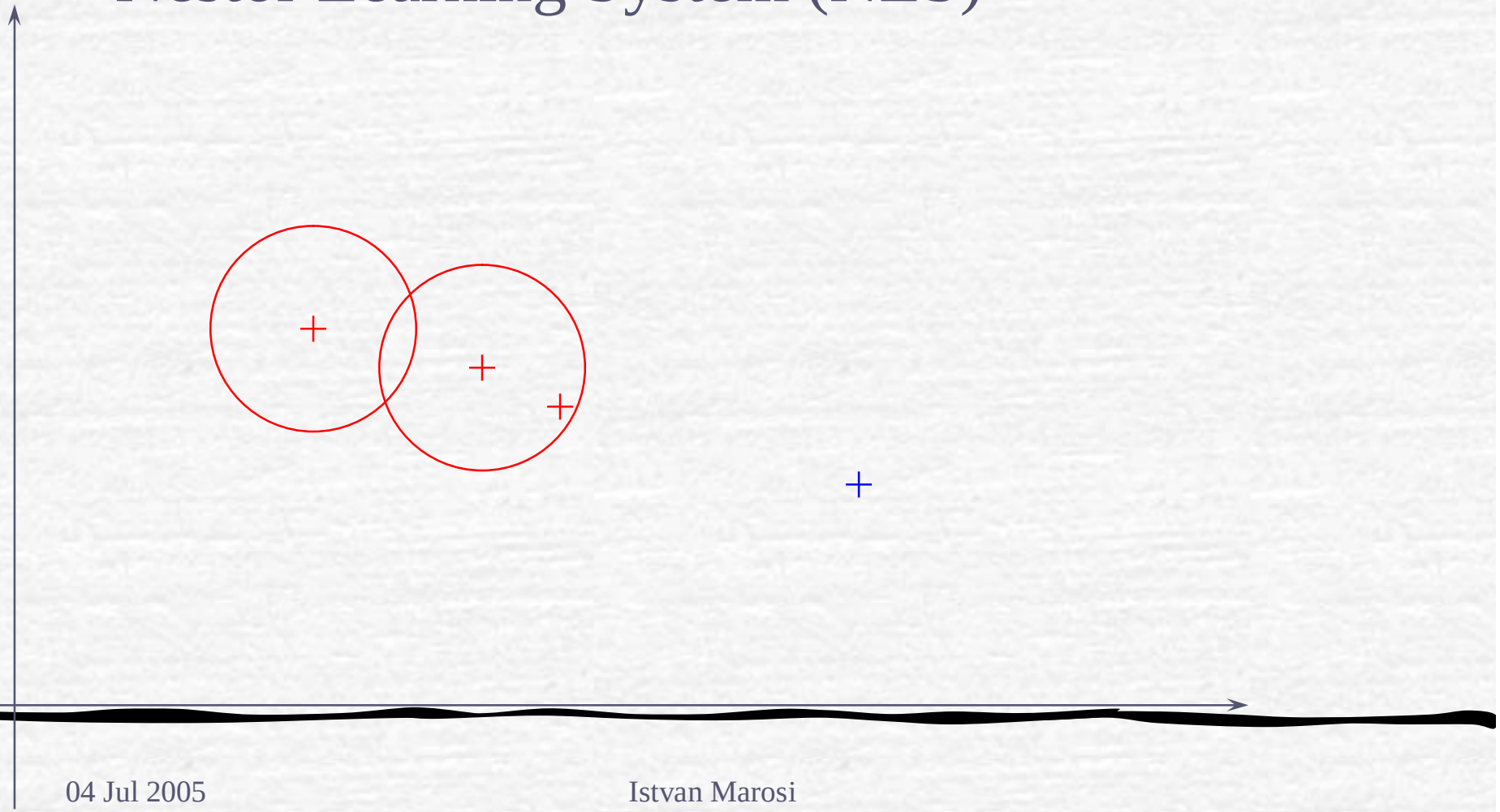
Classification; Training models

- Nestor Learning System (NLS)



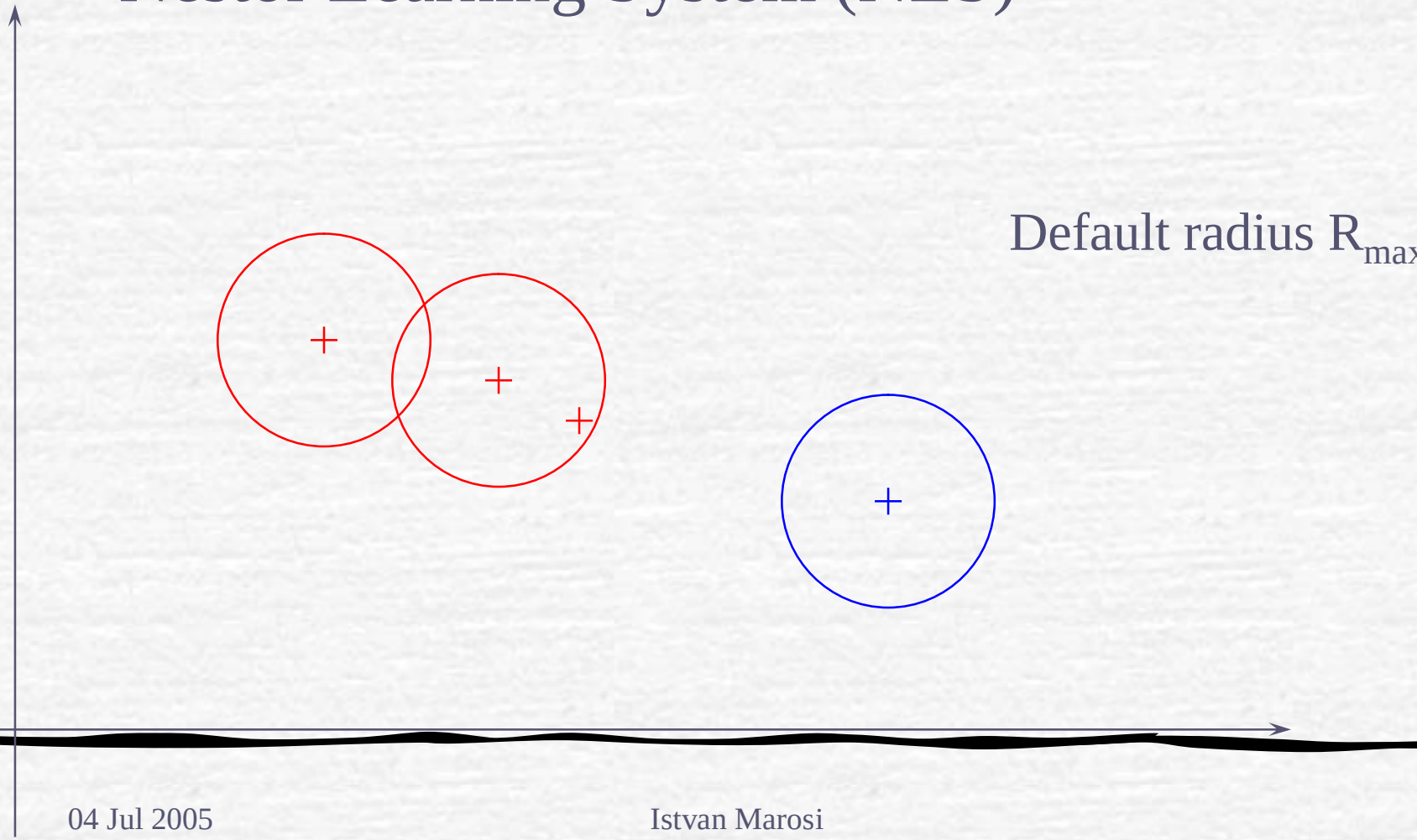
Classification; Training models

- Nestor Learning System (NLS)



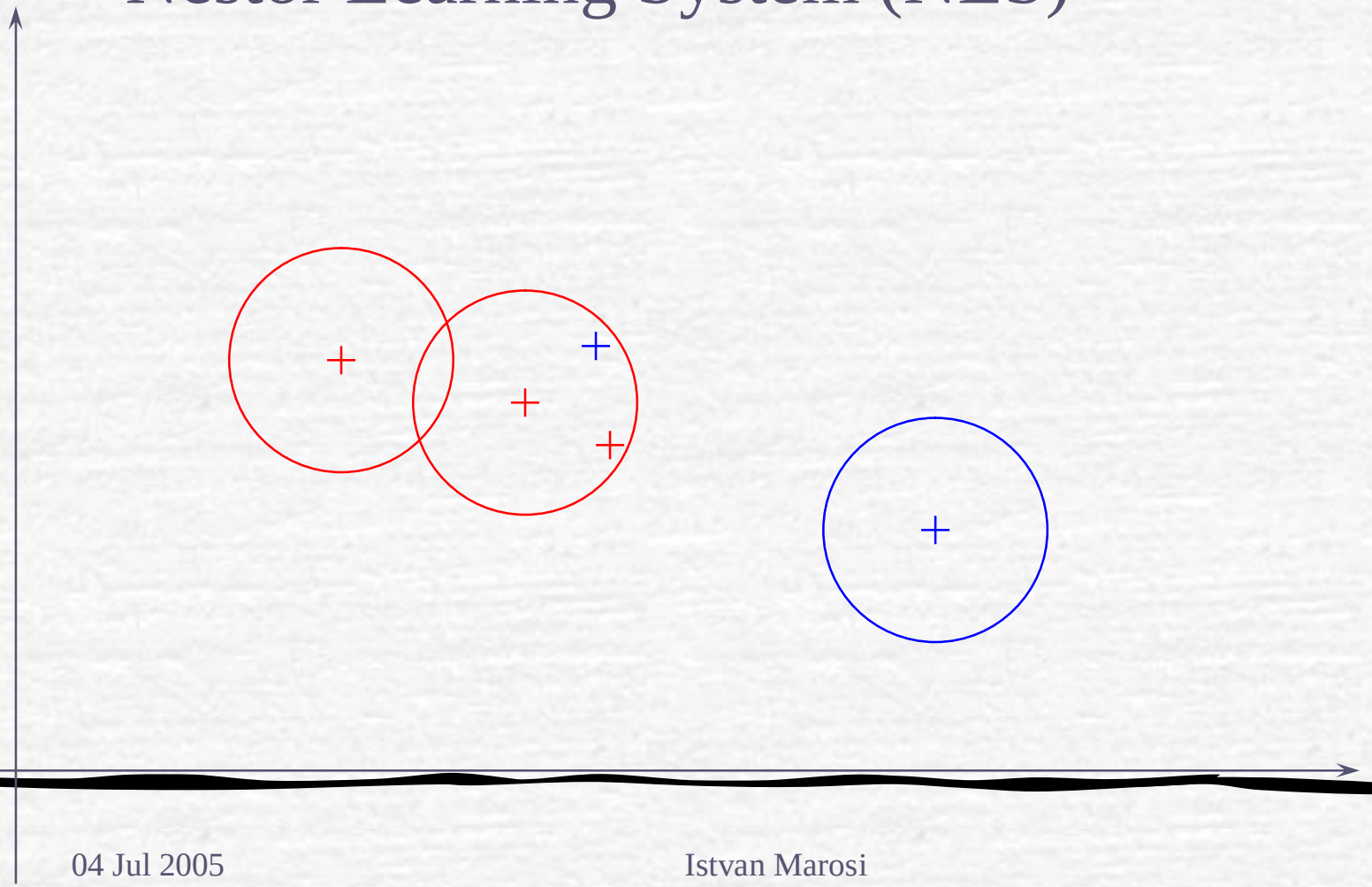
Classification; Training models

- Nestor Learning System (NLS)



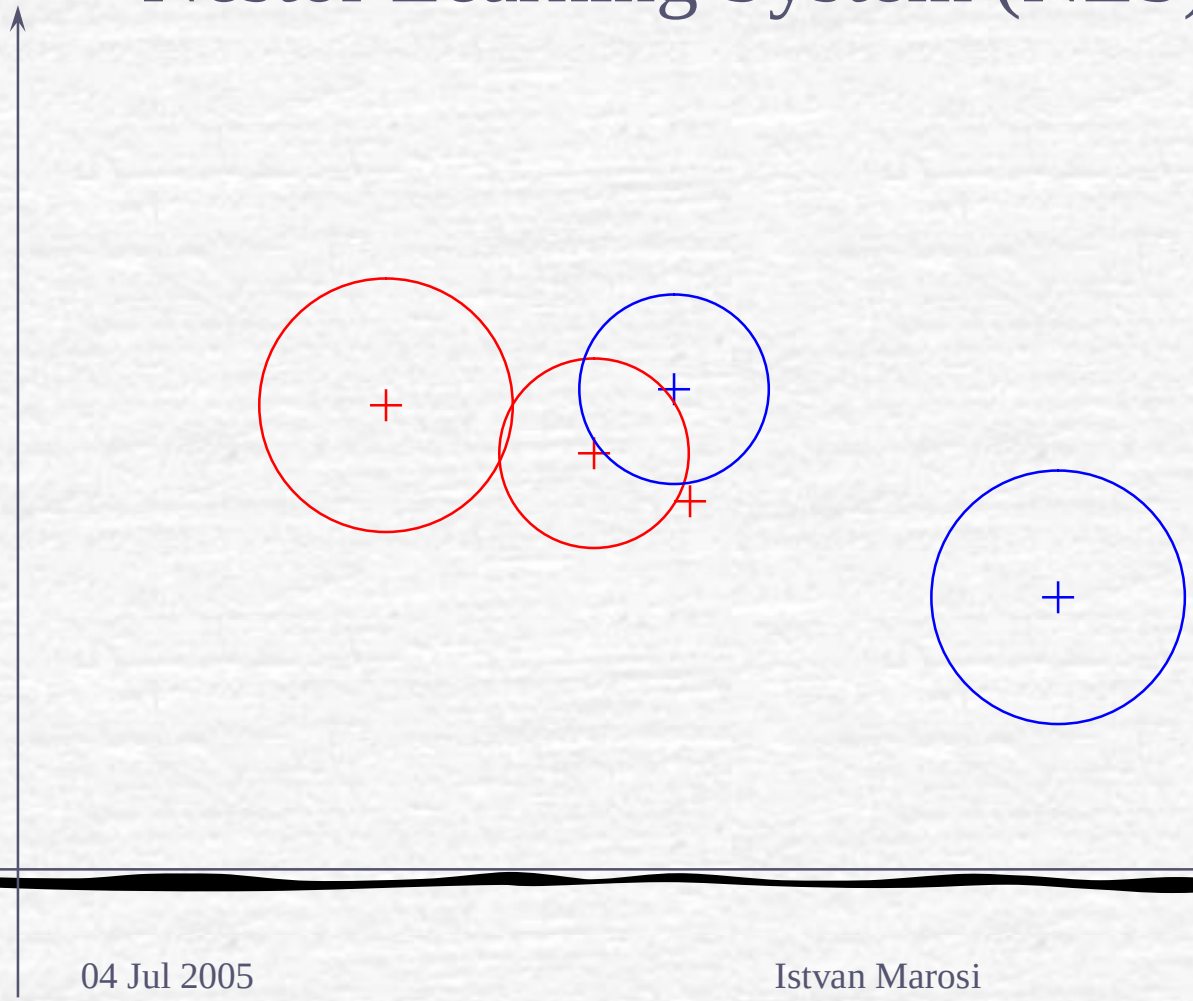
Classification; Training models

- Nestor Learning System (NLS)



Classification; Training models

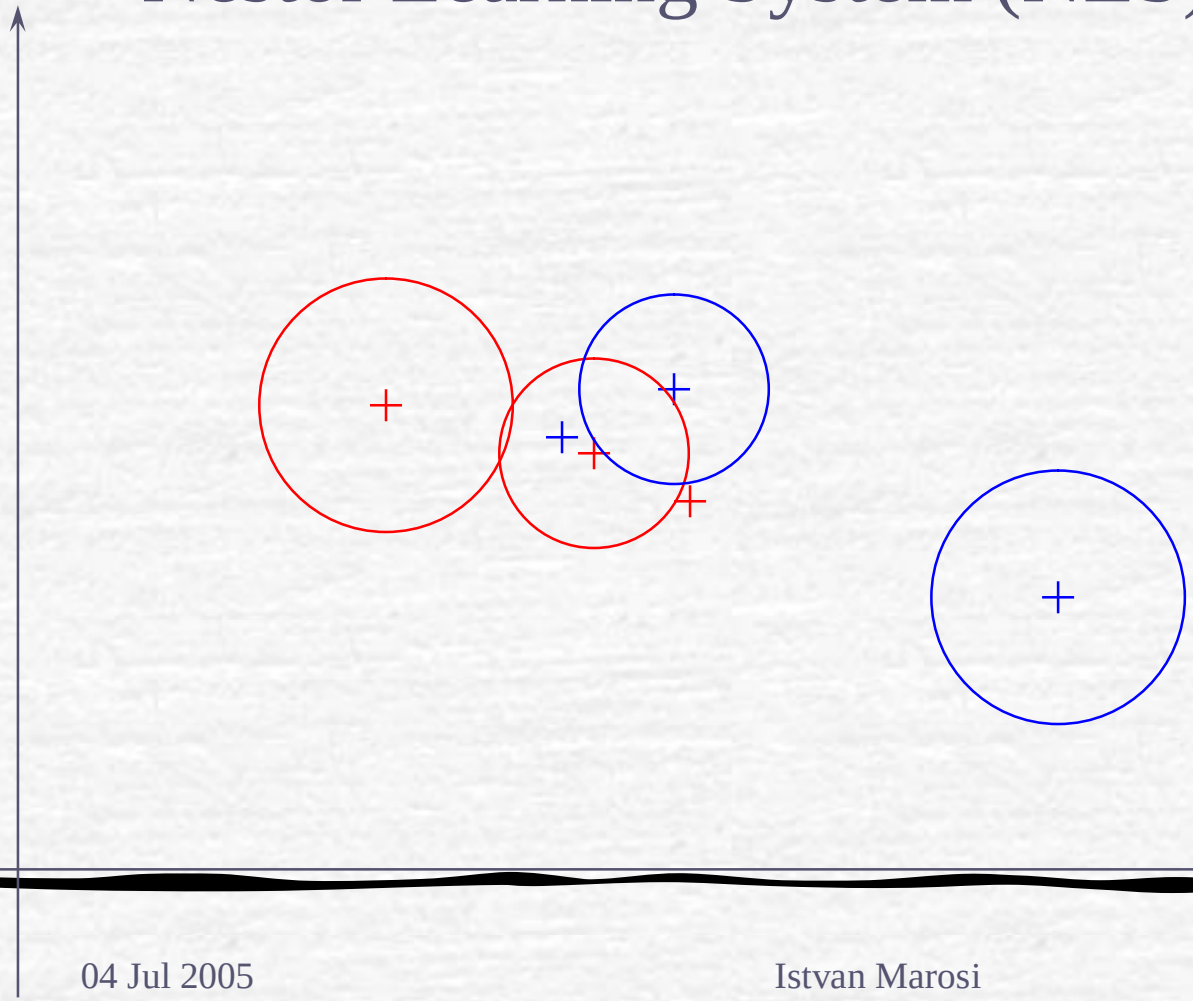
- Nestor Learning System (NLS)



Decreased radius

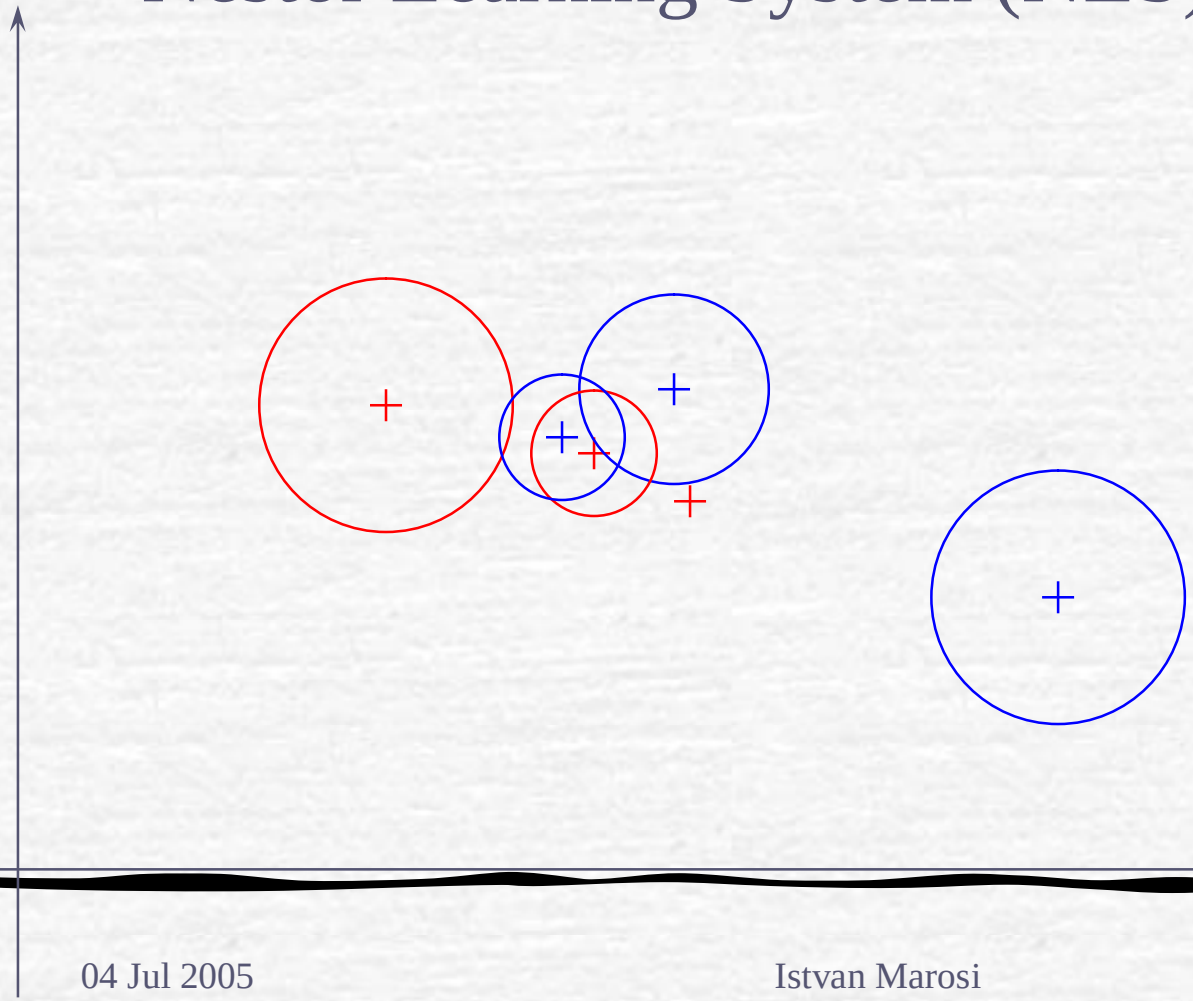
Classification; Training models

- Nestor Learning System (NLS)



Classification; Training models

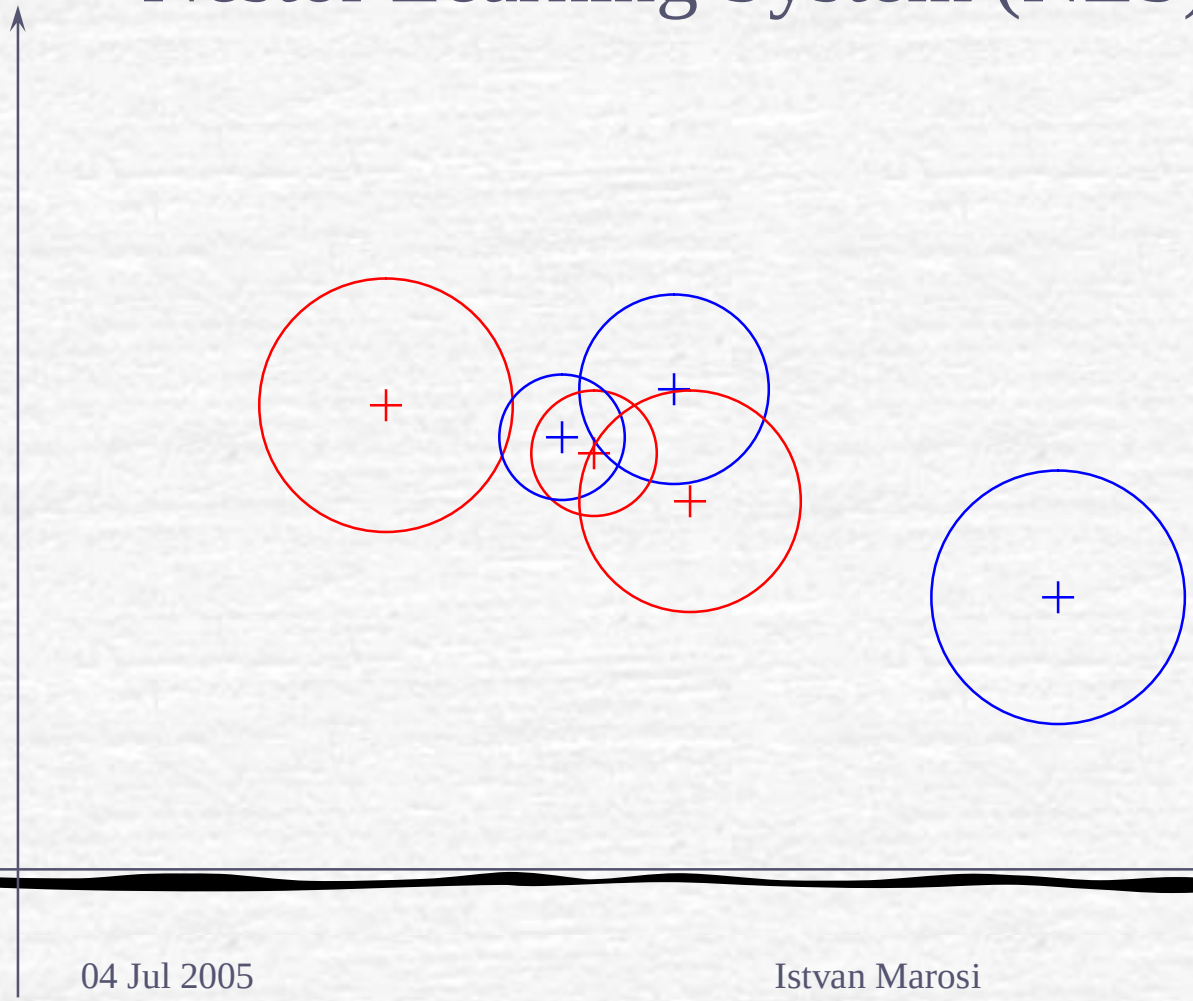
- Nestor Learning System (NLS)



Decreased radius R_{min}

Classification; Training models

- Nestor Learning System (NLS)



Pass 2

Decreased radius

OCR Internals

- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
  - Text recognition
    - *Segmentation*
    - *Calculation of Feature Vector Elements*
    - *Classification*
    - *Language Analysis*
    - *Voting*
  - User assisted correction
  - Result exportation

Voting

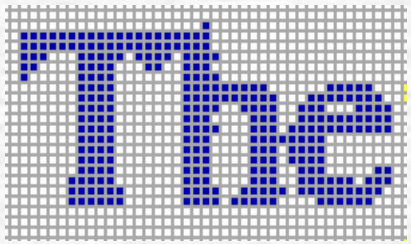
- Text recognition in OmniPage Pro
  - OCR Engines available:
    - Caere's engine ***(codename: Salt & Pepper)***
    - Recognita's engine ***(codename: Paprika)***
    - ScanSoft's engine ***(codename: Fireworx)***

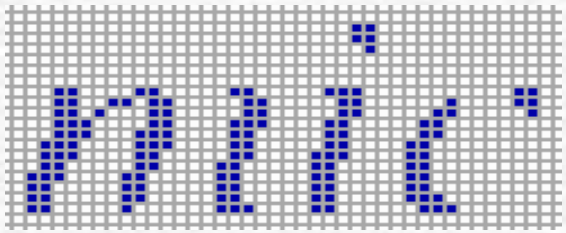
Voting

- Text recognition in OmniPage Pro
  - OCR Engines available:
    - Caere's engine ***(Salt & Pepper)***
      - Uses a Matrix Matching based algorithm
        - feature set: 40 cells of an 8x5 grid
        - good overall description of a shape
        - weaker at detailed structure
    - Recognita's engine ***(Paprika)***
      - Uses a Contour Tracing based algorithm
        - feture set: convex and concave arcs on the contour
        - good detailed description of a shape
        - weaker at overall structure

Voting

- Text recognition in OmniPage Pro
  - OCR Engines available:
    - Caere's engine ***(Salt & Pepper)***
    - Recognita's engine ***(Paprika)***
    - ScanSoft's engine ***(Fireworx)***
  - Segmentation algorithms:





Voting

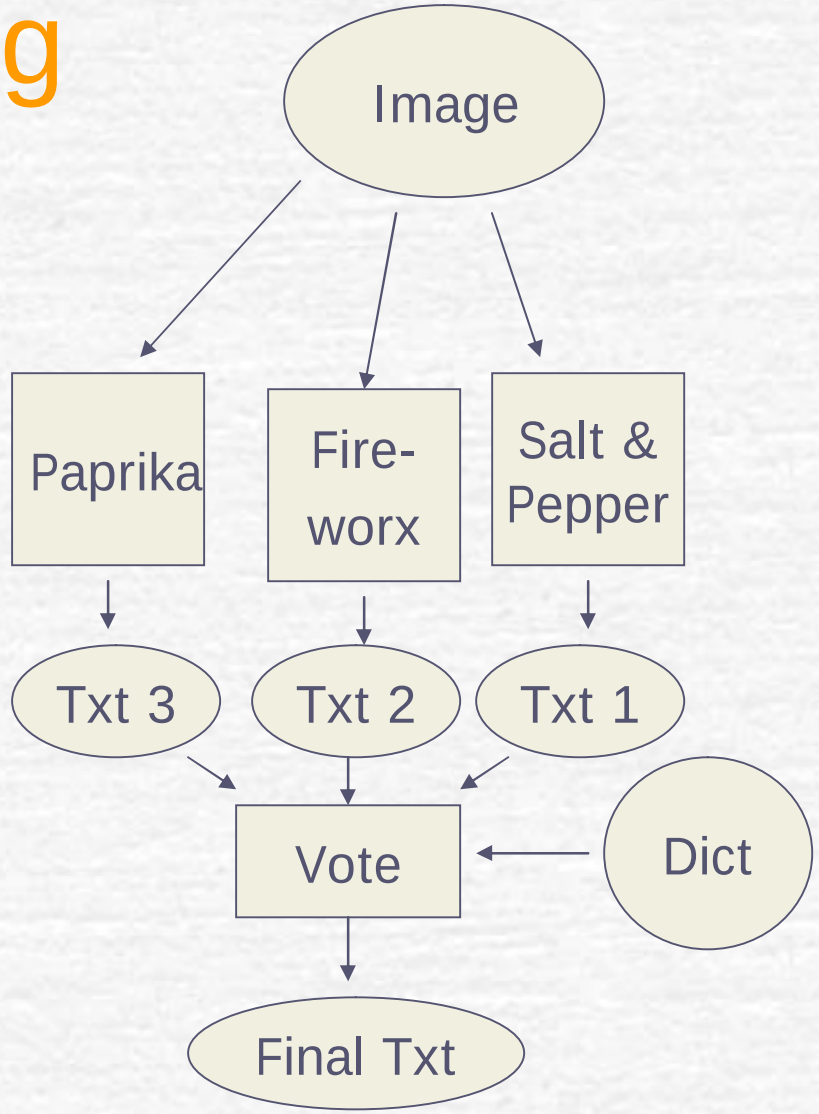
- Text recognition in OmniPage Pro
  - OCR Engines available:
    - Caere's engine ***(Salt & Pepper)***
    - Recognita's engine ***(Paprika)***
    - ScanSoft's engine ***(Fireworx)***
  - Segmentation algorithms:
    - Developed by independent groups
    - Have different strengths and weaknesses

Voting

- Text recognition in OmniPage Pro
  - OCR Engines available
  - Segmentation algorithms
- Conclusion:
  - They are complementary
  - Let’s create a voting system

Voting

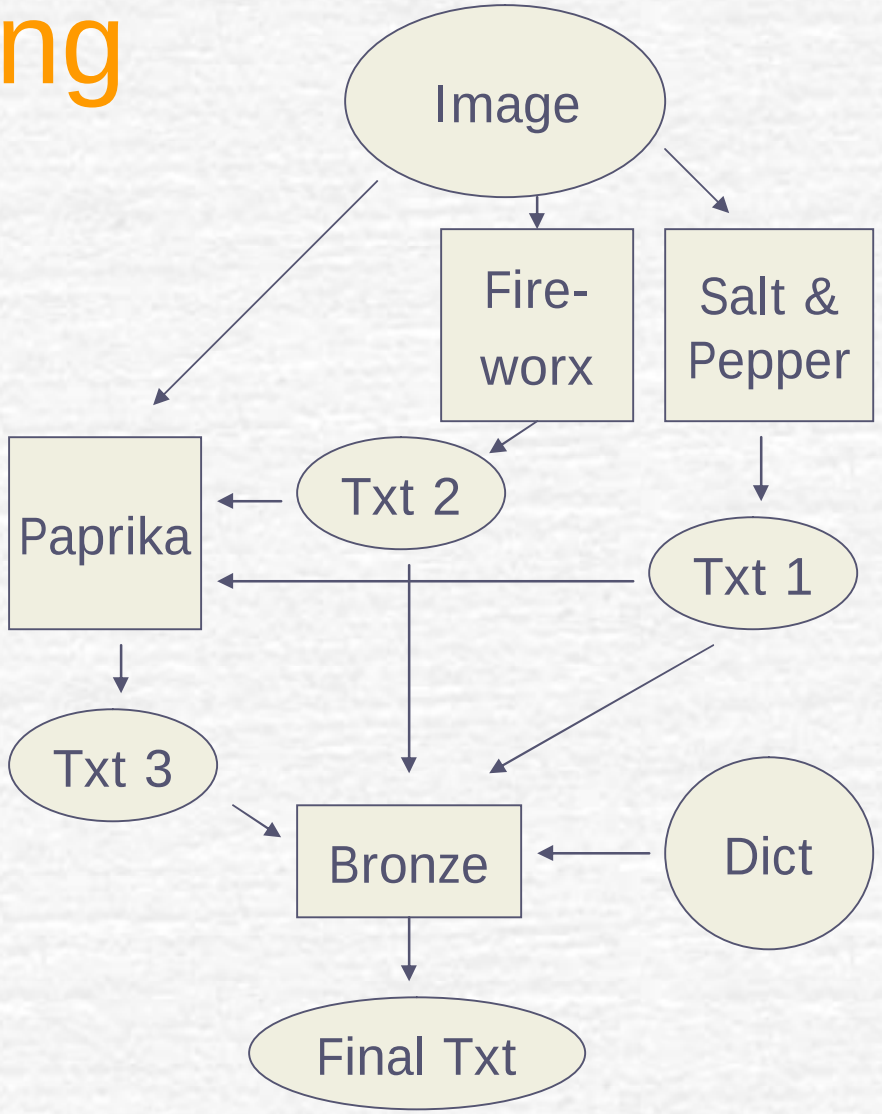
- Voting strategies
  - External „Black box” voting



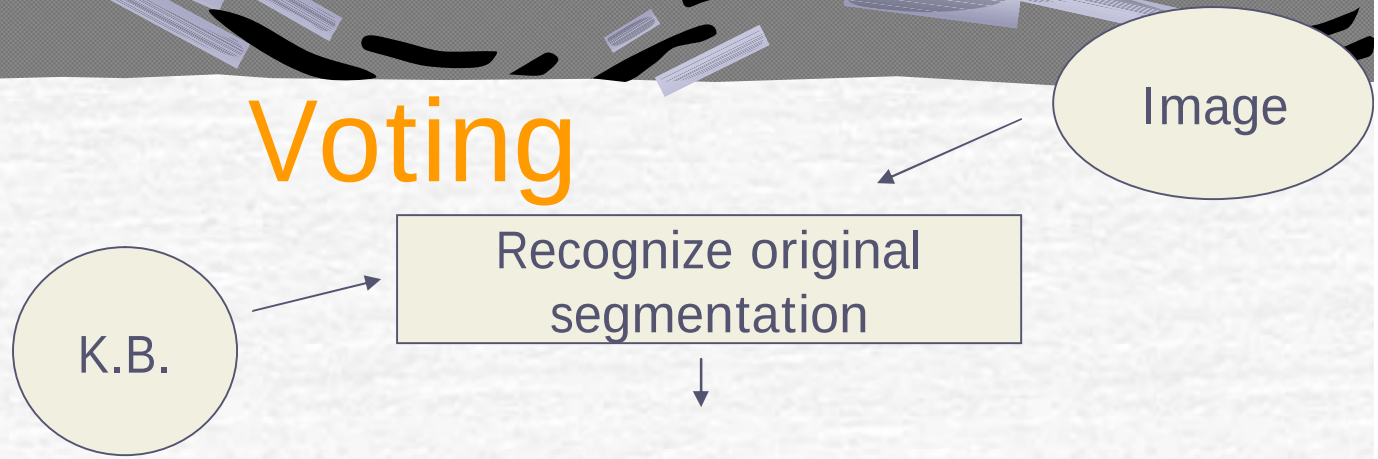
~20% gain

Voting

- Voting strategies
  - External „Black box” voting
  - Internal „Shape” voting



Voting



- Paprika

Original segmentation:

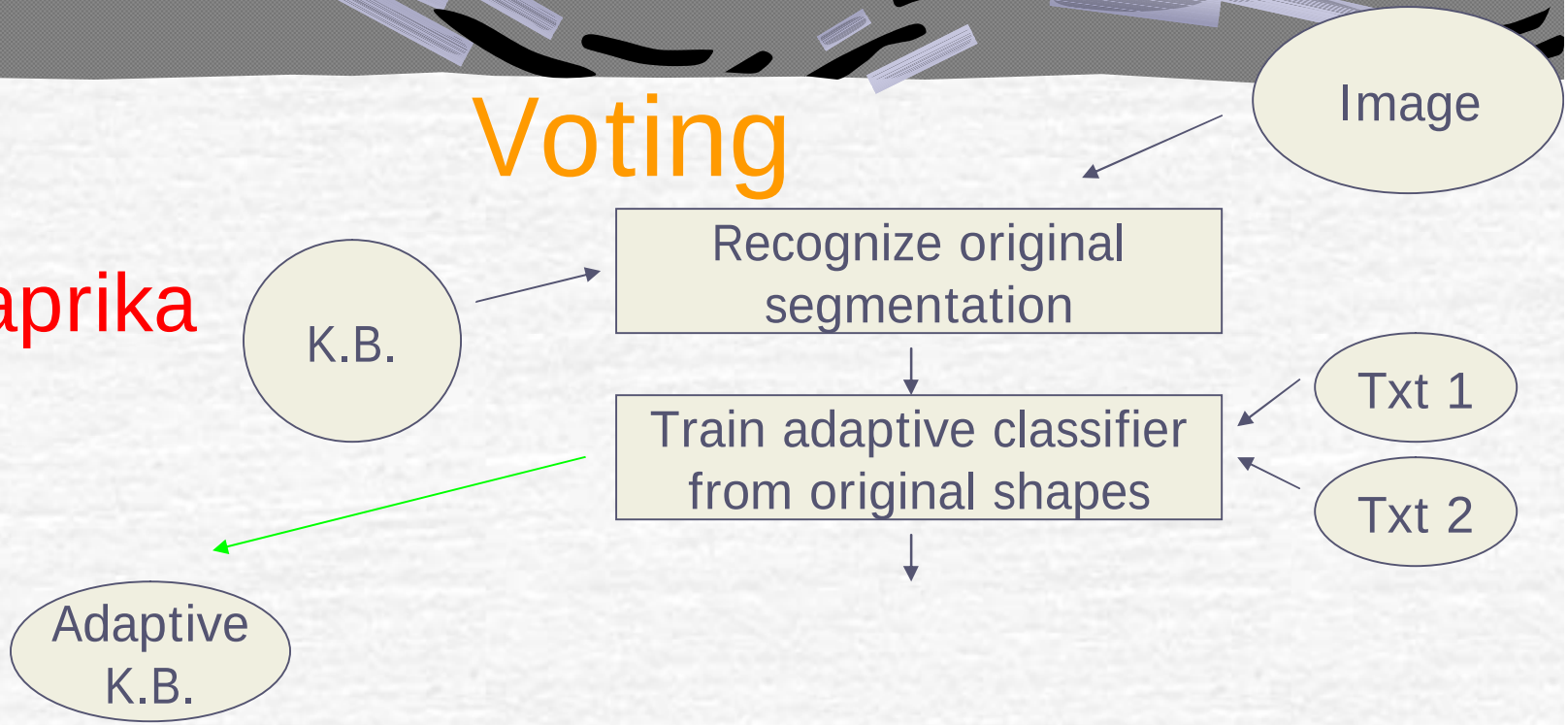
Every independent connected component is a character

Good segmentation: recognize

Bad segmentation: reject

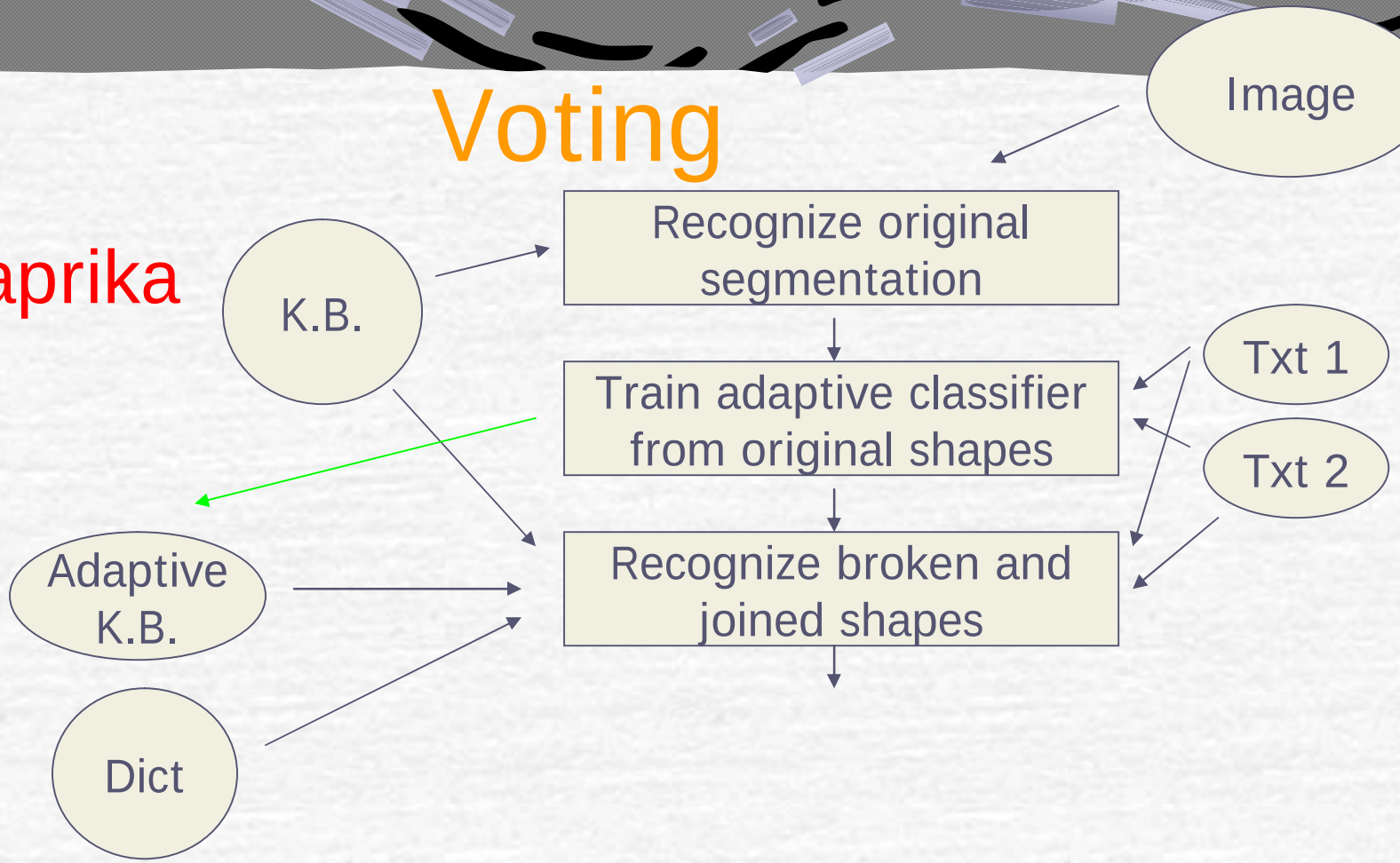
Voting

- Paprika



Voting

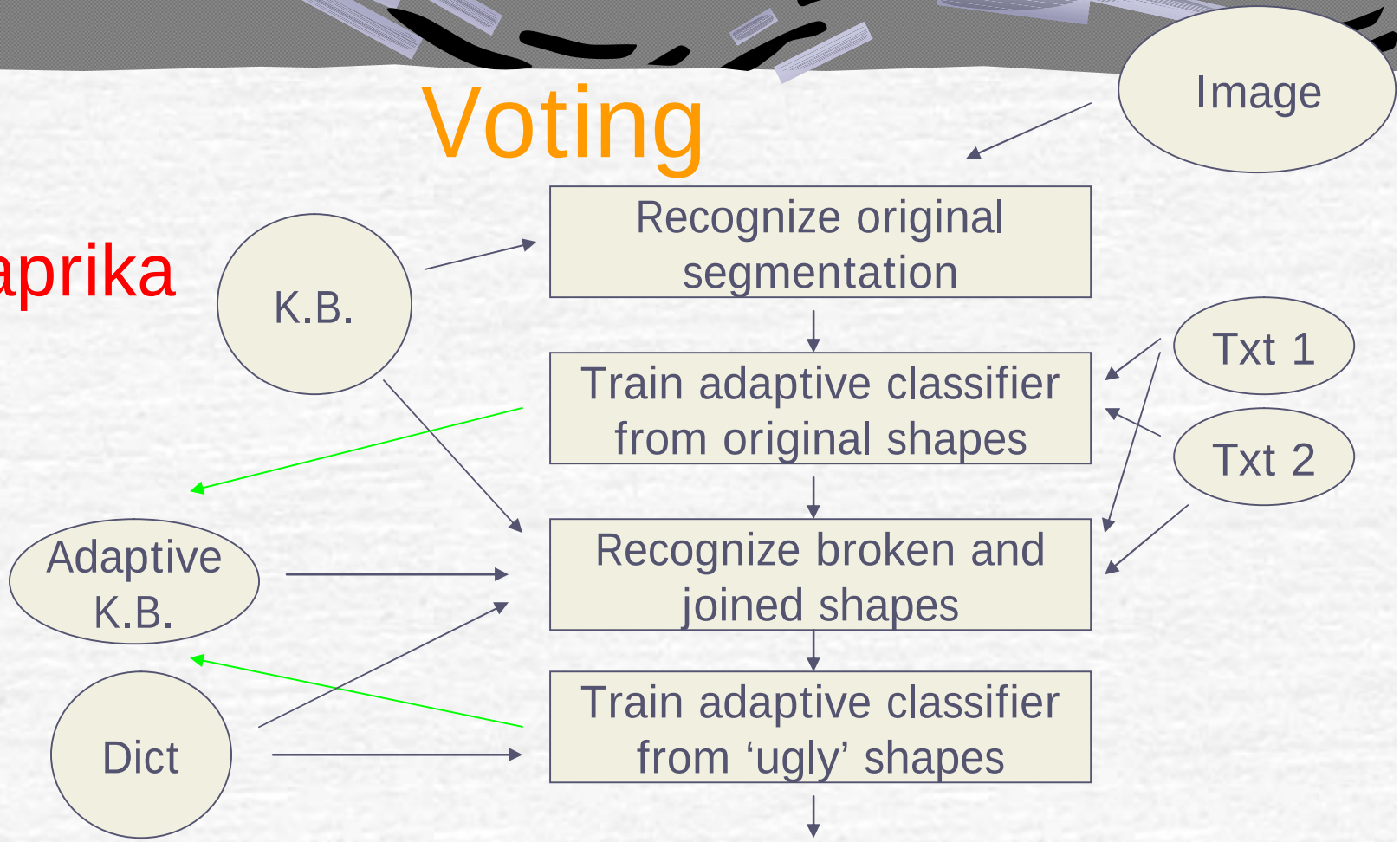
- Paprika



- Try several segmentations
- Loop if unrecognizable

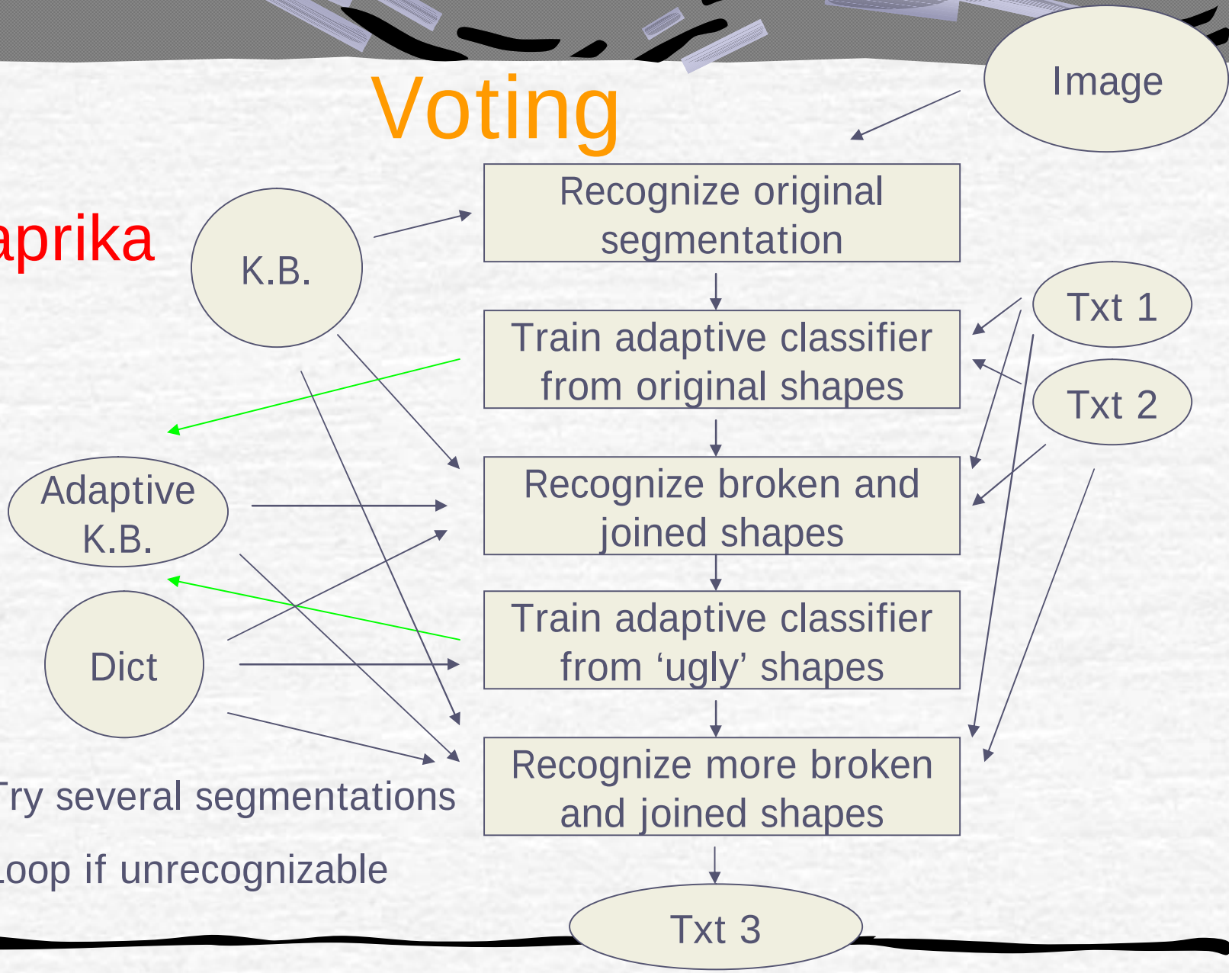
Voting

- Paprika



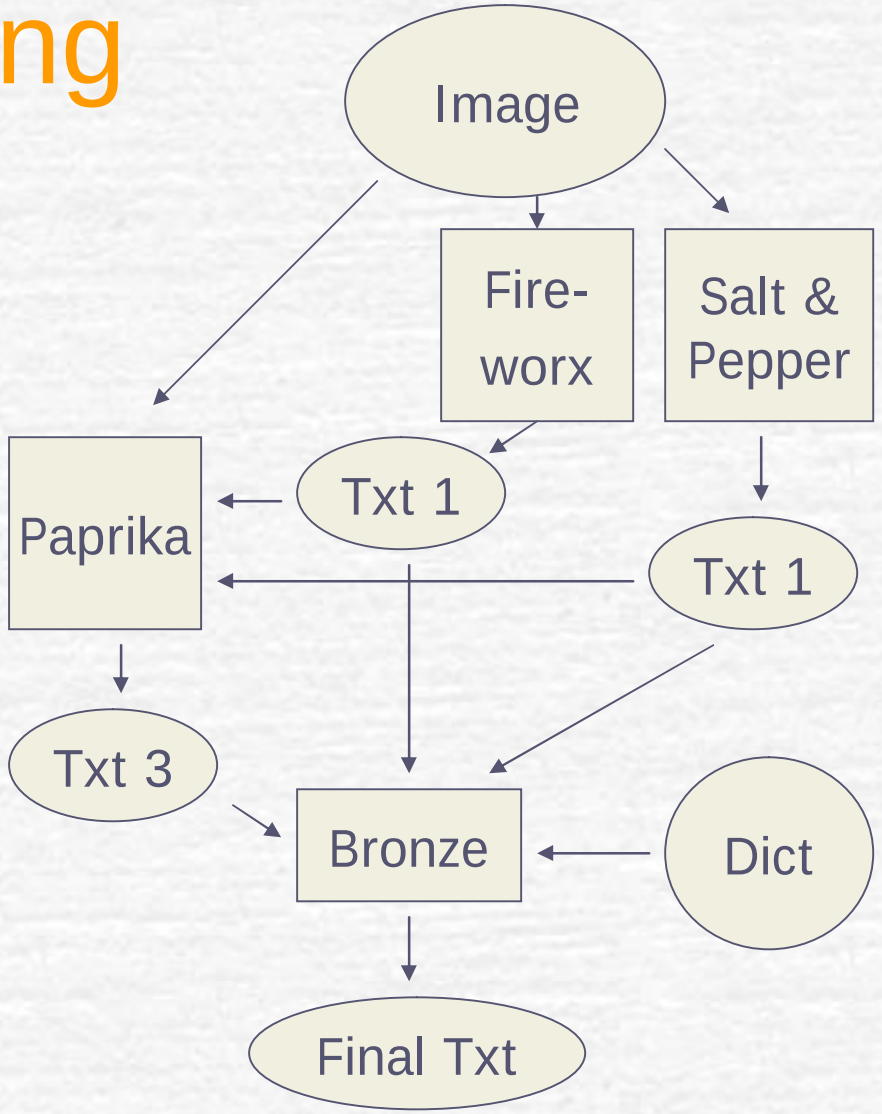
Voting

- Paprika
  - Try several segmentations
  - Loop if unrecognizable



Voting

- Voting strategies



~60% gain

OCR Internals

- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
  - Text recognition
  - User assisted correction
    - By the user's random editing...
      - Pop-up verifier
      - Manual Training
    - By proofreading of doubtful words
  - Result exportation

OCR Internals

- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
  - Text recognition
  - User assisted correction
    - By the user's random editing...
    - By proofreading of doubtful words
      - Correct: User dictionary
      - Changed: IntelliTrain
        - Remember trained characters
        - Apply them on following pages
  - Result exportation

IntelliTrain

Recognized word: *sorneUüng*

IntelliTrain

Recognized word: *sorneUüng*

Fixed word: *something*

IntelliTrain

Recognized word: *sorneUüng*

Fixed word: *something*

IntelliTrain

Recognized word: *sorneUüng*

Fixed word: *something*

Substitutions found: *m* → *rn*

thi → *Uü*

IntelliTrain

Recognized word: *sorneUüng*

Fixed word: *something*

Substitutions found: *m* → *rn*

thi → *Uü*

Perform automatically:

- Learn image pattern and substitution info
- Find similar substituted ('*blue*') text on actual page
- Match against pattern of substitution and correct
- Find such errors on following pages, too

OCR Internals

- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
  - Text recognition
  - User assisted correction
  - Result exportation
    - Combine pages into a Document
      - Header / Footer recognition
      - Page numbers
      - Hyperlinks (e.g. „See Table 20”)
    - Save results

OCR Internals

- Main tasks of an OCR system:
  - Image acquisition
  - Layout recognition
  - Text recognition
  - User assisted correction
  - Result exportation
    - Combine pages into a Document
    - Save results
      - doc file
      - e-mail
      - Speech synthesizer