The Benefit of Ground Truth Data to Semantic Conformance Testing of Fingeprint Minutia Encoding

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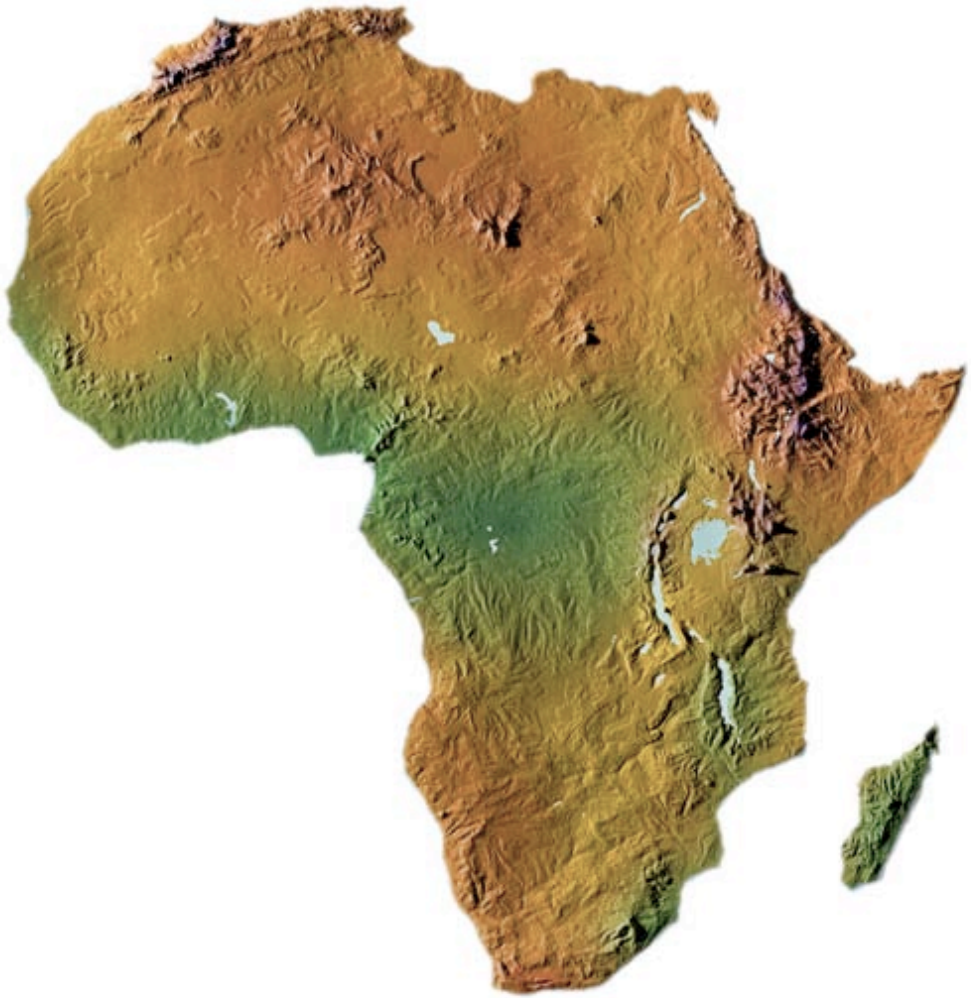
Introduction

- What is „Ground Truth Data“ for Fingerprint Minutia Encoding?

- a winter prespective....

Introduction



This is Africa
and we can consider it as a
~~biometric characteristic~~
geographic characteristic.
It is
a continental part
of our ~~body~~ globe.

Introduction

and

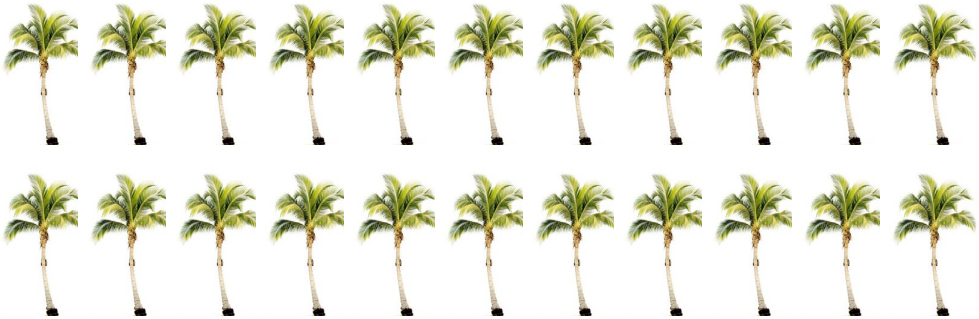
this is the Sahara,

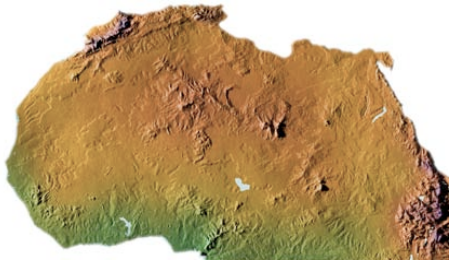
which is

a significant part of Africa

as it is the world‘s largest hot desert.

Introduction





and

this is a palm tree

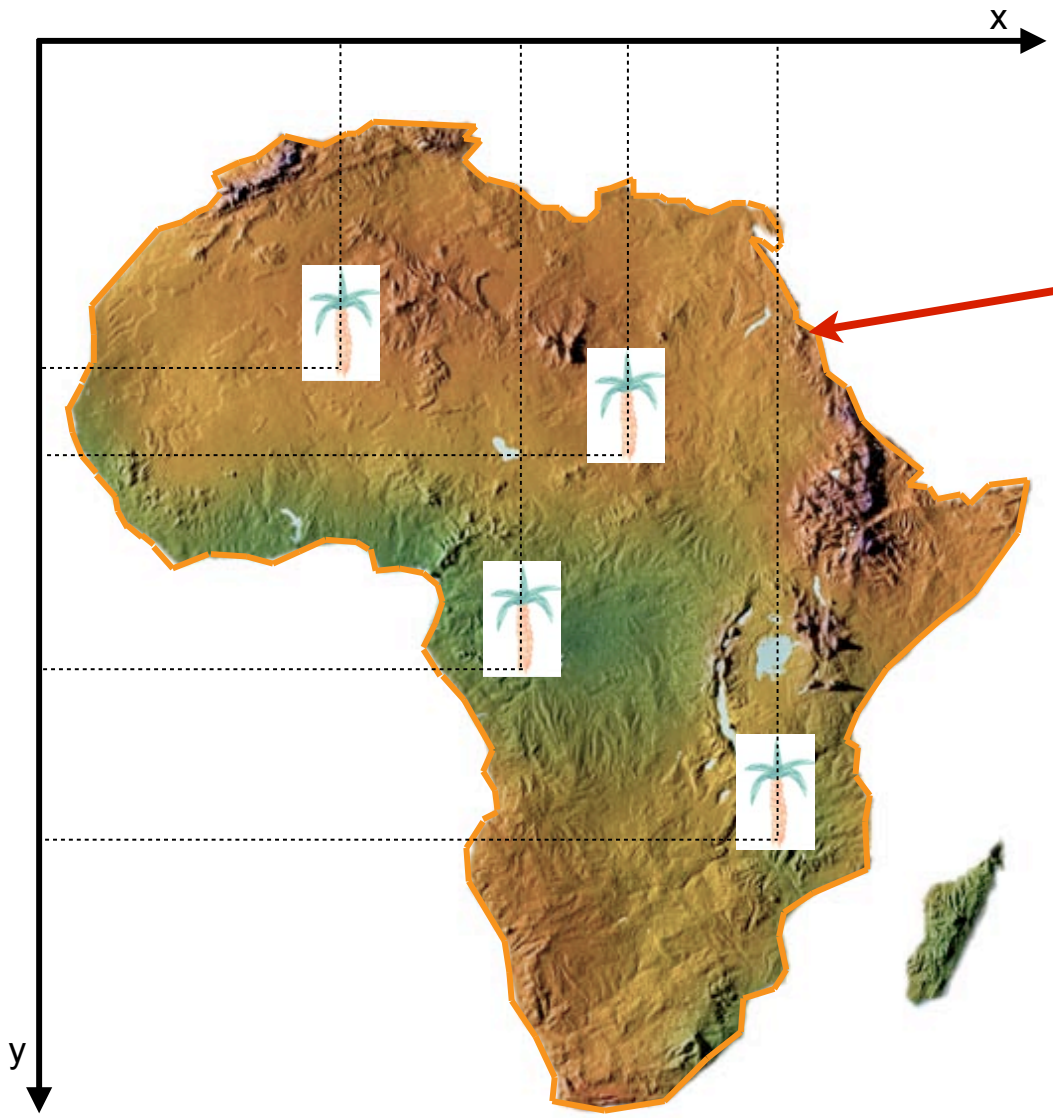
there are many palm trees

in the Sahara.

They serve as landmarks

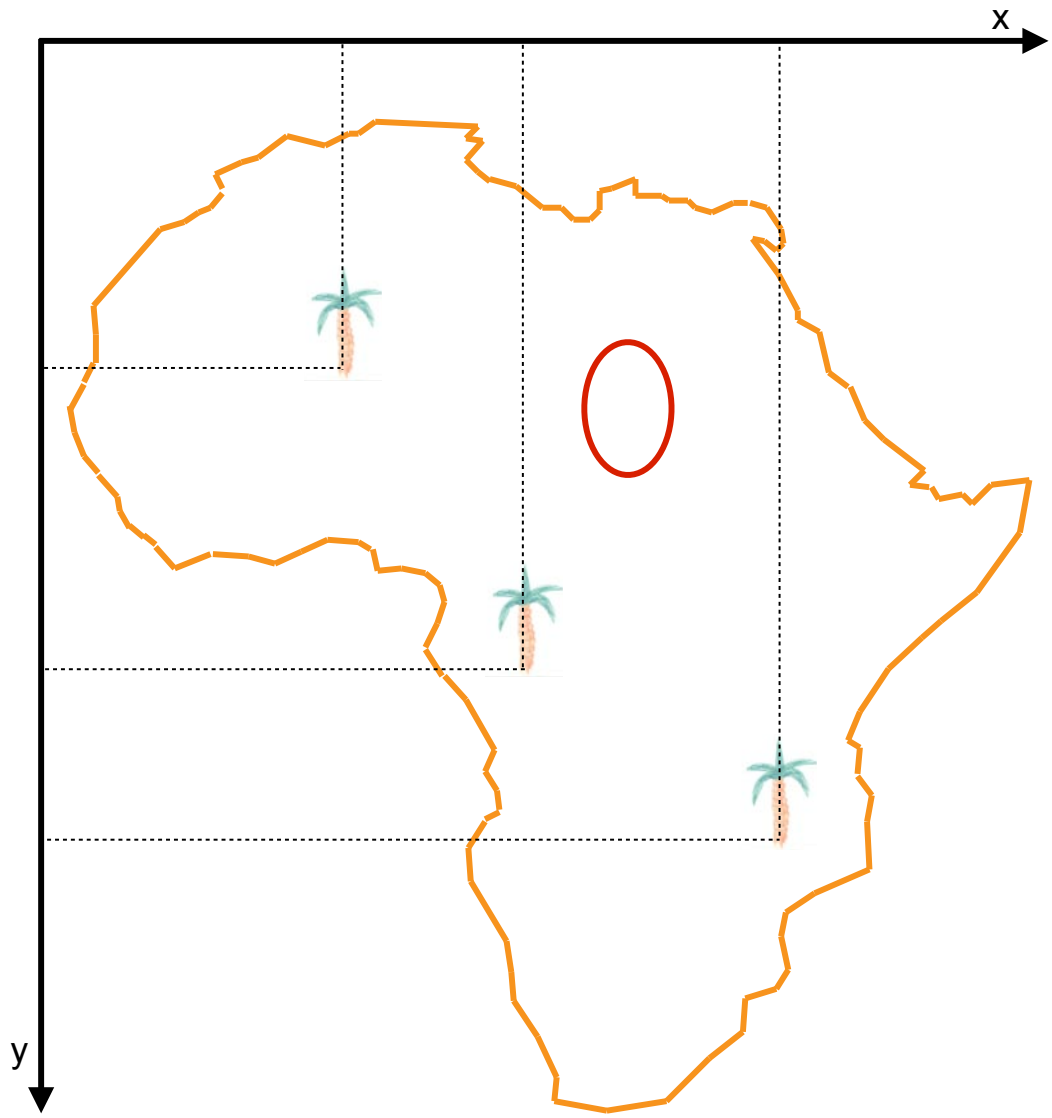
and we like to see them close to some water (oasis).

Introduction



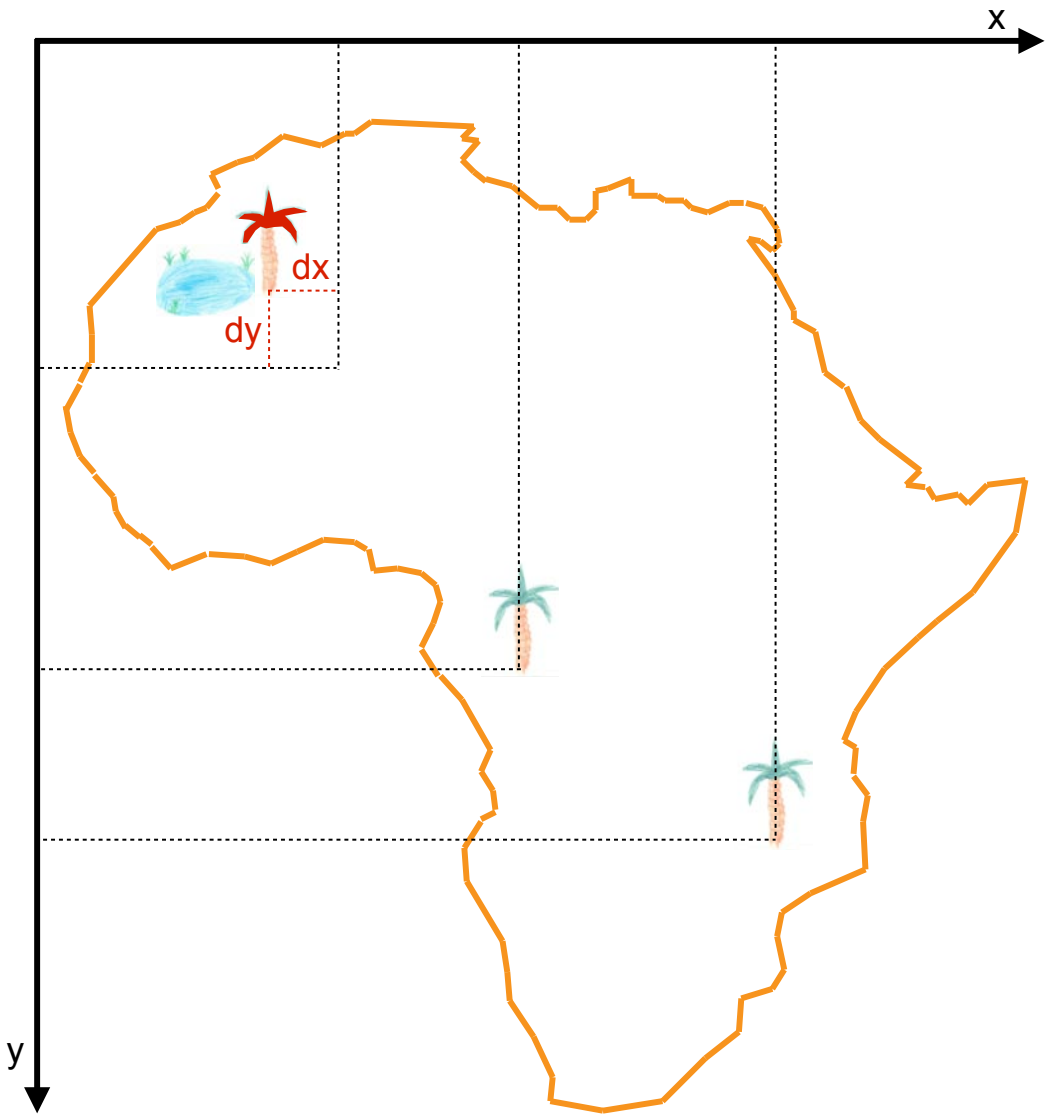
and
this is a representation
of the geographic characteristic
that has been generated
from the geographic sample.
The representation contains
features which encode
the locations of the landmarks.

Introduction



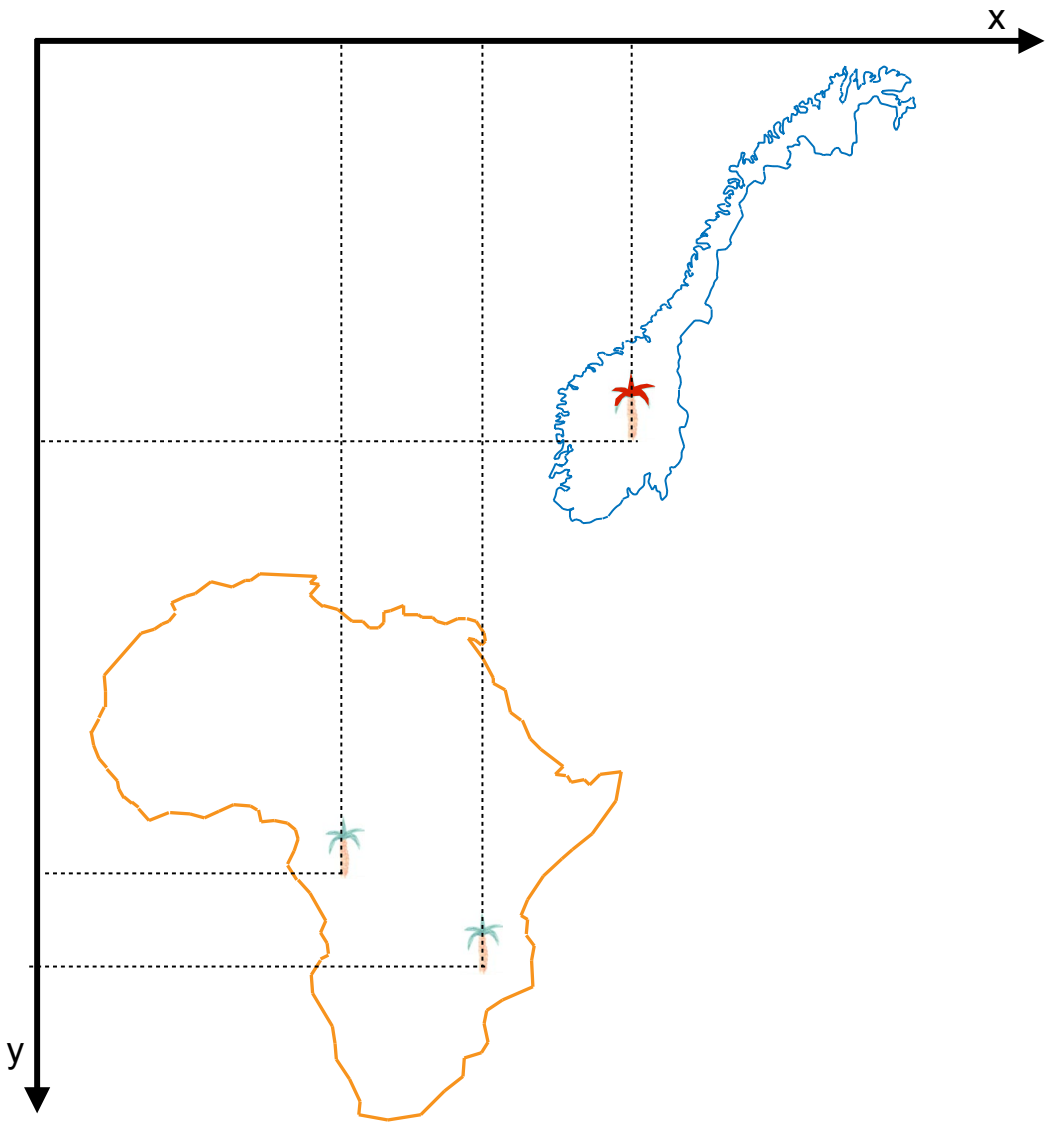
unfortunately
the Sahara is the source
of sandstorms that causes
regionally a bad visibilty.
In consequence
the feature extractor
will not detect the
poorly visible landmark

Introduction



a second problem
is a fata morgana
that causes the
feature extractor to detect
the feature (with an oasis?)
at a dis-located position.
Thus the encoded feature
does not represent the landmark

Introduction



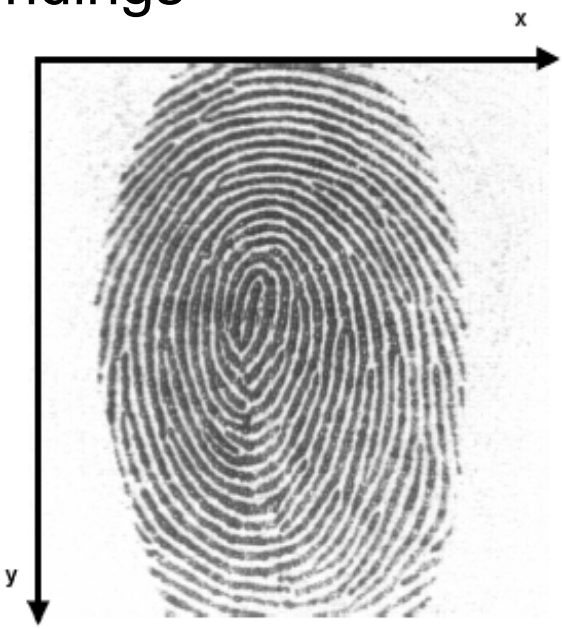
a third problem
could be the globalisation.
If the feature extractor seeks
for landmarks out of area
he may detect falsely a feature
at a position, where
you can find in reality rather
other biological entities (elks)

Properties of
Finger Minutiae Detectors

Representation in Minutia Format

ISO/IEC 19794-2: Biometric data interchange formats - Part 2: Finger minutiae data

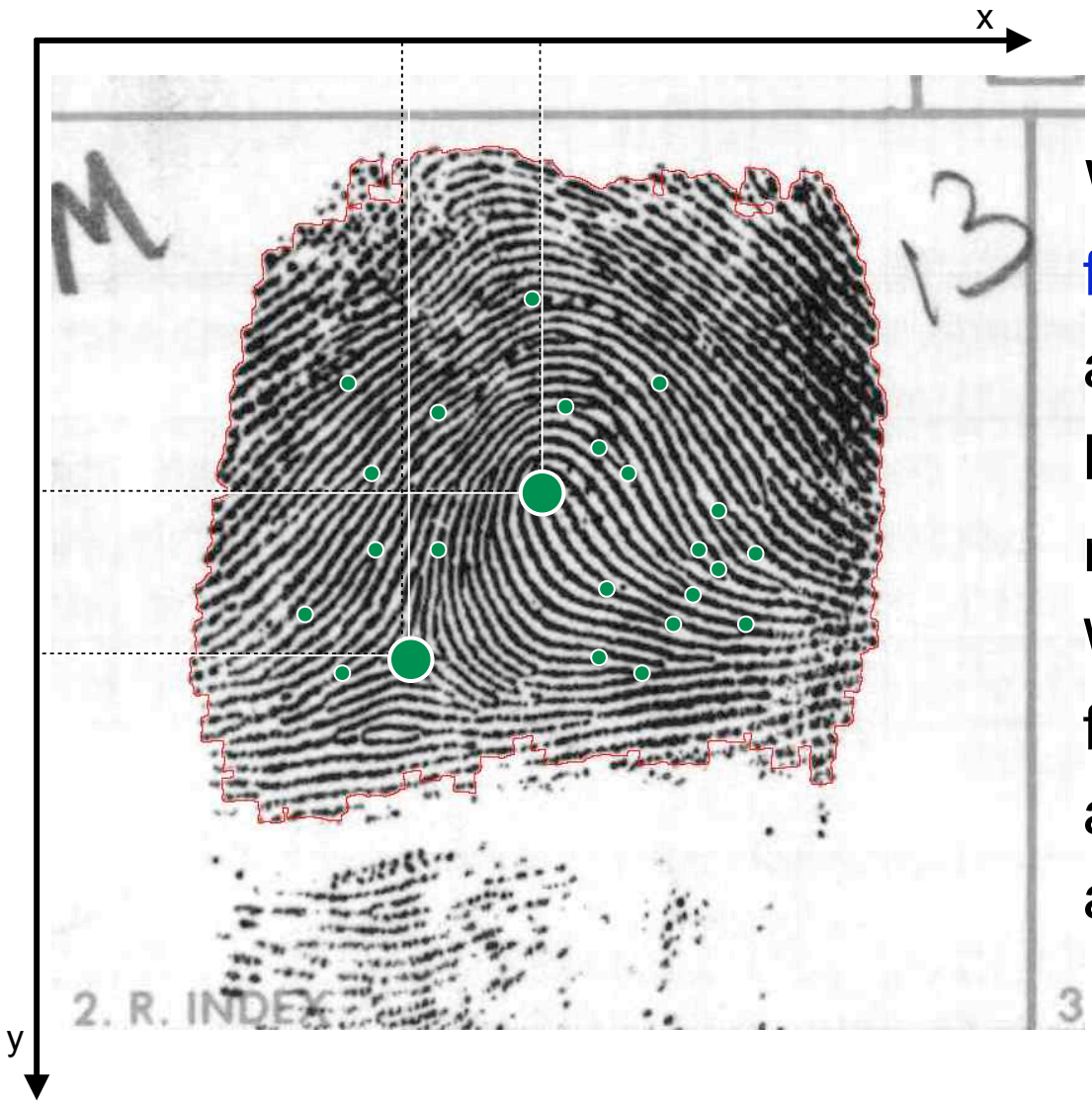
- Ridges and valleys, core and delta
- Ridge bifurcation and ridge endings
  - finger minutiae
- Encoded main features
  - Minutia point (coordinates x,y)
  - Minutia direction (angle θ)
  - Minutia type
- Other features are e.g.
  - quality



latent print

finger

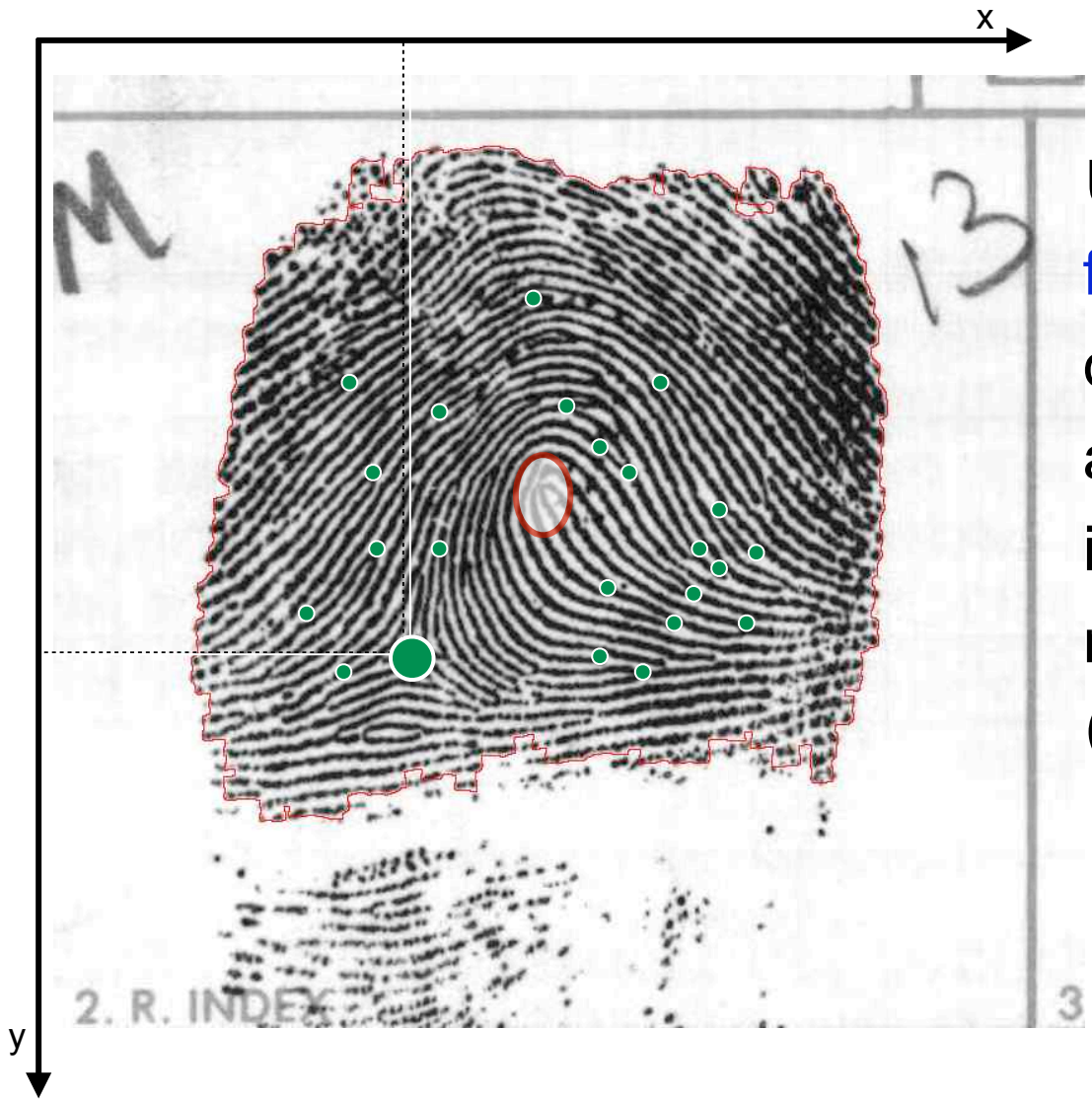
Encoding the Minutia Format



When a ISO 19794-2 compliant feature extractor processes a biometric fingerprint image he generates a minutiae template.

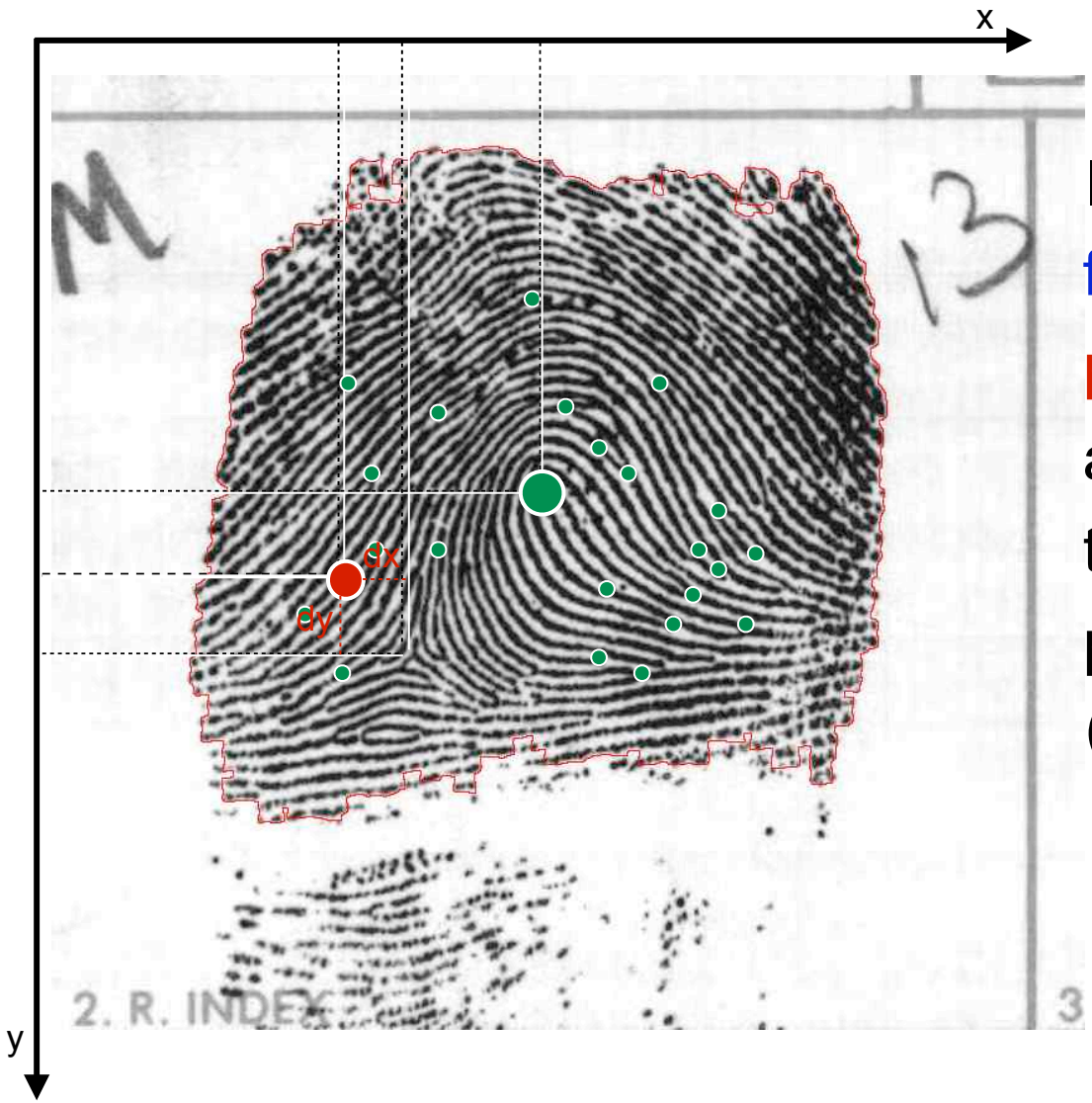
We will find the location for the core and for the delta and for many other minutiae.

Deficiencies of the Minutia Encoder



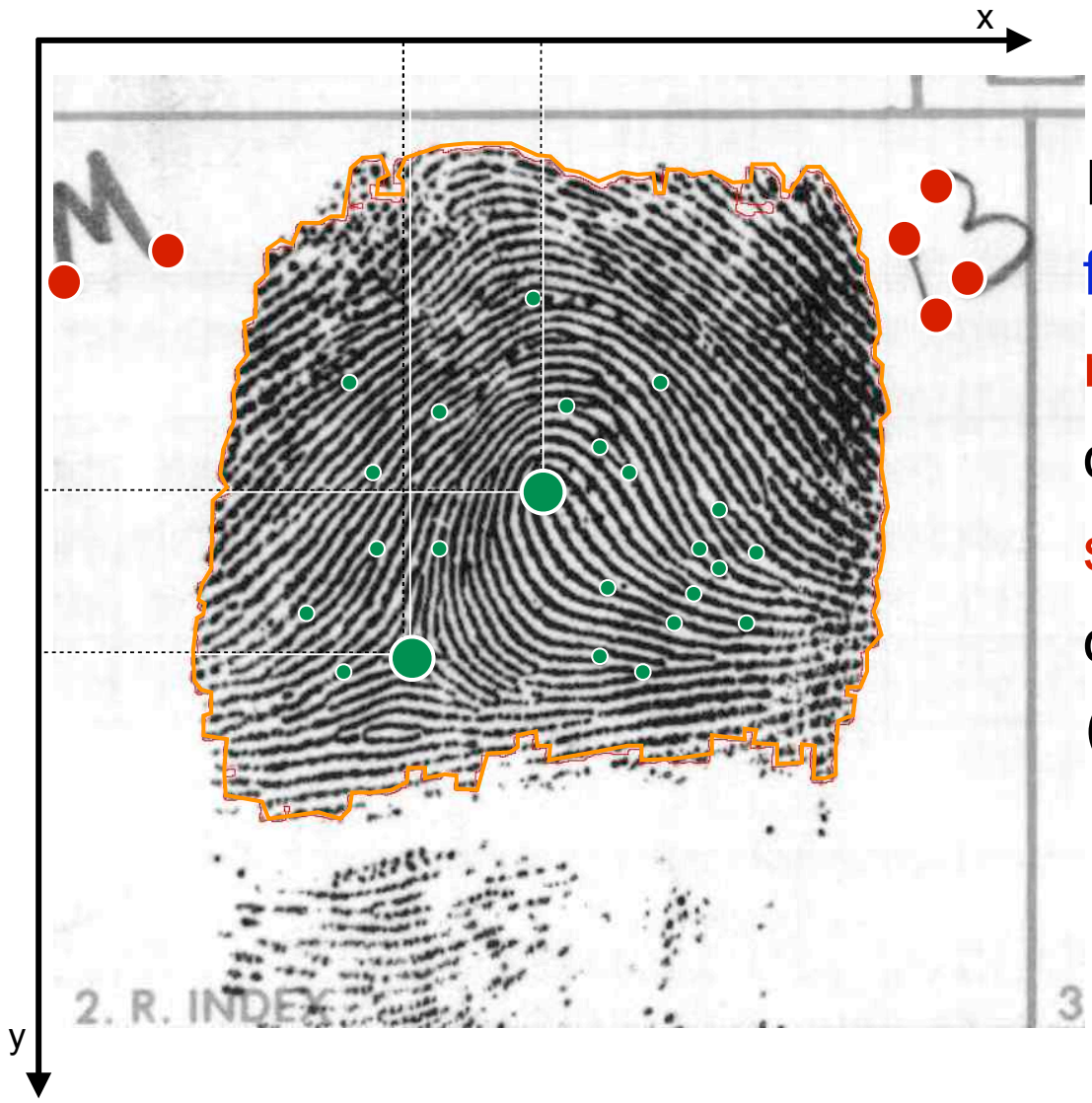
Unfortunately sometimes a feature extractor does not detect a landmark and thus relevant information is missing in the minutiae template. (sandstorm problem)

Deficiencies of the Minutia Encoder



In other cases a feature extractor fails to properly detect a landmark and thus encodes the feature at a dis-located position in the template. (fata morgana problem)

Deficiencies of the Minutia Encoder



Furthermore some feature extractor does not concentrate to the region of interest and thus detect spurious minutiae out of area or at the border of the imprint (globalisation problem)

Conformance Testing Methodology of Finger Minutiae Detectors

Conformance Testing

Conformance testing is defined in a dedicated standard, which is currently under development

- ISO/IEC IS 29109-1 Information technology — Conformance testing methodology for biometric data interchange formats defined in ISO/IEC 19794 — Part 1: Generalized conformance testing methodology
- ISO/IEC FDIS 29109-2 Information technology — Conformance testing methodology for biometric data interchange formats defined in ISO/IEC 19794 - Part 2: Finger minutiae data
- ISO/IEC 29109-1 formulates the relevant test type „A“:
  - attesting that a unit is generating conformant biometric data interchange records.
  - in the case of fingerprint data this tests will verify that a unit (e.g. a minutia extraction algorithm) can create finger minutiae data records (templates) from appropriate fingerprint image data.

Level of Conformance Testing

There are various level of conformance tests:

- Level 1 Basic Data Field Testing:
  - all data fields exist properly (e.g.in the correct encoding.)
- Level 2 Internal Consistency Testing:
  - all data fields are filled with meaningful values and the fields are internally consistent.
- Level 3 Semantic Testing:
  - a semantic test to verify that a generated biometric data interchange record is a faithful representation of the initial digital representation.

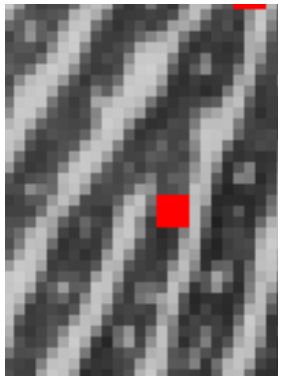
Semantic Conformance Testing

For fingerprint minutiae data

- template consists of automatically generated minutiae (*agm*)
  - *agm*‘s are encoded by an implementation under test (IUT)
- semantic test to be covered by ISO/IEC 29109-2 AMD1
- semantic conformance is assessed by three rates:
  - 1.) Test for the sandstorm and the fata morgana problem:
    - Is the for every ground truth minutia (*gtm*) in the vicinity an automatically generated minutia (*agm*) in the template?
  - 2.) Test for the out-of-area problem (false minutia):
    - How many automatically generated minutiae (*agm*) are placed outside or at the border of a fingerprint area?
  - 3.) Test for spurious minutiae in the fingerprint area:
    - How many automatically generated minutiae (*agm*) do not have a mate in the gtm-set

Proposed Testing Methodology

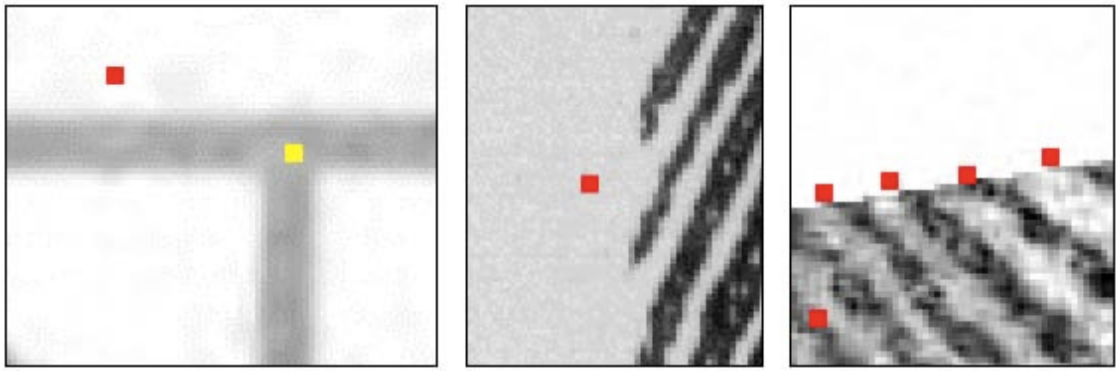
- Sandstorm and fata morgana *gtm*-test:
  - The gt-minutiae assertion test yields a first conformance rate cr_{gtm}
    - indicating the proportion of elements in the set of gt-minutiae for which a corresponding minutia exists in the set of automatically generated minutiae,
    - such that values can be compared for each data field and differences can be measured.
    - the assertion requires the corresponding minutia to be in the vicinity.



bifurcation detected
dislocated as ridge ending

Proposed Testing Methodology

- Out-of-area *agm*-test assertion:
  - asses the number of outside false minutiae (false minutiae)
  - an out-of-area *agm*-minutiae assertion test is yielding a second conformance rate cr_{agm} that is indicating the proportion of elements in the set of *agm* that are inside or at the borderline of the fingerprint area.



Proposed Testing Methodology

- Out-of-area *agm*-test assertion:
  - second conformance rate cr_{agm}

$$\mathrm{cr}_{agm} = \frac{\sum_{i=1}^{nagm} mps_i}{nagm}$$

  - where $nagm$ is the number of elements in the *agm* set and mps_i is the minutia position score for the i-th ag-minutia that indicates the homogenious distribution of ag-minutia with respect to the fingerprint area.
  - metric will reflect a "punishment" for those *agm* that are on the borderline or outside the fingerprint area according

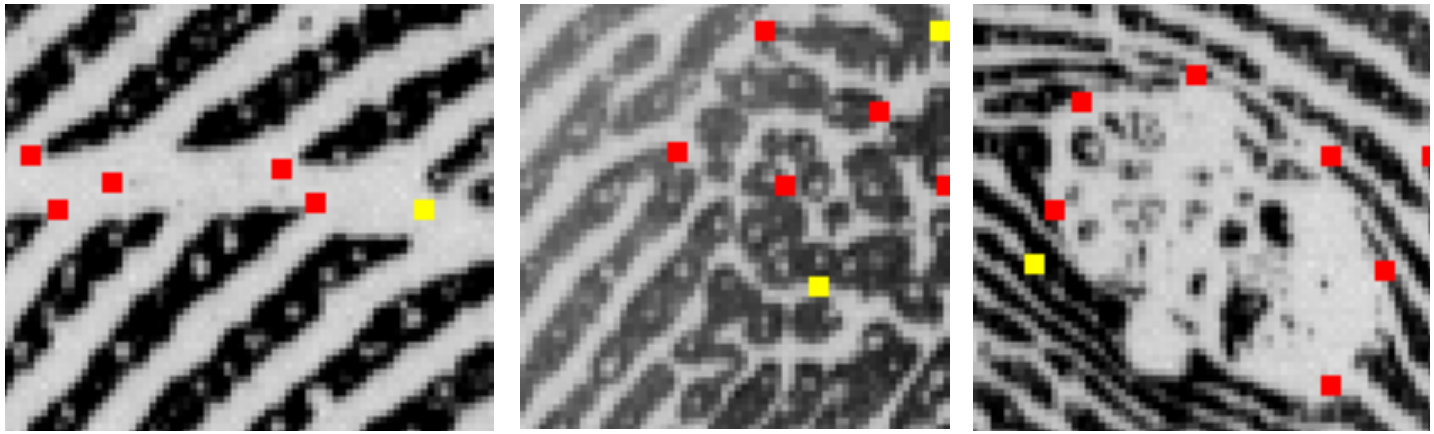
$$\mathrm{mps} = \begin{cases} 0 & \text{if } agm \text{ is outside the fingerprint area} \\ 0,5 & \text{if } agm \text{ is at the borderline} \\ 1 & \text{otherwise} \end{cases}$$

Proposed Testing Methodology

- Spurious *agm*-test assertion:
  - The set of agm minutiae may contain spurious minutiae that are located in the fingerprint area
    - scars, bent skin, skin disease, dirt, etc.
  - third conformance rate cr_{amf}

$$\mathrm{cr}_{amf} = 1 \quad \frac{niagm}{nagm}$$

    - where $niagm$ is the number of focused *agm* inside the fingerprint area, which does not correspond to any *gtm*.



Composing
Ground Truth Fingerprint Minutiae Date

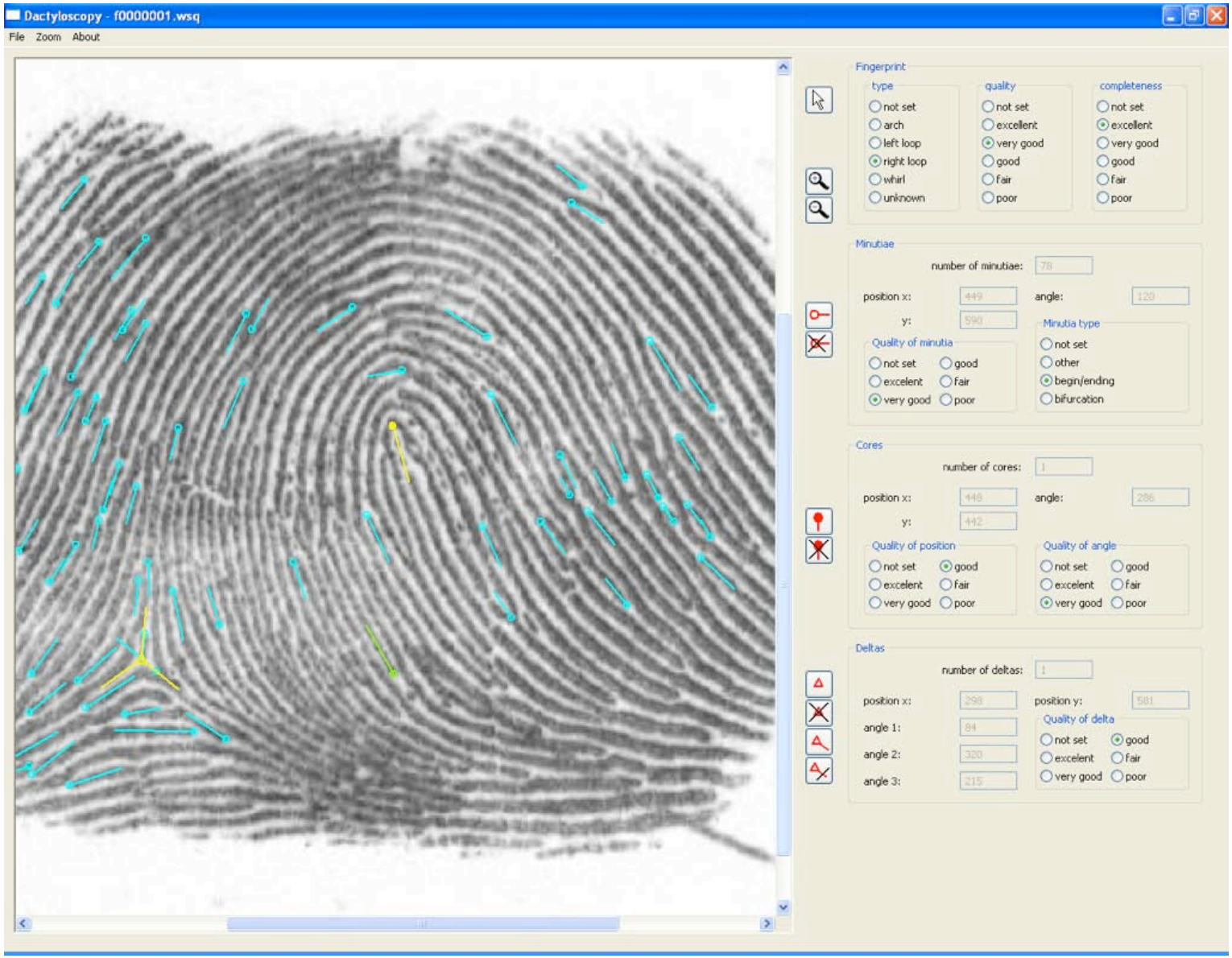
Semantic Conformance Testing

Challenge for implementing Semantic Testing:

- What is the „real minutia coordinate“?
- need for ground truth database (*gtd*) with minutiae data
  - need for public available fingerprint image data that is not restricted by privacy regulations
    - NIST special databases:
      SD14 rolled data and mostly ink with few live scanned images
      SD29 flat data /plain impression but all ink
  - need for dactyloscopic experts that define the truth!
    - Germany: Federal Criminal Police Office (BKA)
    - Australia: CrimeTrac
    - Czech Republic: Criminalistic institute Prague

Graphical User Interface

Ground Truth Minutia - GUI



Benefit of

a Ground Truth Minutiae Database

Benefit of a Ground Truth Database

Database can serve for many purposes

- providing the ground for development of a semantic conformance test methodology
- providing the ground for semantic conformance tests according ISO 29109-2 AMD1
- providing the ground for development and calibration of fingerprint image sample quality metrics
  - NFIQ2-development and training
- providing the ground for dactyloscopic training software

Initial Test Results

Test Results

Results BIOSIG 2009

- 17 images, max 11 experts each
- average $ngtm$: 59
- average agm: 100 (for NIST mindtct)

conformance rates	cr_{gtm}	cr_{agm}	cr_{amf}
average	0,353	0,885	0,662
std. deviation	0,179	0,066	0,178

Test Results

Results BioKeyS 2010

- 3 experts opinions each for 975 images (733 used)
  - SD14: 486 images / SD29: 247 images
- SD14 average *ngtm*: 76 (min 7 / max 174)
- SD14 average *agm*: 201 (min 87 / max 366) (NIST mindtct)

conformance rates	cr_{gtm}	cr_{agm}	cr_{amf}
average	0,464	0,857	0,645
std. deviation	0,092	0,063	0,123

- Generating this result was kindly supported by the German BSI under the BioKeyS-Pilot-DB project

Conclusion

- Conformance testing essential step in system selection
- Semantic conformance testing requires ground truth data
- Further datyloscopic experts groups welcome
- Testing methodology under development
  - fusion of conformance rates
  - thresholds for the conformance rate
- Further data segments addressed soon

Further Information

on Semantic Conformance Testing

- On March 5, at 11:30 a session on fingerprint feature markup and testing will be held.
  - This workshop will discuss work in this area, interoperability, reference datasets, and the possibilities for semantic conformance testing.
- Publications:
  - C. Busch, D. Lodrova, E. Tabassi, W. Krodel: "Semantic Conformance Testing for Finger Minutiae Data", in Proceedings of the IEEE International Workshop on Security and Communication Networks (IWSCN), Trondheim, ISBN 978-82-997105-1-0, pages 17-23, (2009)
  - D. Lodrova, C. Busch, E. Tabassi, W. Krodel, M. Drahansky: „Semantic Conformance Testing Methodology for Finger Minutiae Data“, in Proceedings BIOSIG 2009, (2009)
- Website with information on the topic
  - http://www.igd.fraunhofer.de/~busch/gtd

Thank you for your attention
and many thanks
to the dactyoloscopic experts
contributing to the
ground truth database

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