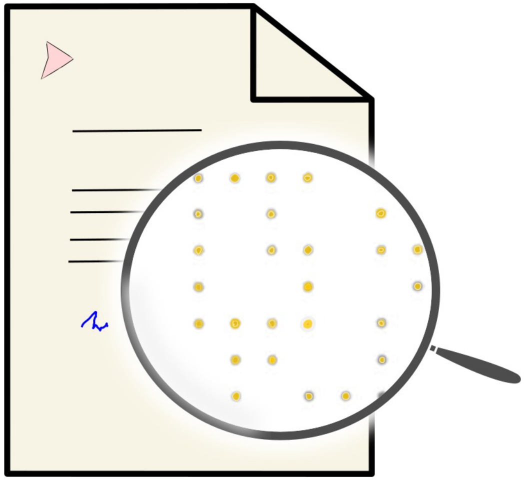
# PRINTER FORENSICS



Stephan Escher

09.05.2019

# Metadata

- Stephan Escher (stephan.escher@tu-dresden.de)
- Lehrstuhl Datenschutz und Datensicherheit – TU Dresden
- Projekt: Duplikatsprüfung und Forensik an gedruckten Dokumenten
- https://dfd.inf.tu-dresden.de

- Kooperationspartner: Dence GmbH (dence.de)
- Förderer: BmWi

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

# Motivation

- Last 30 years: development of high quality and low-cost printers, scanners, image manipulation tools

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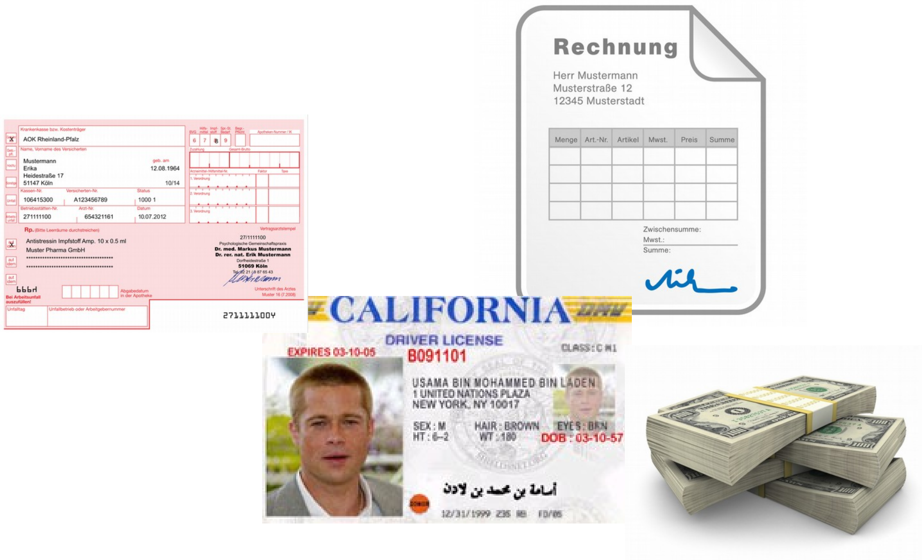
- Used everywhere: PIDs, credentials, money, certificates, contracts, …



Krankenkasse bzw. Kostenträger
☒ AOK Rheinland-Pfalz
Name, Vorname des Versicherten
Mustermann
Erika
Heidestraße 17
51147 Köln
geb. am 12.08.1964
10/14

| Kassen-Nr. | Versicherten-Nr. | Status |
|---|---|---|
| 106415300 | A123456789 | 1000 1 |
| **Betriebsstätten-Nr.** | **Arzt-Nr.** | **Datum** |
| 271111100 | 654321161 | 10.07.2012 |

| BVG | Hilfs-mittel | Impf-stoff | Spr.-St. Bedarf | Begr.-Pflicht | Apotheken-Nummer / IK |
|---|---|---|---|---|---|
| 6 | 7 | 8 | 9 | | |

Zuzahlung Gesamt-Brutto
Arzneimittel-/Hilfsmittel-Nr. Faktor Taxe
1. Verordnung
2. Verordnung
3. Verordnung

Rp. (Bitte Leerräume durchstreichen)
☒ aut idem Antistressin Impfstoff Amp. 10 x 0.5 ml
Muster Pharma GmbH
aut idem
aut idem

Vertragsarztstempel
27/1111100
Psychologische Gemeinschaftspraxis
**Dr. med. Markus Mustermann**
**Dr. rer. nat. Erik Mustermann**
Dorfheidestraße 1
**51069 Köln**
Tel. 02 21 / 9 87 65 43
Unterschrift des Arztes
Muster 16 (7.2008)

6664
Abgabedatum in der Apotheke
**Bei Arbeitsunfall auszufüllen!**
Unfalltag
Unfallbetrieb oder Arbeitgebernummer
271111100Y

**Rechnung**
Herr Mustermann
Musterstraße 12
12345 Musterstadt

| Menge | Art.-Nr. | Artikel | Mwst. | Preis | Summe |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Zwischensumme:
Mwst.:
Summe:

CALIFORNIA DMV
DRIVER LICENSE
EXPIRES 03-10-05
B091101
CLASS: C M1
USAMA BIN MOHAMMED BIN LADEN
1 UNITED NATIONS PLAZA
NEW YORK, NY 10017
SEX: M HAIR: BROWN EYES: BRN
HT: 6-2 WT: 180 DOB: 03-10-57
أسامة بن محمد بن لادن
12/31/1999 236 RB FD/05

# Motivation

- Last 30 years: development of high quality and low-cost printers, scanners, image manipulation tools
- Used everywhere: PIDs, credentials, money, certificates, contracts, …
- Anybody can create, manipulate and duplicate documents and images

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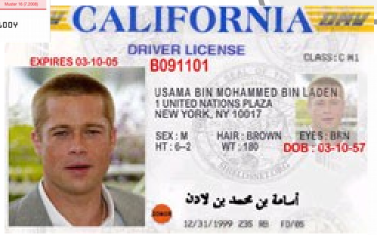
Zwischensumme:
Mwst.:
Summe:



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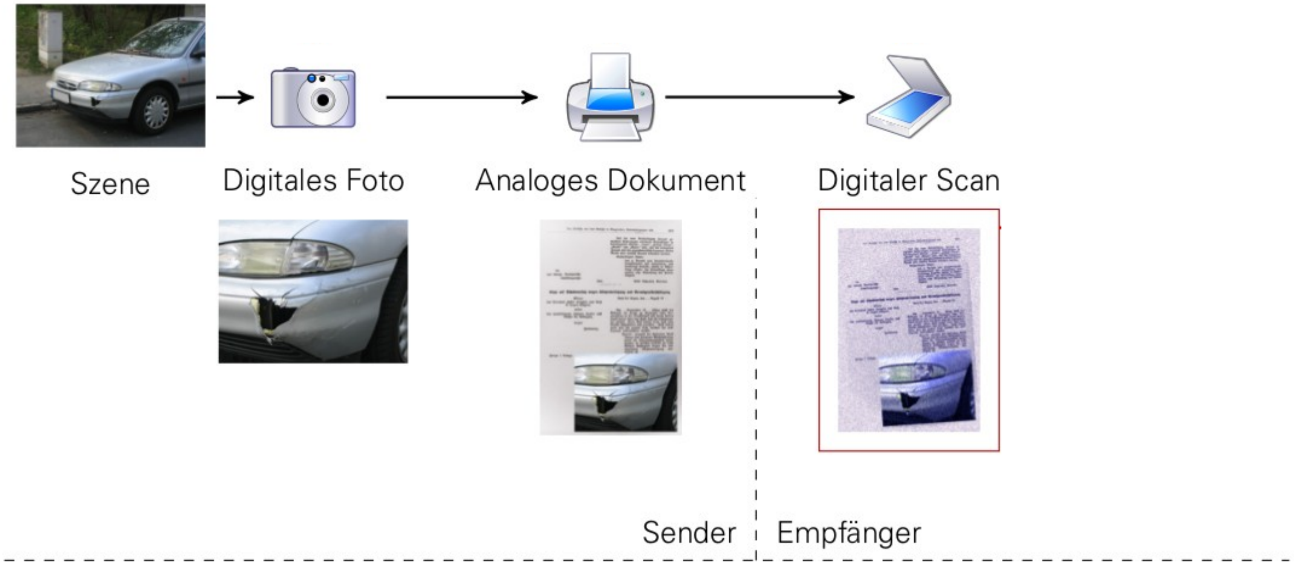
أسامة بن محمد بن لادن
12/31/1999 235 RB FD/05

# Project Use Case - Insurance



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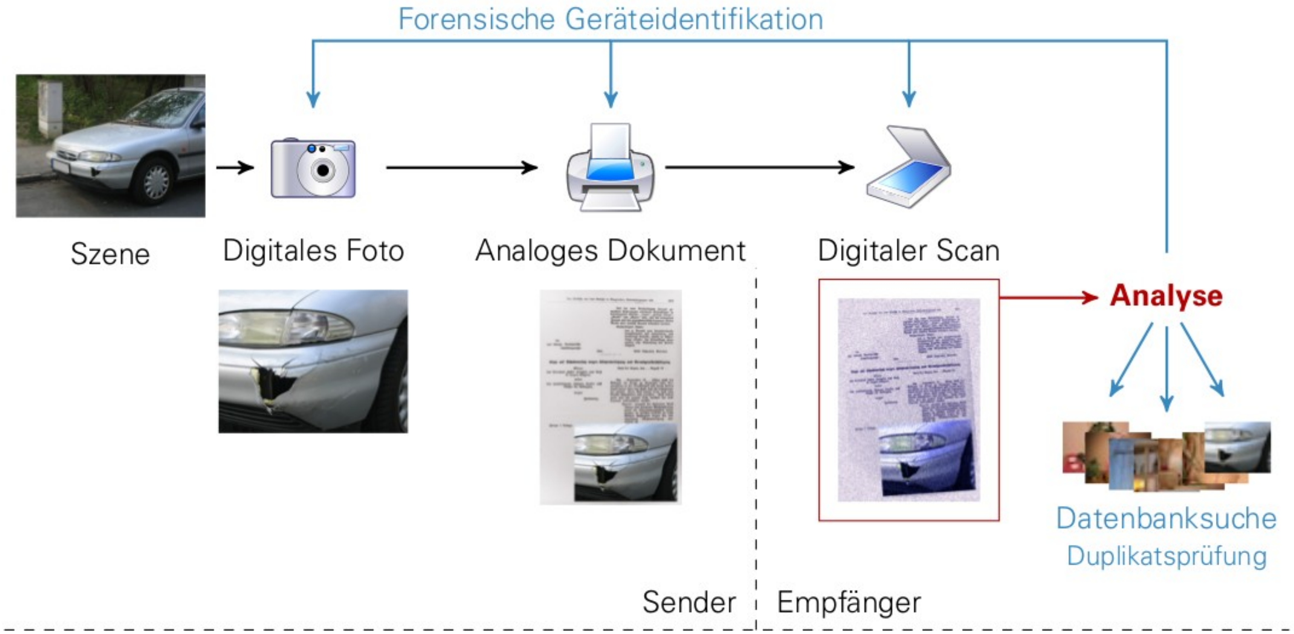
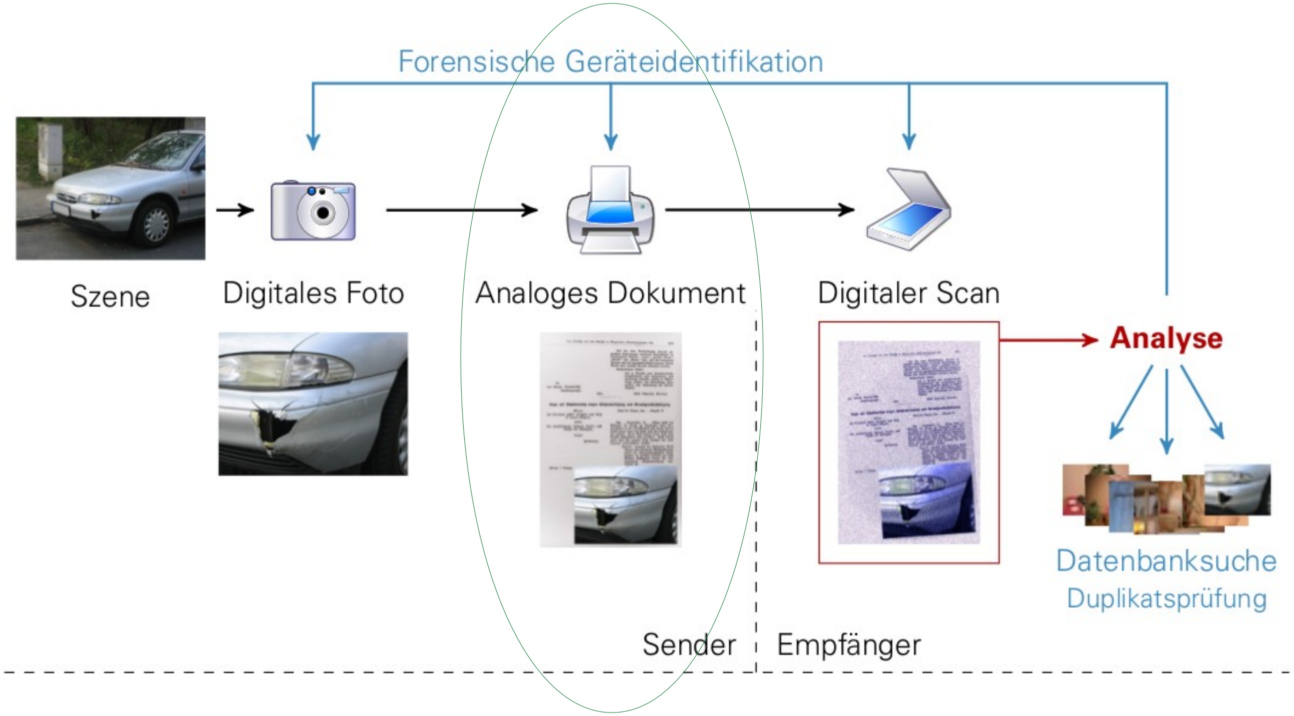


# Printer Forensics



# Printer Forensic Questions

- **Printer technology**
- Printer device
- Comparison of multiple documents
- Forgery detection
- Age of a document

SPORT

Sparen und siegen

Sieben Jahre lang brachte Schuldenklub TSV München 1860 die Fußball-Bundesliga in Mißkredit. Der Klub stieg ab, Konkurs drohte. Jetzt ermöglicht ein Notprogramm die Rettung.

→

Laserprinter
Inkjet
Photocopier
Offset
...

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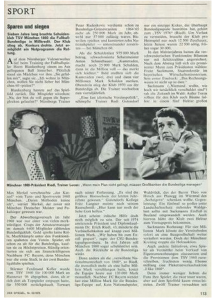

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Auf dem Nürnberger Valznerweiher lief beim Training der Fußballspieler Horst Blankenburg einem ins Aus gelaufenen Ball hinterher. Plötzlich stand ein Mädchen vor ihm. „Sie gefallen mir", sagte sie. „Ich wohne in München, wollen Sie nicht lieber bei München 60 spielen?"

Blankenburg hastete auf das Spielfeld zurück. Die Mitspieler witzelten: „Na, der bist du wohl gegen die Superglocken gelaufen?" Nürnbergs Trainer Max Merkel verscheuchte „das Katzerl" vom Turn- und Sportverein 1860 München. „Deren Methoden kenne ich", verriet Merkel, der zuvor mit München Deutscher Meister und Pokalsieger gewesen war.

Der Abwerbungsversuch im Jahr 1968 war nur einer von vielen merkwürdigen Coups der Amateurmanager im damals 6400 Mitglieder zählenden Bundesligaklub. Geld spielte keine Rolle, Machtkämpfe unter den Funktionären spalteten den Verein. Spieler, oft schon zu alt für die Bundesliga, kauften sie zu Höchstpreisen. Ständig orientierten sie sich am finanzkräftigeren Nachbarn FC Bayern, denn München war die erste Stadt, in der zwei Bundesligaklubs spielten.

Stürmer Ferdinand Keller wurde vom TSV 1860 für 100 000 Mark an Hannover 96 abgegeben, dann, als er sich dort als Topspieler entpuppt hatte, für 550 000 zurückgekauft. Torwart Petar Radenkovic verdiente schon zu Bundesliga-Gründerzeiten 1964/65 mehr als 250 000 Mark im Jahr, obwohl nur 57 000 zulässig waren. Bisweilen spielten und kassierten zehn Nationalspieler — untereinander zerstritten — bei München 60.

Als die Schuldenlast 975 000 Mark betrug, schwadronierte Schatzmeister Anton Schmidbauer: „Kameraden, macht noch 25 000 Mark Schulden, dann ist die Million voll — das merkt sich leichter." Bald mußten sich die Kameraden zwei, drei und dann vier Millionen Mark Schulden merken. Obendrein stieg der Klub 1970 aus der Bundesliga ab. Die Trainer wechselten nun vierteljährlich.

„Eine fast idiotische Vereinspolitik", schimpfte Trainer Rudi Gutendorf nach seiner Entlassung. „Es sind die größten Hornochsen der letzten Jahrzehnte gewesen." Gutendorfs Kollege Fritz Langner meinte nach seinem Rausschmiß: „Hier kann nur noch der liebe Gott helfen."

Jetzt scheint irdische Hilfe doch noch möglich zu sein. Der seit 1974 amtierende Präsident und Diplomkaufmann Dr. Erich Riedl, 43, minderte die Verbindlichkeiten auf knapp zwei Millionen Mark. „Wir haben bis zum Exzeß gespart", sagte der CSU-Bundestagsabgeordnete. In drei Jahren soll München 1860 sogar schuldenfrei sein. Auch die Rückkehr in die Bundesliga winkt.

Denn anders als die „verwöhnte Nationalmannschaft von 1860", so Riedl, die monatlich mehr als eine halbe Million Mark verschlungen hatte, kostet die Equipe heute nur 120 000 Mark monatlich. Nachbar FC Bayern wendet fast eine Million Mark für die Bundesliga-Equipe auf. Kein Nationalspieler, nur ein einziger Kicker, der überhaupt Bundesligaspiele bestritten hat, gehört zum „TSV 1976" (Riedl). Um Verlust zu vermeiden, braucht der Klub pro Heimspiel nur noch 12 500 Zuschauer, letzte Saison waren 22 500 nötig, früher sogar 30 000.

In den Meisterjahren hatten die verschwenderischen Funktionäre Bilanzen nur mit Schätzzahlen angereichert. Nach dem Abstieg ließ sich ein prominenter Mann zum Präsidenten wählen: Franz Sackmann, Staatssekretär im bayerischen Wirtschaftsministerium. Sein erster Eindruck: „Das Rechnungswesen ist nicht up to date."

Sackmann („Niemand wußte, wie hoch wir tatsächlich verschuldet sind") sah die Zukunft im Wald: Außer Toren sollten für den Klub auch Bäume fallen: in einem fünf Hektar großen Waldstück, das der Baron Theo von Hirsch aus Planegg im Würmtal den „Sechzigern" schenken wollte. Gegenleistung: Ein fünfmal so großes unter Landschaftsschutz stehendes Waldgebiet sollte mit Sackmanns Einfluß in Bauland umgewandelt werden. Auch hiervon hätte der Klub zwei Hektar zum Vorzugspreis bekommen.

Sackmanns Rechnung: Für vier Millionen Mark könnte der Vereinsboden sofort an eine Baugesellschaft weiter veräußert werden. Doch der Münchner Kreistag stoppte die Holzauktion.

Auch andere Initiativen, etwa Spieler als Vermittler beim Verkauf von Eigentumswohnungen einzusetzen und die Provisionen dem TSV 1860 zuzuschreiben, fruchteten wenig. Ebenso mißlang eine Plakettenverkaufsaktion „I like 1860".

Denn immer weniger liebten die Fans ihre Spieler, die zwar teuer waren, aber auf dem Spielfeld kaum etwas leisteten. Zwölf Trainer verbrauchten seit

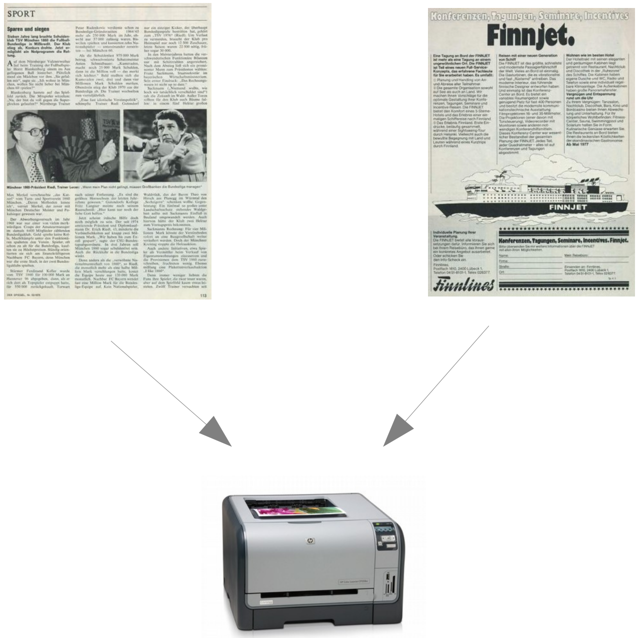
Münchner 1860-Präsident Riedl, Trainer Lucas: „Wenn mein Plan nicht gelingt, müssen Großbanken die Bundesliga managen"

DER SPIEGEL, Nr. 52/1976 113

Brand HP
Modell M553
Device CNCXF526

# Printer Forensic Questions

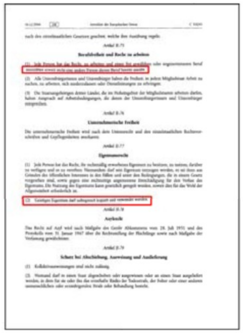
- Printer technology
- Printer device
- **Comparison of multiple documents**
- Forgery detection
- Age of a document



Same source printer?

# Printer Forensic Questions

- Printer technology
- Printer identification
- Comparison of multiple documents
- **Forgery detection**
- Age of a document



Was the document forged, …?

# Possible Solutions

- **Active Techniques**

  embed proactively information (extrinsic signatures) in documents before or while printing

- **Passive Techniques**

  use print artifacts (intrinsic signatures) caused by the printing mechanism

# Passive Techniques

- Use of intrinsic signatures

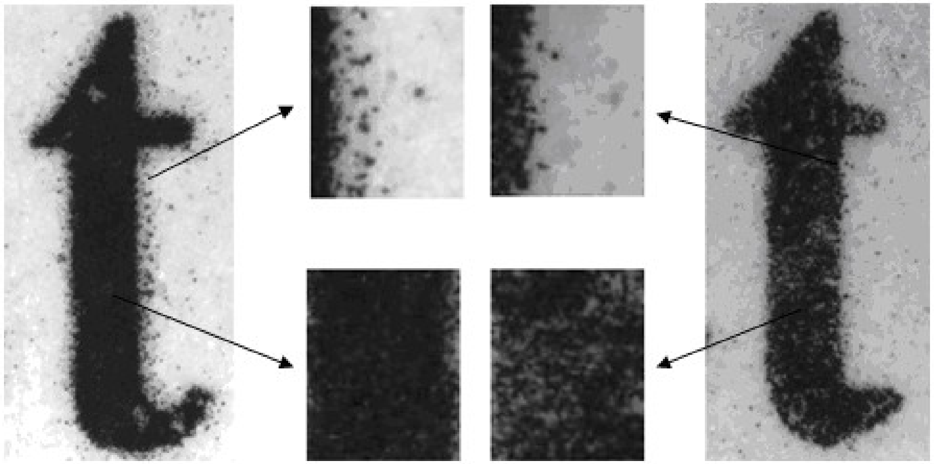
  → printing artifacts which are technology / brand / model / device dependent

  → electromechanical / mechanical imperfections, differences between constructions of printer models

  → should be stable over several printouts

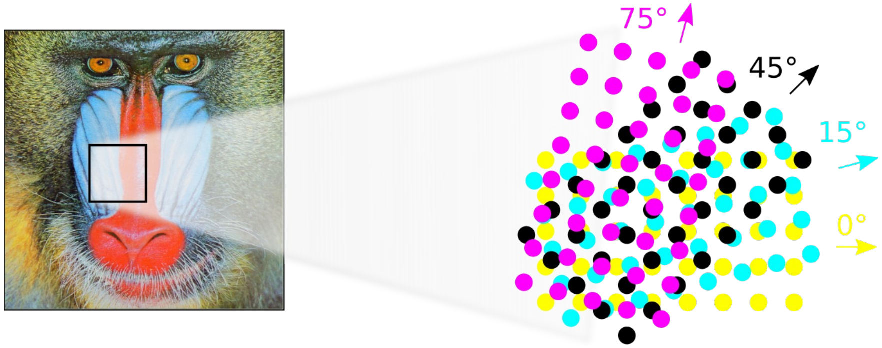
# Intrinsic Signatures - Text

- **Micro textures**
- **Edge structur**
    - Roughness
    - Gradient
- Overspray
- Geometric distortion



# Intrinsic Signatures - Images

- **Halftoning**
  - Arrangement (AM)
  - Dot shape
- Color noise
- Geometric distortion (Banding, ...)



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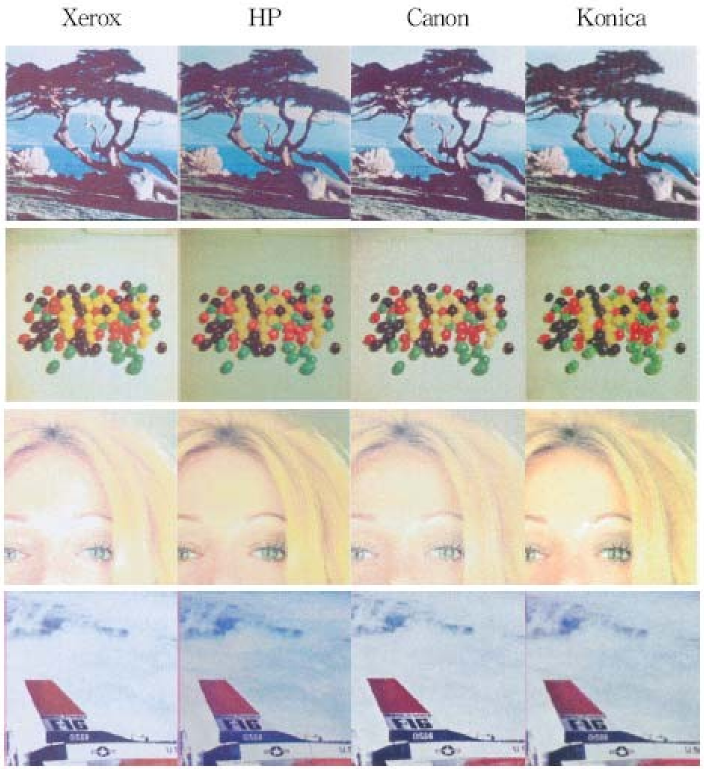
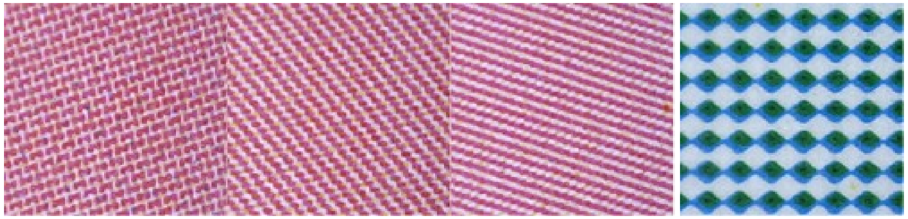


# Findings

- Many potentially influencing parameters which could change the signature itself
    - Driver settings (e.g. toner save modi, resolution), age of the toner, used paper (plain vs. recycled), different font types, …
    - Forgery of signature sometimes possible (e.g. halftoning)
- Possible overlaps for large datasets
- Max. identification rate: printer model

→ *active methods* are more accurate



# Active Techniques

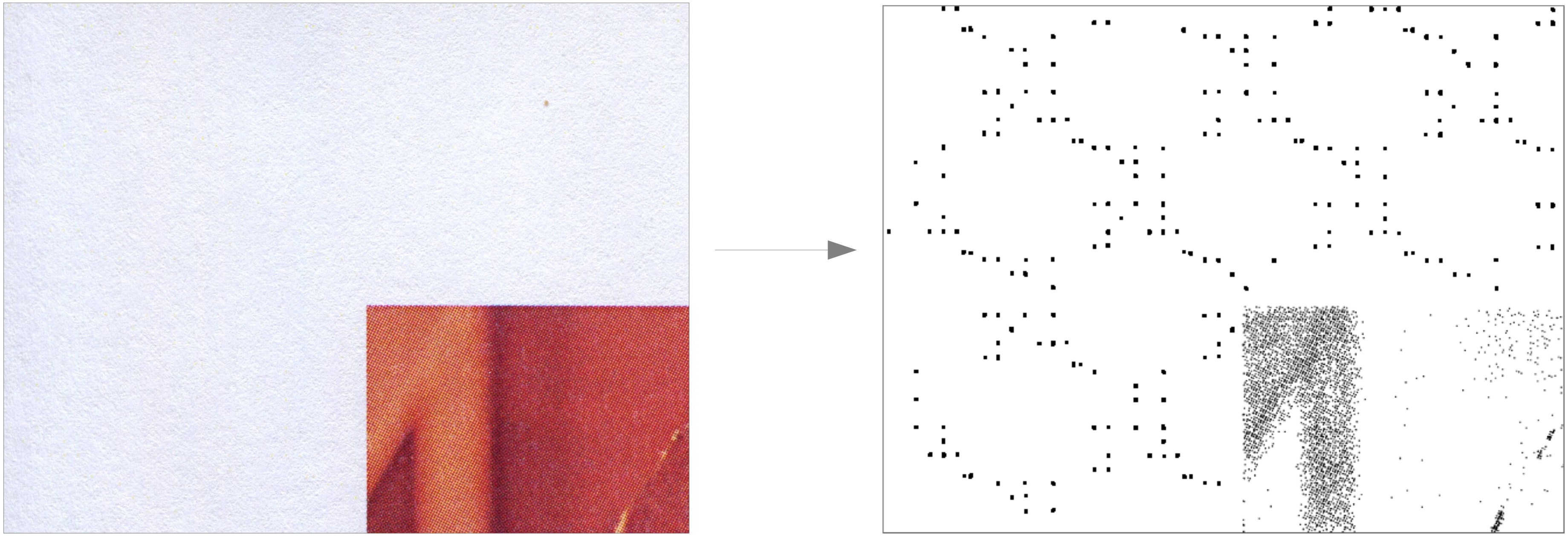
- Embed information in documents before or while printing (extrinsic signatures)
- Concrete information within the document
- Needs access to the document or printer device
- Unusable for project use case – except **Tracking Dots**

# Tracking Dots

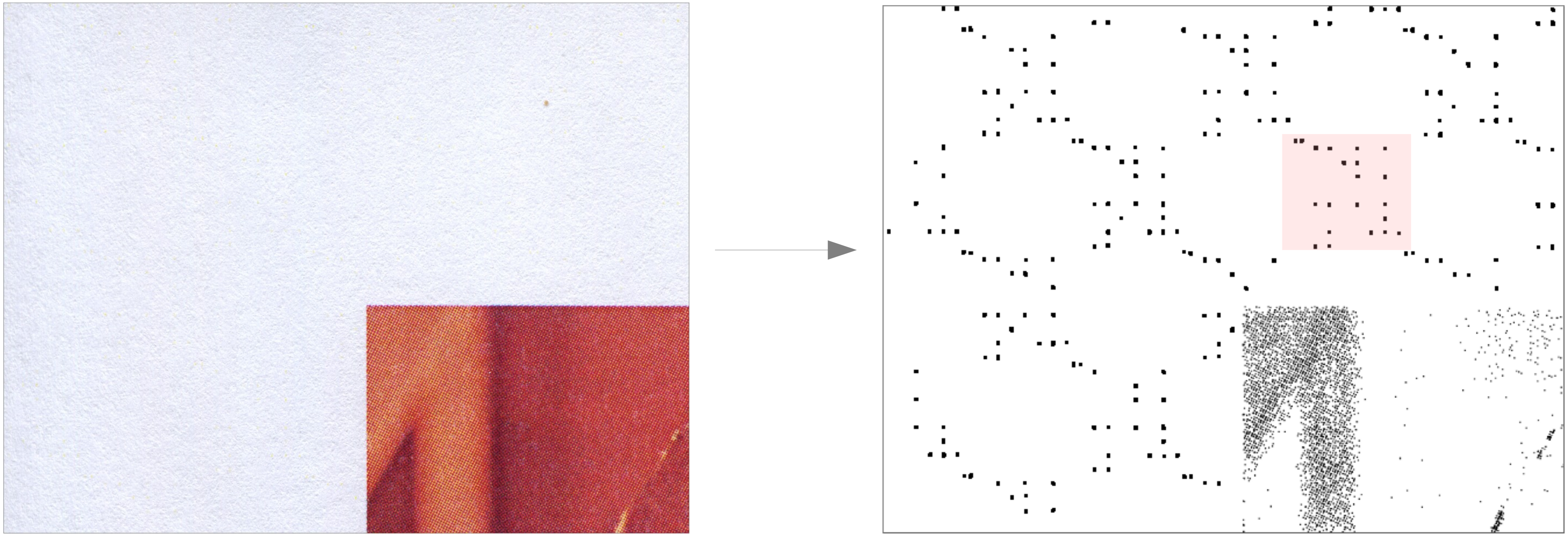
- Tiny Yellow Dots (~0.003 mm - not visible to the naked eye) ordered in matrices
- Repeated over entire document
- Implemented in colour laser printers itself
  → embedded while printing
- Found in 2005 by EFF and DFKI
  - Decoded 1 Pattern
  - Tracking dot pattern contains a serial number, date and time

→ *Reuse Tracking Dots for Project Use Case?*

# Tracking Dots

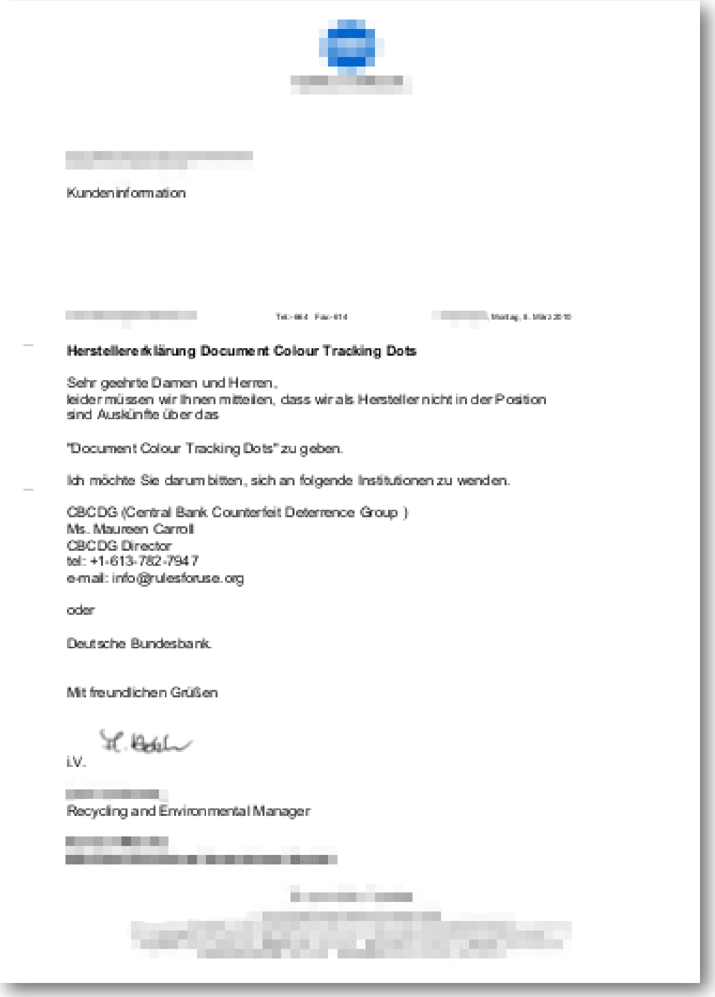


# Tracking Dots



# Tracking Dots

- Official reason, embedded information and structure unknown
- Several manufacturers contacted
- Printer manufacturer (document from 2010): Please contact the following institutions:
    - Central Bank Counterfeit Deterrence Group (CBCDG)
    - German Federal Bank
- CBCDG: „Not a CBCDG product“



[redacted]

[redacted]

Kundeninformation

[redacted] Tel.-664 Fax-614 [redacted], Montag, 8. März 2010

**Herstellererklärung Document Colour Tracking Dots**

Sehr geehrte Damen und Herren,
leider müssen wir Ihnen mitteilen, dass wir als Hersteller nicht in der Position
sind Auskünfte über das

"Document Colour Tracking Dots" zu geben.

Ich möchte Sie darum bitten, sich an folgende Institutionen zu wenden.

CBCDG (Central Bank Counterfeit Deterrence Group )
Ms. Maureen Carroll
CBCDG Director
tel: +1-613-782-7947
e-mail: info@rulesforuse.org

oder

Deutsche Bundesbank.

Mit freundlichen Grüßen

i.V.

[redacted]
Recycling and Environmental Manager

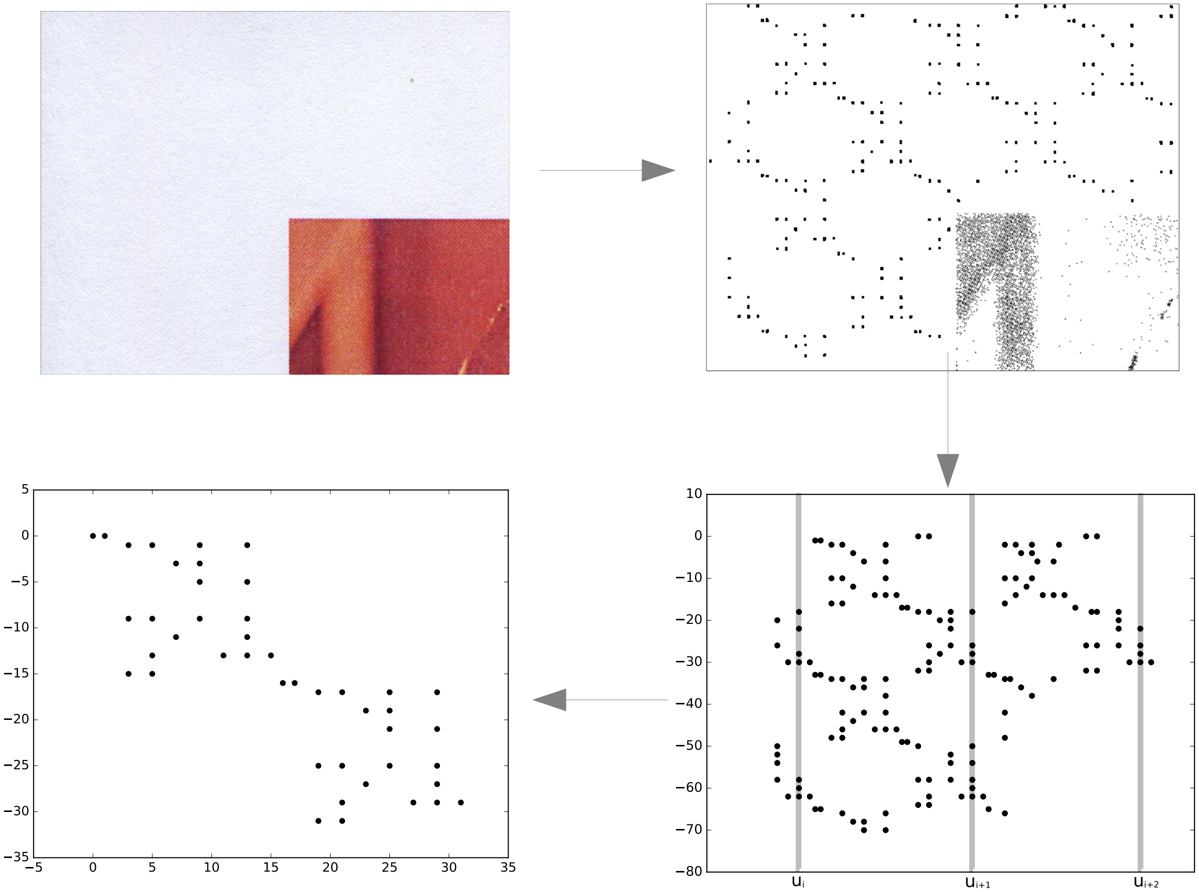
[redacted]

[redacted]

# Tracking Dots - Extraction

- Developed own extraction algorithm
- Scanned printout → digital tracking dot matrix

# Tracking Dots - Extraction



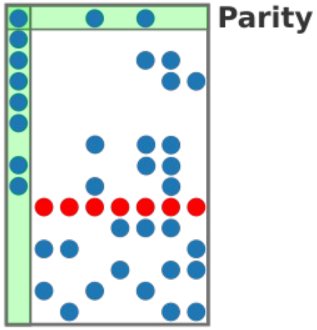
# Tracking Dots - Dataset

- 1286 prints with images and text from
  - 141 colour laser printers a 106 models by 18 manufacturers
  - Own dataset and from DFKI
- Extracted all tracking dot pattern

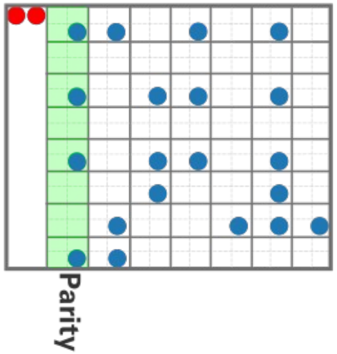
# Tracking Dots – Patterns

- 5 different patterns found in dataset
- 4 Pattern structure decoded (marker, information bits, error detection bits, …)
- 2 Pattern fully decoded (information)
- Nearly all colour laser printers affected

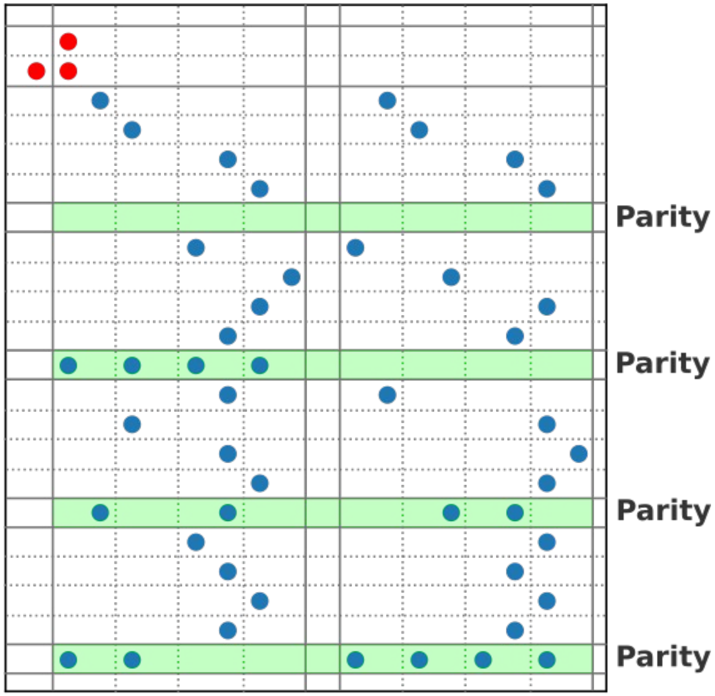
## Pattern 4



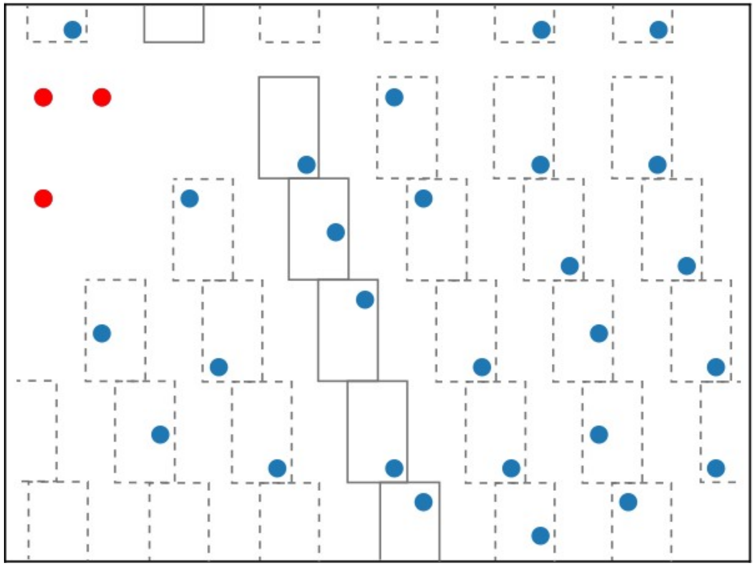
## Pattern 1



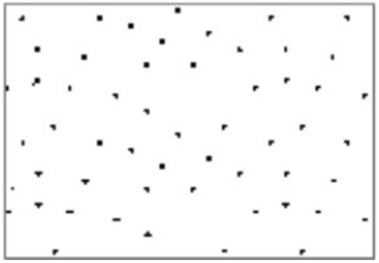
## Pattern 2



## Pattern 3



## Pattern 5

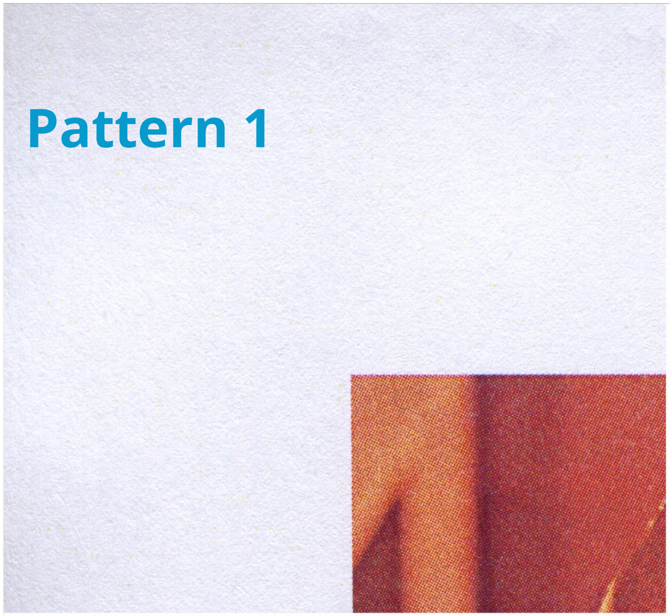


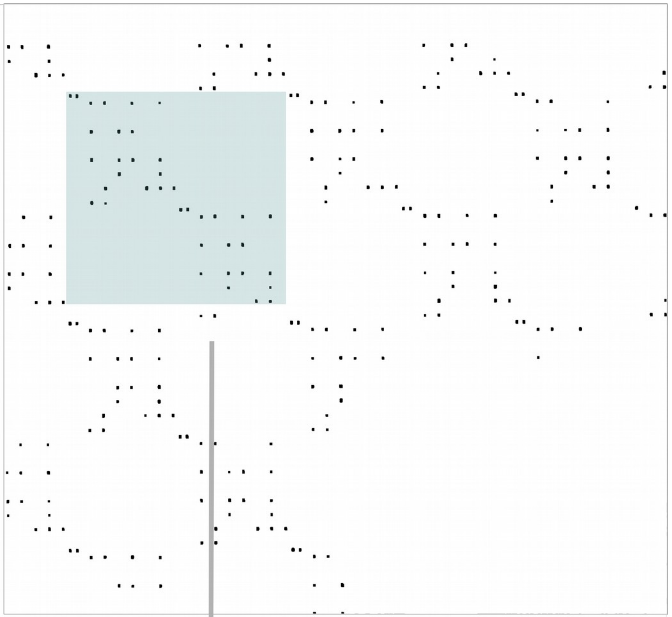
# Tracking Dots – Patterns

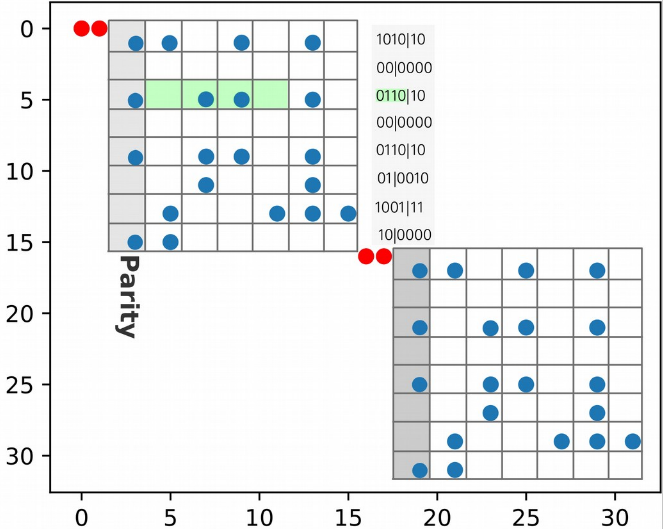
| Pattern | Manufacturer |
|---|---|
| 1 | Lanier, NRG, Ricoh, Savin |
| 2 | HP, Kyocera, Lexmark, Okidata, Ricoh |
| 3 | Epson, Konica Minolta |
| 4 | Dell, Epson, Xerox |
| 5 | Canon |

Samsung, Tektronix and Brother not affected (only small quantity in dataset)

# Pattern 1

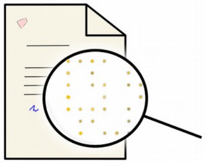






| | | |
|---|---|---|
| 0000 | → | 0 |
| 0111 | → | 7 |
| 1001 | → | 9 |
| 0100 | → | 4 |
| 1001 | → | 9 |
| 0110 | → | 6 |
| 0000 | → | 0 |
| 0001 | → | 1 |
| 0110 | → | 6 |
| 0000 | → | 0 |
| 0001 | → | 1 |
| 0101 | → | 5 |

Seriennummer des Druckers: W794P601601



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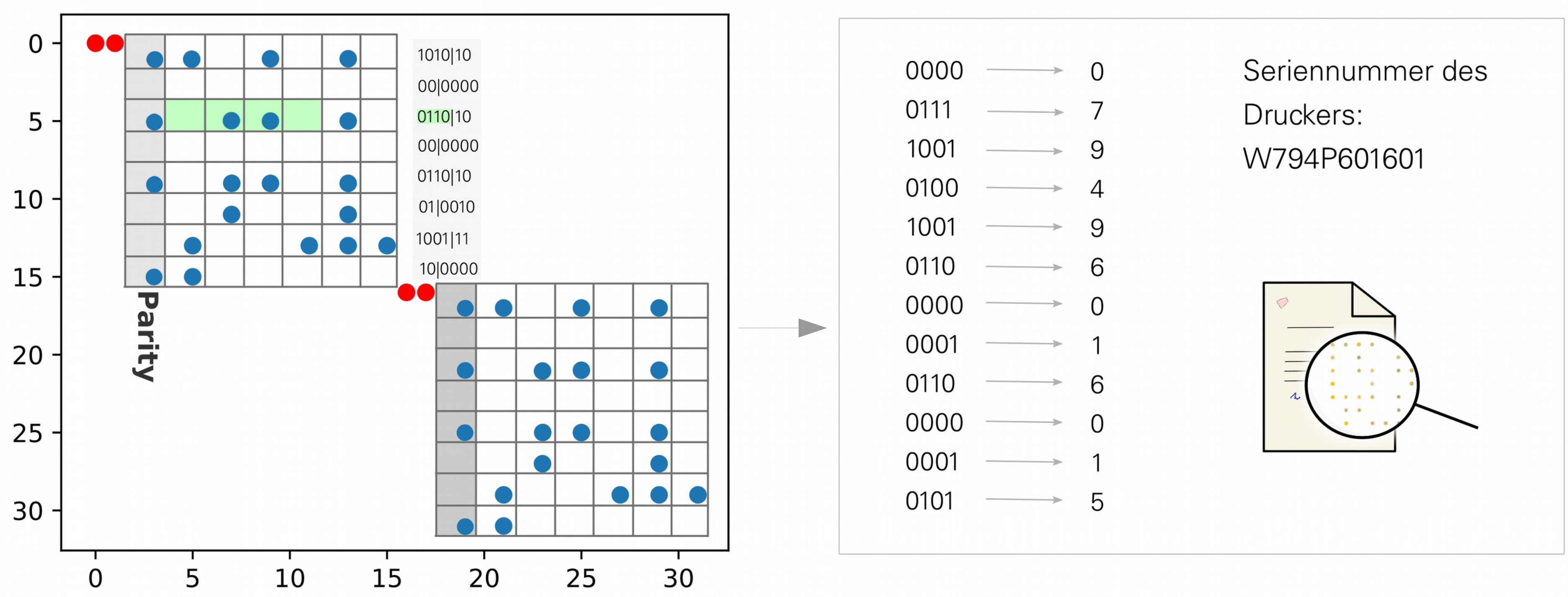


| | | |
|---|---|---|
| 0000 | → | 0 |
| 0111 | → | 7 |
| 1001 | → | 9 |
| 0100 | → | 4 |
| 1001 | → | 9 |
| 0110 | → | 6 |
| 0000 | → | 0 |
| 0001 | → | 1 |
| 0110 | → | 6 |
| 0000 | → | 0 |
| 0001 | → | 1 |
| 0101 | → | 5 |

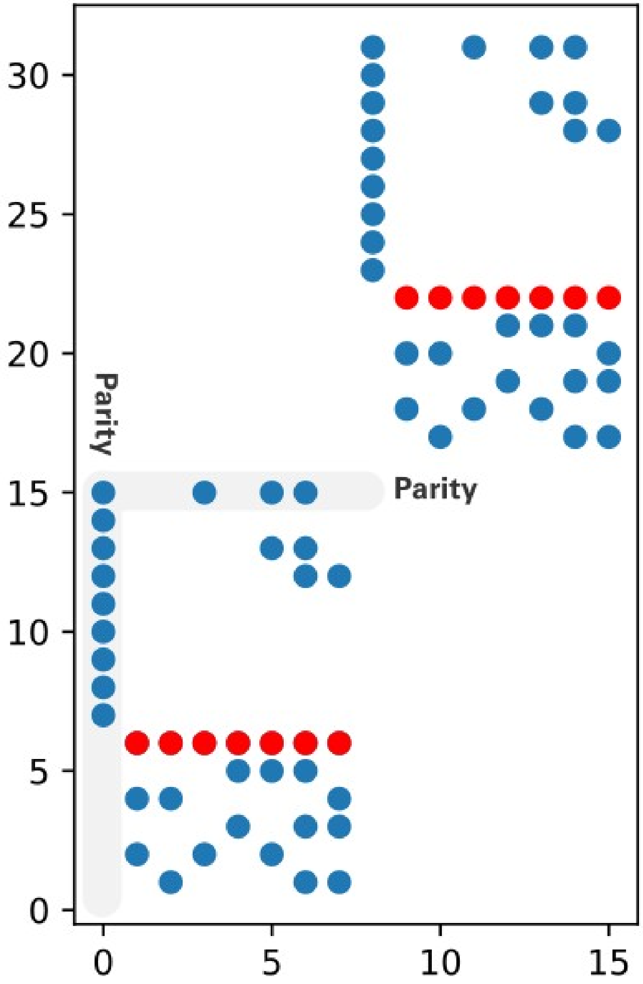
Seriennummer des Druckers: W794P601601

- (7,6,2) even parity code
- Red: marking dots

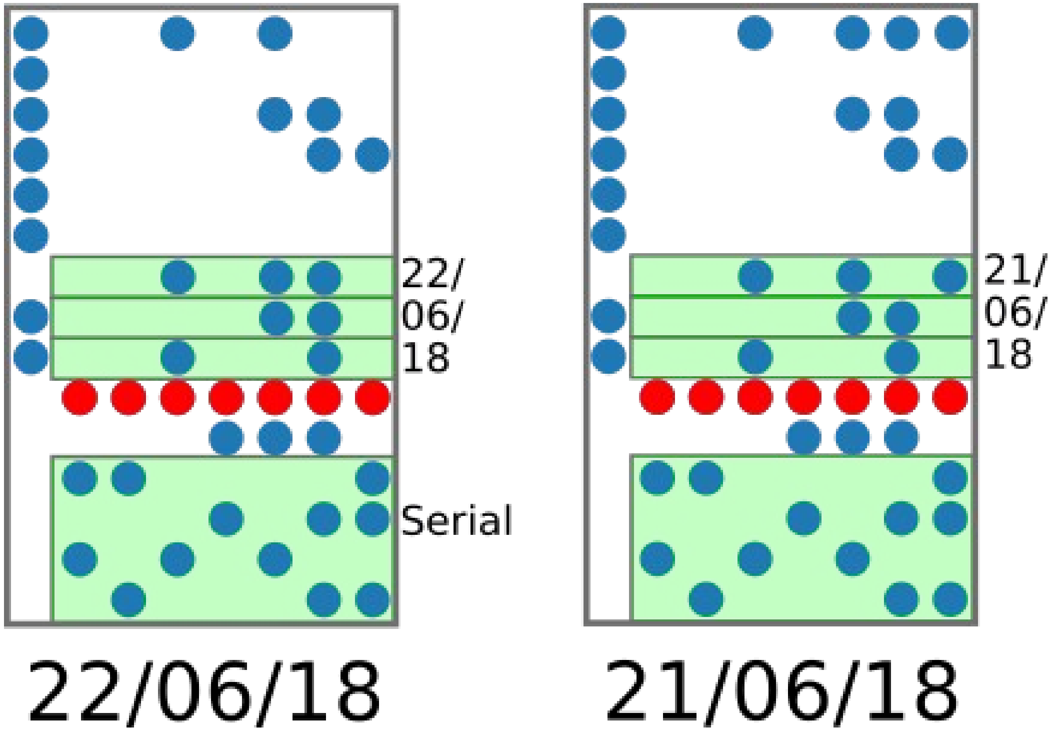
- *Serial number* as 4 binary bit blocks

# Tracking Dots – Pattern 4

- 6 digits of *serial number, date and time*
- (8,7,2) odd parity code – (15,14,2) odd parity code
- Repeated in offset



# Tracking Dots – Pattern 4



# Tracking Dots - Privacy

- No access control: Tracking data can be read by anyone
- Privacy and Security Chair!

→ Prevent arbitary tracking

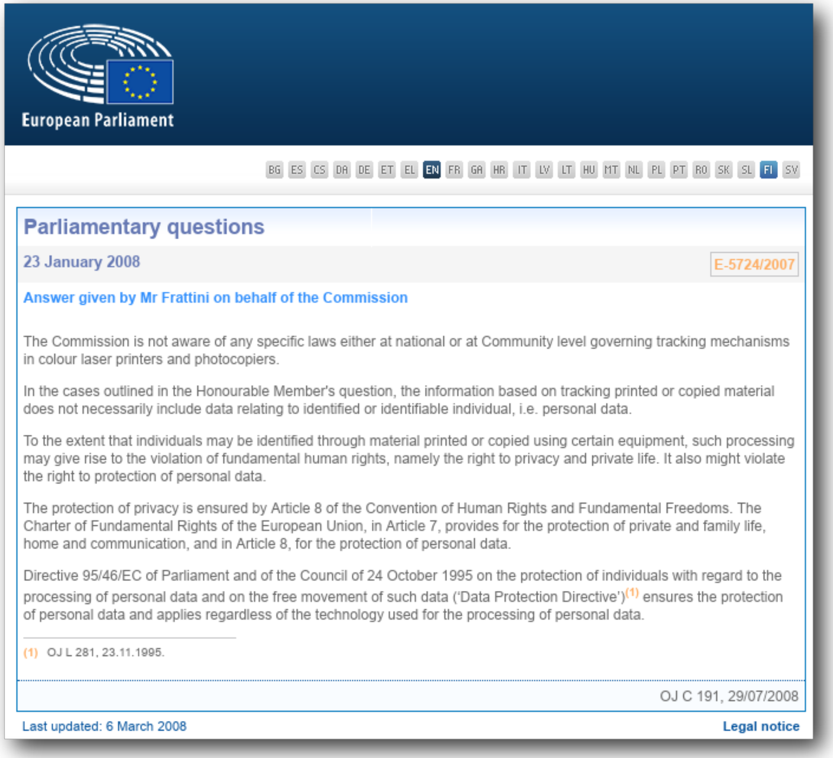
→ Developed also anonymization methods

# Tracking Dots - Privacy

- Question by Satu Hassi (Verts/ALE) 1 : „Does the Commission believe that the current practices of manufacturers […] are consistent with relevant Community law on data protection and consumer protection?“

- EU Parliament:
  The dots „might violate the right to protection of personal data“

- Time Stamp: 2008



European Parliament
BG ES CS DA DE ET EL EN FR GA HR IT LV LT HU MT NL PL PT RO SK SL FI SV

Parliamentary questions

23 January 2008 E-5724/2007

Answer given by Mr Frattini on behalf of the Commission

The Commission is not aware of any specific laws either at national or at Community level governing tracking mechanisms in colour laser printers and photocopiers.

In the cases outlined in the Honourable Member's question, the information based on tracking printed or copied material does not necessarily include data relating to identified or identifiable individual, i.e. personal data.

To the extent that individuals may be identified through material printed or copied using certain equipment, such processing may give rise to the violation of fundamental human rights, namely the right to privacy and private life. It also might violate the right to protection of personal data.

The protection of privacy is ensured by Article 8 of the Convention of Human Rights and Fundamental Freedoms. The Charter of Fundamental Rights of the European Union, in Article 7, provides for the protection of private and family life, home and communication, and in Article 8, for the protection of personal data.

Directive 95/46/EC of Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data ('Data Protection Directive')[1] ensures the protection of personal data and applies regardless of the technology used for the processing of personal data.

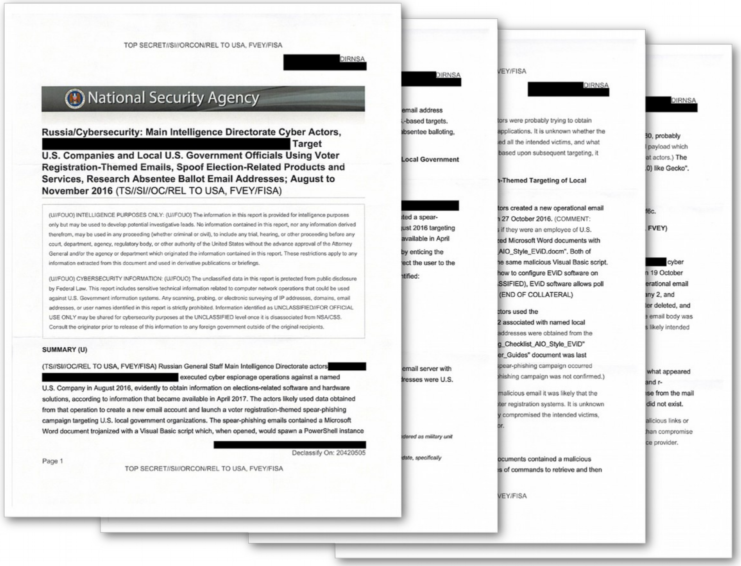
[1] OJ L 281, 23.11.1995.

OJ C 191, 29/07/2008

Last updated: 6 March 2008 Legal notice

# Tracking Dots - Privacy

- Serial Number = unique identification number
- Possible linkability to e.g. credit card number, IP address, …
- Dots possibly used in court by NSA in 2017 because of leaking secret documents



TOP SECRET//SI//ORCON/REL TO USA, FVEY/FISA

[redacted] DIRNSA

National Security Agency

**Russia/Cybersecurity: Main Intelligence Directorate Cyber Actors, [redacted] Target U.S. Companies and Local U.S. Government Officials Using Voter Registration-Themed Emails, Spoof Election-Related Products and Services, Research Absentee Ballot Email Addresses; August to November 2016** (TS//SI//OC/REL TO USA, FVEY/FISA)

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**SUMMARY (U)**

(TS//SI//OC/REL TO USA, FVEY/FISA) Russian General Staff Main Intelligence Directorate actors [redacted] executed cyber espionage operations against a named U.S. Company in August 2016, evidently to obtain information on elections-related software and hardware solutions, according to information that became available in April 2017. The actors likely used data obtained from that operation to create a new email account and launch a voter registration-themed spear-phishing campaign targeting U.S. local government organizations. The spear-phishing emails contained a Microsoft Word document trojanized with a Visual Basic script which, when opened, would spawn a PowerShell instance

[redacted]

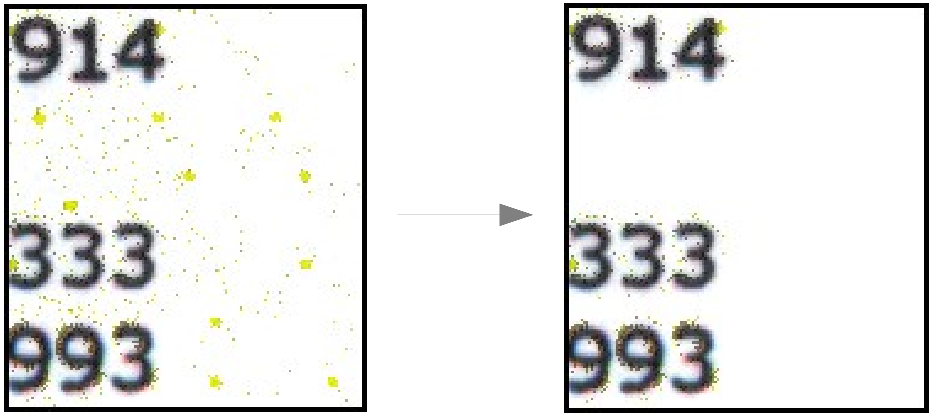
Declassify On: 20420505

Page 1

TOP SECRET//SI//ORCON/REL TO USA, FVEY/FISA

# Remove Tracking Dots on Scans

- Mask printed area of the document
- Invert Mask
- Fill white



# Mask Tracking Dots on Print outs

→ Overlaying the tracking dots

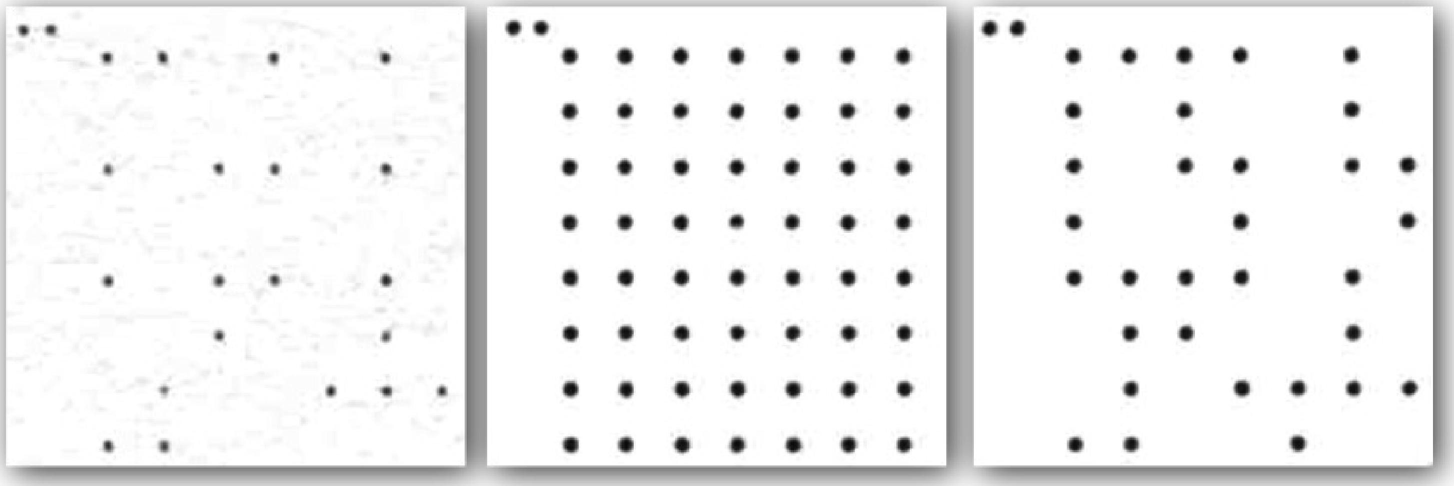
- Position of dots must be known

  → Print calibration page with position markers

- Scan it
- Tracking dot extraction
- Measure distance between tracking dots and markers

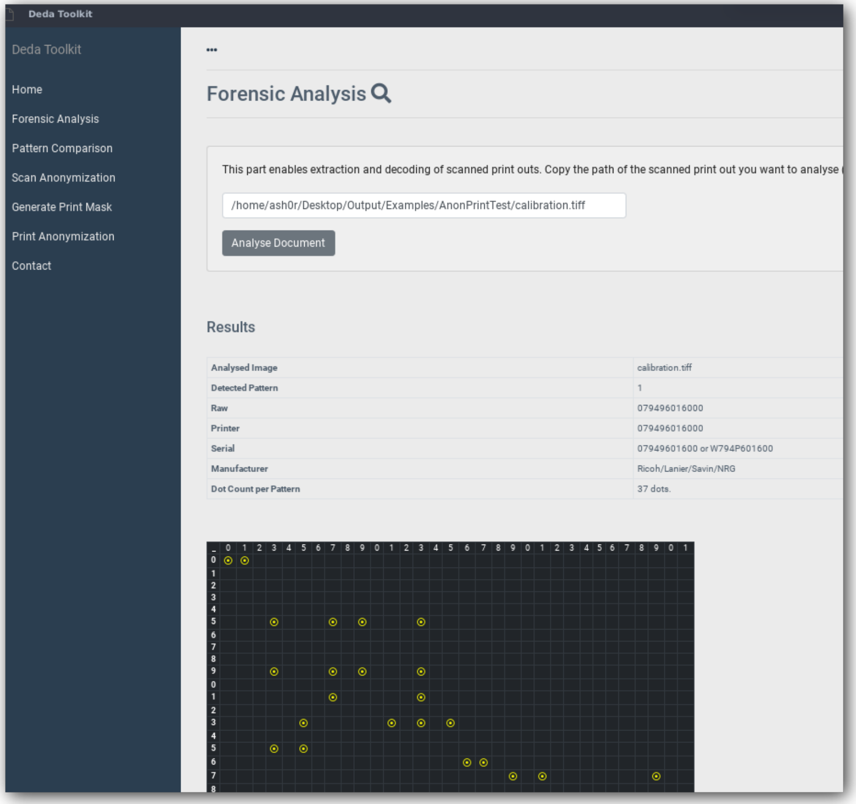
# Mask Tracking Dots on Print outs

- Fill extracted tracking dot matrice with additional dots to destroy encoded information
- Embed tracking dot mask in document with correct distances and overprint existing tracking dots



# DEDA

- Toolkit for whole workflow of extracting, decoding and anonymization of tracking dots
- Install Python 3
- $ pip3 install deda
- $ deda_gui
- dfd.inf.tu-dresden.de



## Forensic Analysis

This part enables extraction and decoding of scanned print outs. Copy the path of the scanned print out you want to analyse

/home/ash0r/Desktop/Output/Examples/AnonPrintTest/calibration.tiff

### Results

| | |
|---|---|
| Analysed Image | calibration.tiff |
| Detected Pattern | 1 |
| Raw | 079496016000 |
| Printer | 079496016000 |
| Serial | 07949601600 or W794P601600 |
| Manufacturer | Ricoh/Lanier/Savin/NRG |
| Dot Count per Pattern | 37 dots. |

| _ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | ⊙ | ⊙ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | ⊙ | | | | ⊙ | | ⊙ | | | | ⊙ | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | ⊙ | | | | ⊙ | | ⊙ | | | | ⊙ | | | | | | | | | | | | | | | | | |
| 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | | | | | | | | ⊙ | | | | | | ⊙ | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | ⊙ | | | | | | ⊙ | | ⊙ | | ⊙ | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | ⊙ | | ⊙ | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | ⊙ | ⊙ | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | ⊙ | | ⊙ | | | | | | | | ⊙ | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

# Summary

- Tracking dots reusable for project use case
    - If tracking dots detected and decodable – use these
    - Else use intrinsic signatures
- Content still unknown / hidden by manufacturers
- We have
    - Identified codes
    - Boosted data privacy
    - Designed anonymisation method
    - Created and evaluated own toolkit
- In work: Pattern 5, Decoding of Pattern 2 and 3