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Detection of Counterfeit Coins with Optical Methods and Their Industrial Implementation

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Ralf Freiberger

Overview

- Purpose
- Different methods for detection of counterfeit coins
- Optical methods
- Examples
- Summary and outlook

Purpose

- Detecting fakes among genuine coins is mainly a matter of manual inspection.
- Contactless optical methods to identify fakes in a high throughput process are the newest challenge for Mints.
- Visual indications of counterfeits can be <u>everywhere</u> (obverse, reverse, edge).

Purpose

An interactive process between **all** vision stations which is based on the inspection results **and** an empirical contingency table of all known fake characteristics raises the inspection reliability up to 100%.

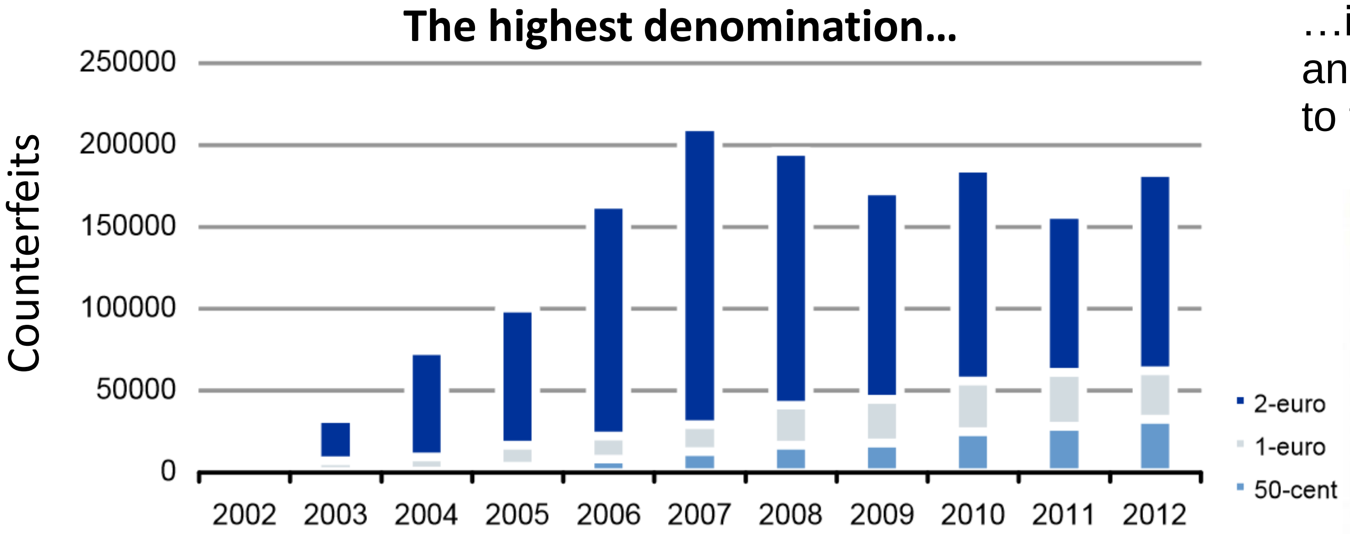
Goal:

1.) Output of genuine coins → almost 100% safe !

2.) False reject rate → to be minimized (no genuine coins in reject-box).

Detection of Counterfeit Coins with Optical Methods and Their Industrial Implementation

Purpose



The protection of euro coins in 2012 Situation as regards euro coin counterfeiting and the activities of the European Technical & Scientific Centre (ETSC) Based on Article 4 of Commission Decision C (2004) 4290 of 29 October 2004

…is mostly the main problem and causes the highest harm to the national economy.

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Different methods for detection of counterfeit coins

Non-contactless inspections:

- Manual inspection: excellent quality, but too slow.
- Mechanical inspection (e.g. weight, center of gravity): not fast enough for industrial use and less information.
- Chemical inspection (e.g. micrographs): slow, destructive and less information.

Different methods for detection of counterfeit coins

Contactless inspections:

Electro-magnetic (e/m)-sensors

- Reliable and fast, but only if the alloy or dimension is *wrong* in the fakes !
- e/m-sensors fails if alloy and dimension is *correct* or within tolerances in the fakes !

Different methods for detection of counterfeit coins

Contactless inspections:

Tendering for the alloy of coins creates a problem for mints:
Different suppliers have slightly different compositions of alloy within the given specification.

In counterfeit coins the alloy is also nearly the same and often within specification.

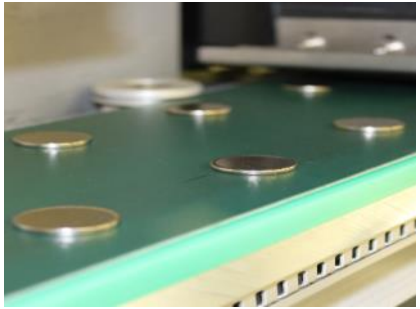
⇨ Many counterfeit coins pass the e/m-sensor with the result „correct alloy".

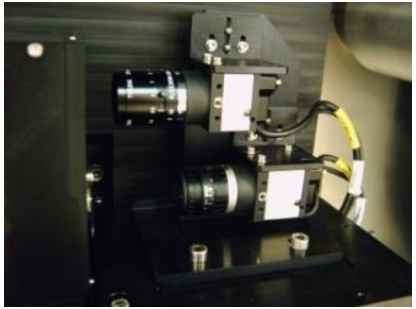
⇨ An additional and reliable check is necessary !

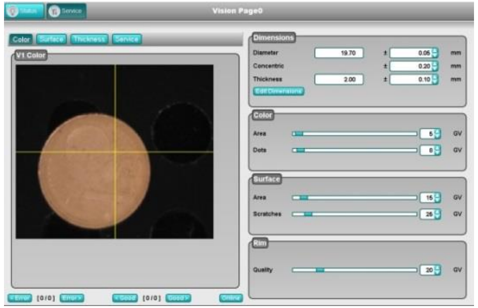
Optical methods

Optical methods are contactless and the fastest methods.

3000 coins / min are state of the art.







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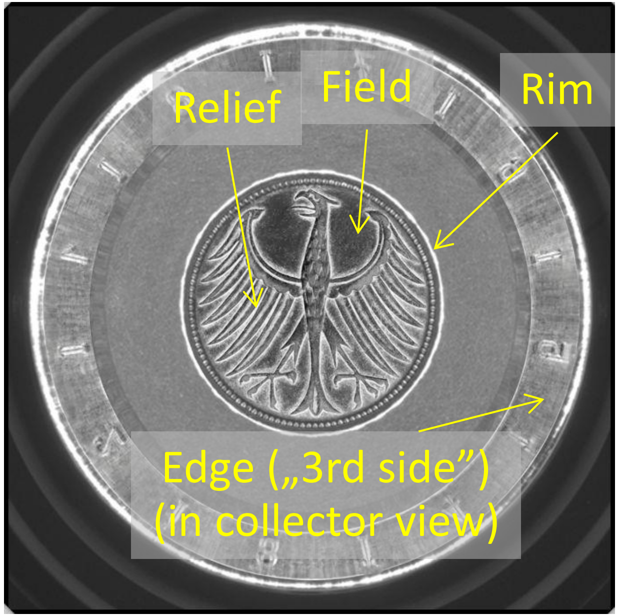
Optical methods



Obverse and reverse are checked in separate stations plus each time the edge in the *collector view* (edge visualized in a top view image).

These four characteristics (left hand image) are exemplarily; for different reasons detailed techniques cannot be explained here.

More details: „Coin edge inspection“, Ralf Freiberger, Technical Forum WMF, Berlin, 2015.

Optical methods

Why is it useful to combine vision units ?

Often we have a correlation between characteristics in fakes:

- Bag or tooling-marks *(comparison date vs. bag or tooling-marks)*

  No two or more genuine coins have identical bag marks.
  Bag marks on fakes result from defects of the original which are transferred to counterfeiters master-die.
- Quality is different on obverse and reverse

  Counterfeiters often take same (*old*) transfer/impact die for undated side and produce *new* dies for dated side *(comparison obverse vs. reverse)*
- Genuine and Counterfeit show different behavior concerning aging

  (comparison date vs. quality)
- …

Optical methods

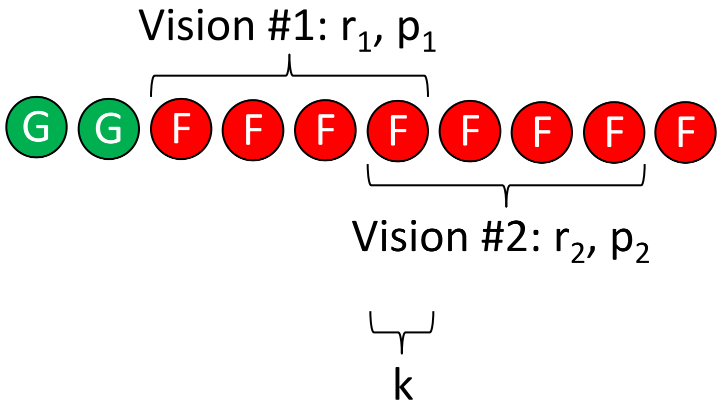
Why is it useful to combine vision units ?

The combination of results from different vision-stations and the knowledge of the correlation between counterfeit characteristics rises the inspection reliability dramatically !

Example: 1st vision unit checks reverse, 2nd vision unit checks obverse.
In the case of counterfeited coins made by impact dies the quality of the two surfaces could be different. For each vision unit the surface of a coin could look OK, but the *comparison* of both could expose the counterfeit.

Optical methods

Combining visions



- Vision #1: Detection of a characteristic that can be found on r_1*100% of all counterfeit coins. This characteristic can be detected at vision #1 with a probability of p_1*100% .
- Vision #2: Detection of a characteristic that can be found on r_2*100% of all counterfeit coins. This characteristic can be detected at vision #2 with a probability of p_2*100% .
- On k*100% of all counterfeit coins two characteristics can be found. One characteristic can be detected with vision #1, the other one with vision #2.

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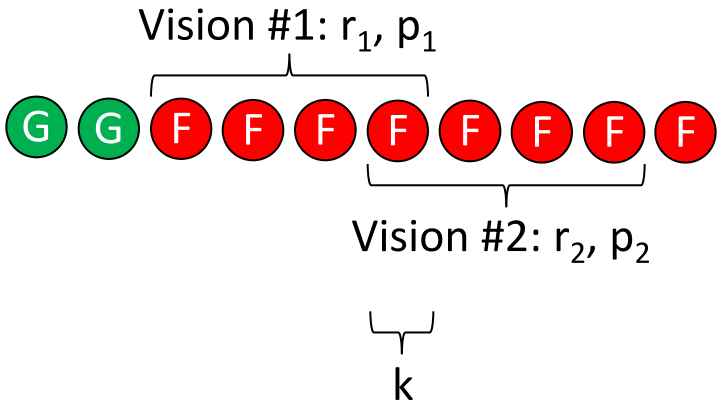
Optical methods

Example:



The detection performance of the complete system is:

$$P = k^* [1-(1-p_1)^*(1-p_2)]+(r_1-k)^*p_1+(r_2-k)^*p_2$$

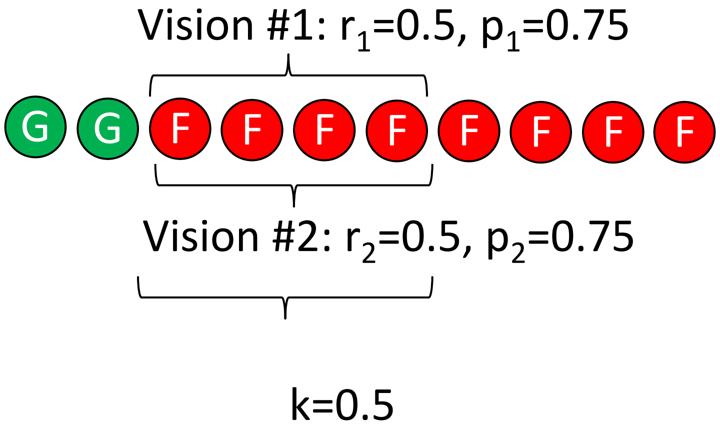
The maximum detection performance is (lets say vision #1 = 100% and vision #2 100 %)

$$P = (r_1 + r_2 – k) * 100\%$$

Ralf Freiberger

Optical methods

Example:



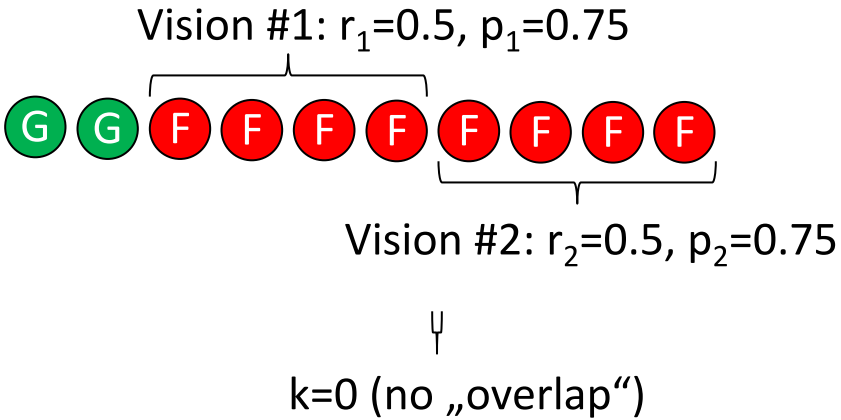
P_1 = 37.5 % (only vision #1)

P_2 = 37.5 % (only vision #2)

P = 46.875 % detection performance

Optical methods

Example:



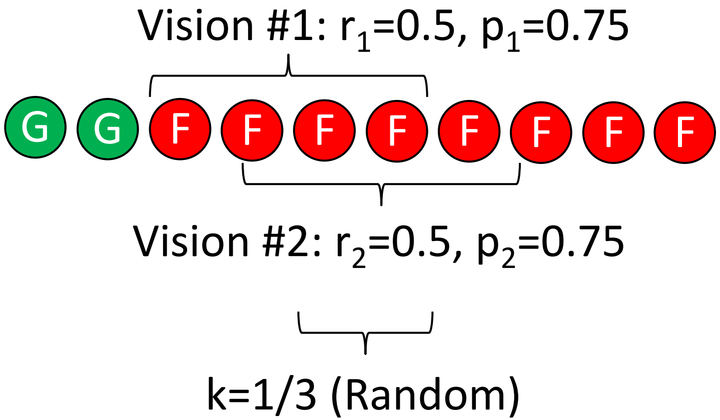
P_1 = 37.5 % (only vision #1)

P_2 = 37.5 % (only vision #2)

P = 75 % detection performance

Optical methods

Example:



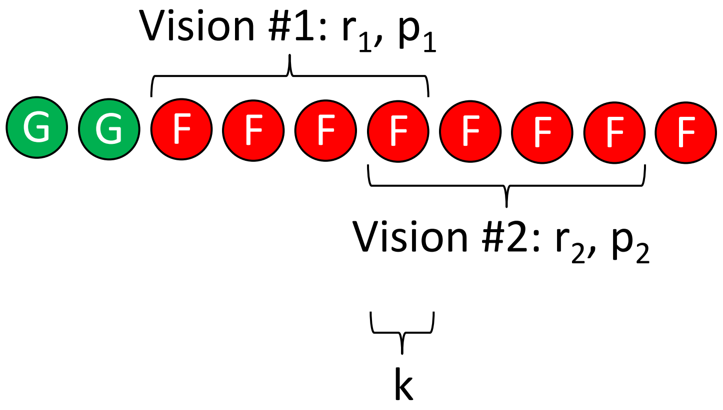
P_1 = 37.5 % (only vision #1)

P_2 = 37.5 % (only vision #2)

P = 56.25 % detection performance

Optical methods

Example:

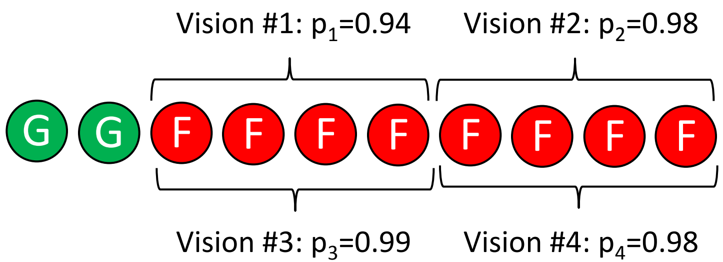


- The detection performance of the complete system is influenced by:
- $p_{1,}$ p_2 … probability to find characteristic
  → This can be increased by better vision algorithms etc.
- $r_{1,}$ r_2 … ratio of one characteristic
  → fixed
- k: correlation of the characteristics
  → Depends on the empirical knowledge of mints, experts, counterfeiters, police…

Optical methods

Example:

P = 99.950 % !



- Lets say 10 million* circulation coins with 0.02% counterfeit-rate = 2000 counterfeit coins.

  → Task: Check of 2000 counterfeit coins:

- Using only vision #3 (highest p=0.99)
  → 1010 counterfeits coins are not detected !

- Combination of all visions
  → Only 1 counterfeit coin will not be detected !

  → The failure-rate is approx. 1000 times lower !!

*e.g. 0.2% of all 2€-coins in the EU ! Could be checked in less than three days !

Optical methods

The failure-rate in this example is

1 coin per 10 million circulation coins = 0.1 ppm !

Optical methods

Integration and evaluation:

The results of the different vision-stations have to be connected and after all available information is collected the coin passes as „OK“ or is rejected.

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Optical methods

Criteria	Coin #1	Coin #2	Coin #3	Coin #4	Coin #5	Coin #6	Coin #7	…	Coin #n
„Perfect“ Criteria (**P=100%**)	OK	OK	OK	No result	OK	False	False		
Rim (P<100%)	OK	OK	No result	No result	OK	OK	False	…	…
Edge (P<100%)	OK	No result	No result	No result	OK	OK	False	…	…
Field (P<100%)	OK	OK	No result	No result	OK	OK	False	…	…
Relief (P<100%)	OK	OK	No result	No result	False	False	False	…	…
…	…	…	…	…	…	…	…	…	…
Result	OK	OK	OK	No result	No result	False	False	…	…

„OK“ as result appears, when no „False“ is in the column above.
„False“ as result appears, if at least one „False“ is in the column above.

Optical methods

Criteria	Coin #1	Coin #2	Coin #3	Coin #4	Coin #5	Coin #6	Coin #7	…	Coin #n
„Perfect“ Criteria (**P=100%**)	OK	OK	OK	No result	OK	False	False		
Rim (P<100%)	OK	OK	No result	No result	OK	OK	False	…	…
Edge (P<100%)	OK	No result	No result	No result	OK	OK	False	…	…
Field (P<100%)	OK	OK	No result	No result	OK	OK	False	…	…
Relief (P<100%)	OK	OK	No result	No result	False	False	False	…	…
…	…	…	…	…	…	…	…	…	…
Result	OK	OK	OK	No result	No result	False	False	…	…

„No result“ appears, when the result is unclear, for example the coin is damaged too much or a big overlap is between newer counterfeit and older genuine coins or the result is not logical. These coins are collected in a separate ejection-box.

Optical methods

Coins are separated automatically after the evaluation:

1.) Pass = Genuine & good quality

2.) Eject box 1 = Genuine & poor quality

3.) Eject box 2 = Genuine & some characteristic to be defined by operator (e.g. coins older than 19xx)

4.) Eject box 3 = Unclear, can be evaluated again or manually investigated

5.) Eject box 4 = Counterfeit coins

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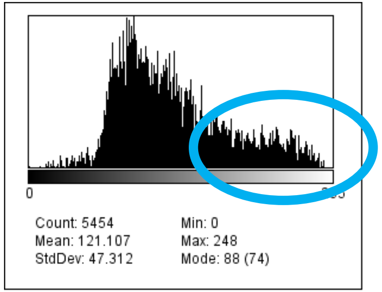
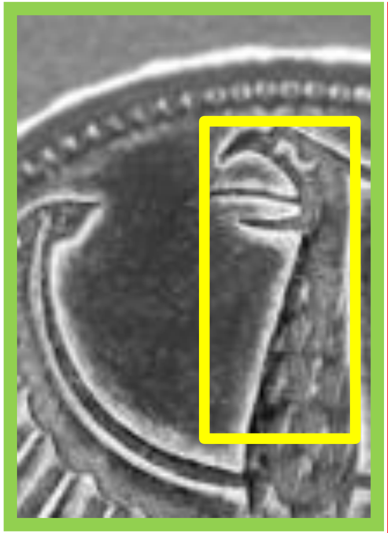
Example (relief-contrast)



Finger print

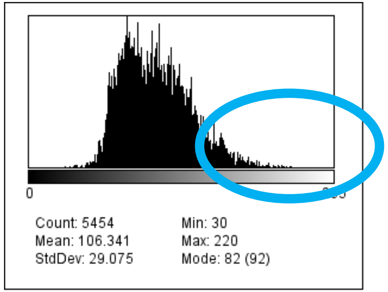
$\sigma = 47$

Good contrast



Genuine

Counterfeit

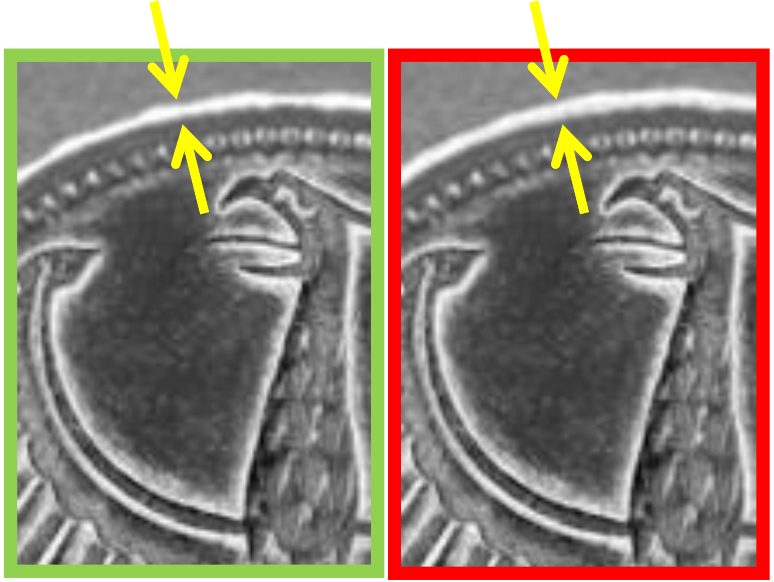


Finger print

$\sigma = 29$

Poor contrast

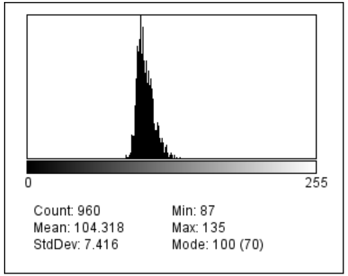
Example (rim-width)



Genuine Counterfeit

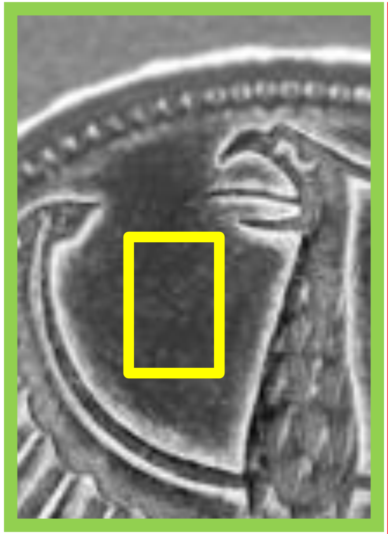
With special illumination techniques the rim appears broader on many fakes.

Example (field-roughness)

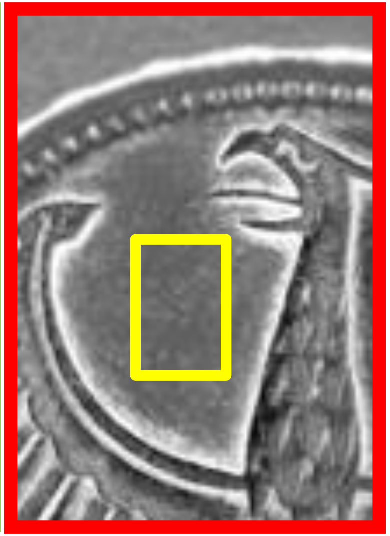


$\sigma = 7$

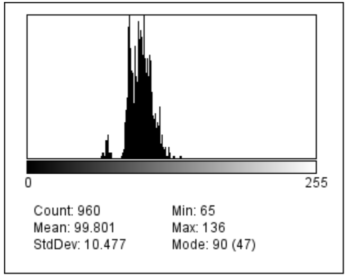
Flat surface



Genuine



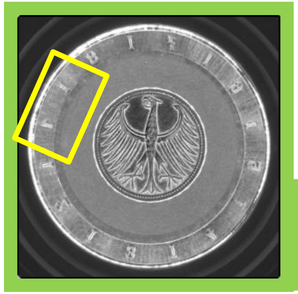
Counterfeit



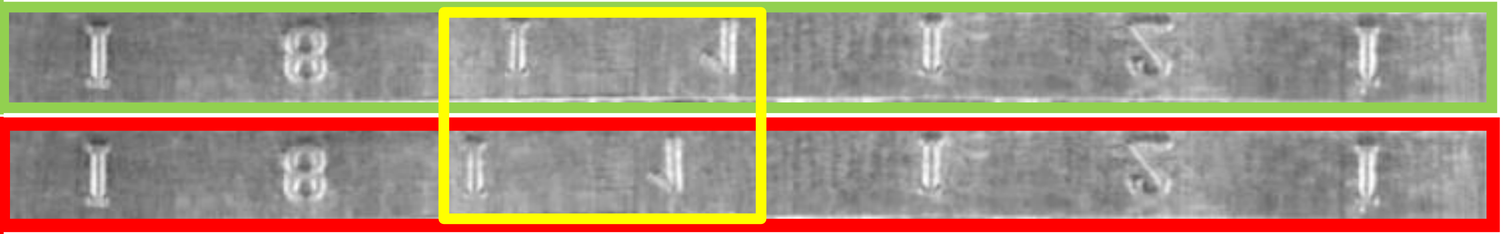
$\sigma = 10$

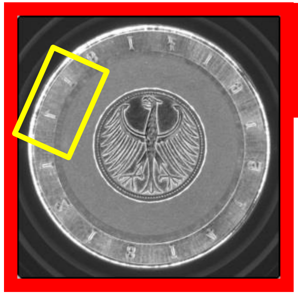
Rough surface

Example (edge-lettering)



Genuine





Counterfeit

Summary and outlook

Optical methods

- Contactless and very fast
- Integration in high-throughput processes
- Vision-software evaluates and combines all results of each coin
- High detection performance
- Low false rejects

Thank you very much for your attention !

Questions ?

Please also visit us at booth B26.

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