Recognizing Banknote Patterns for Protecting Economic Transactions

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***Abstract*—In this paper, we describe the functionality and operational features of a system for recognizing and authenticating EURion constellation in Euro bank notes. This system will be showcased in a demonstration showroom of the IMPRESS workshop at DEXA 2010, presenting the specific coding and processing requirements of this pattern.**

***Keywords*-Economic transactions, EURion, Pattern recognition**

I. Introduction

Banknotes have many protection measures. Some of them are well known (e.g. watermarks, security thread or foil-strips). However, other resources are not as well known by the general public. Among them, we can find the EURion constellation, a pattern of points that protects banknotes against counterfeiting.

This pattern has its specific coding and processing requirements, which will be presented. We also introduce its geometrical characteristics and how it is detected by embedded hardware and software applications.

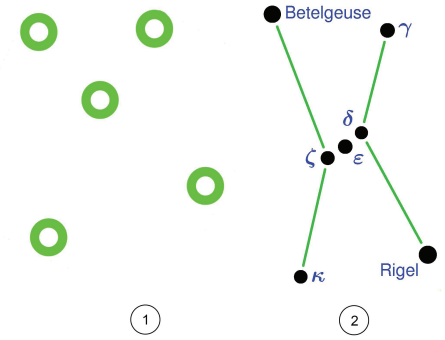
The remainder of the paper is structured as follows. Section II introduces the characteristics of the EURion constellation on bank notes. Section III describes the experimental results obtained with our methodology for recognizing and authenticating EURion constellations. Finally, Section IV concludes and glimpses the future work.

II. The EURion constellation

The EURion constellation is a pattern of symbols which can be found in a large amount of banknote designs since 1997. This pattern is one of many security features in a banknote. It is added to allow the detection of a banknote by a software inside a digital image. If the software detects the banknote, it blocks the reproduction to prevent counterfeiting in colour photocopiers or scanners. Instead of analysing the whole image, searching the similarities between the image and every banknote, the software only searches for a simple geometric pattern, which implies less computational complexity.

The name "EURion constellation" was coined by Markus Kuhn [1], who revealed the pattern in 2002 when he detected that a colour photocopier denied the reproduction of banknotes. As Fig. 1 shows, the name is a mixture between the Orion constellation, which has a similar shape, and the Euro's ISO 4217 designation (i.e. EUR) [2]. The EURion constellation first described by Kuhn consists of a pattern of five small yellow, green or orange circles, which is repeated across areas of the banknote in different orientations (see 1 in Fig. 1).

Figure 1. The EURion (1) and Orion (2) constellations



Existing patent applications [3] [4] suggest that there is some work related to pattern detection in banknotes. On one hand, the patent defined by OMRON Corporation [3] describes an image processing device which detects a banknote. Furthermore, it describes an image processing scheme and device which can solve various problems (e.g. not requiring a large memory capacity, performing high-speed processing in real time, producing a low cost device and reducing the probabilities of false positives) as well as the copier, scanner and printer in which they are used. On the other hand, the patent defined by S. Lim [4] details both a specific pattern detection method and apparatus for perceiving input images includes a specific pattern that is incorporated in a banknote, which may not be copied, and a copying machine.

To our knowledge, in spite of the aforementioned patents, every technical detail involving the EURion constellation is kept secret. For instance, the European Central Bank has never mentioned anything about this constellation. Indeed, the public security features [5] that are included in Euro notes are the followings:

- **Intaglio Printing:** It is used to apply a tactile relief to the front side of the banknotes.

- **Watermark:** If a banknote is held up to the light, we can see a watermark on both sides of the non-printed area showing both the predominant architectural motif and the numeral value.
- **Security Thread:** The Euro banknotes contain an embedded security thread which is visible when the banknote is held up against the light.
- **See-through Register:** It is a feature found in the upper left-hand corner on the front of the banknote. Irregular shapes printed on the front and back of the Euro banknotes form a complete numeral value when held up against the light.
- **Foil Strip or Foil Patch:** When the banknote is tilted, either the numeral numeral or another design (e.g. the Euro symbol or the architectural motif) appears as an hologram with shifting colours.
- **Iridescent Stripe or Optically Variable Ink:** On one hand, the stripe varies in colour from light yellow to gold yellow when the note is tilted. On the other hand, banknotes contain an optically variable colour element.
- **Micro-printing:** There are tiny printings on some areas of the banknote which can be discovered by using a magnifying glass.
- **Ultra-violet Properties:** There are different characteristics that are revealed against ultraviolet light.
- **Infra-red Properties:** Using an infra-red viewer, we can see the right part of the intaglio pattern as well as the foil stripe.

Figure 2. 10 Euro note with some EURion constellations marked

III. Experimental Results

We evaluated the EURion constellation features using a reverse engineering process. We started trying to reproduce a 10 Euro note with every EURion constellations covered. In this step, the 10 Euro note could be reproduced. Therefore, the only feature which avoid Euro note copies in a multifunctional printer is the EURion constellation.

As the reproduction is allowed, we continued checking the relative orientation of the constellations. Although the EURion constellations included in banknotes have different orientations, we tried copying and moving the Euro note in different orientations. The banknote did not reproduce in any of these tests. Thus, the orientation of the constellation do not take into account along the detection process.

The next step in our reverse engineering process was to check the number of constellations needed to avoid the reproduction of the banknote. In order to attain our objective as fast as we could, we applied a binary search [6]. In our first attempt, we attempted to reproduce, as a minimum, only one EURion constellation. As a result, the banknote failed to be reproducible. Hence, if the hardware system detects a single constellation, the reproduction process will be interrupted. In other words, a document can not be copied or scanned if it includes only a single EURion constellation.

Moreover, we checked if the colour of the constellation is taken into account and if a complete constellation is necessary for intercepting the copying. Both of them were carried out in parallel way. In the first one, we tested several colours. To begin, we analysed colours mentioned by Kuhn [1] (i.e. green, orange and yellow). In this way, we discovered that pure colours do not work correctly. Nevertheless, if the multifunctional printer detects noisy colours, the ERUion constellation is much better detected. To conclude, we analysed other colours. If other colours are used in the EURion constellation, the multifunctional printer allows us to reproduce the banknote. Thus, the EURion constellation drawing colour must be green, orange or yellow but with some irregularities in order to reproduce the banknotes deterioration.

In the second parallel test, we isolated only one EURion constellation. In order to test the completeness of the constellation, we covered its points. In this step, we also used a binary search to achieve our objective. Starting with the lowest limit of covered points, we discovered that the constellation must be completely drawn to avoid the copies. In other words, if the constellation is not formed by its five points, the multifunctional printer do not detect the pattern.

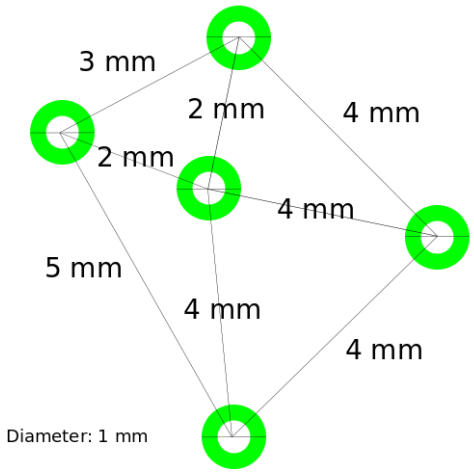
Finally, we checked what size the constellations should have. Actually, the EURion constellation's points have 1 mm of diameter in the Euro notes. To our knowledge, no previously published research deals with this feature. Hence, firstly, we tested a smaller diameter and the security feature failed to work. Secondly, we tested a larger diameter

and this security feature also failed. Therefore, the EURion constellation must always have the same measures.

In summary, the EURion constellation must satisfy the following constraints:

- At least one EURion constellation is needed.
- The EURion constellation must be completely drawn.
- The EURion constellation drawing colours are green, orange and yellow with some irregularities in order to reproduce the banknote's colours.
- The orientation of the EURion constellation is not taken into account.
- The measures of the EURion constellation must always be the same (see Fig 3)

Figure 3. Measures of the EURion constellation



Once the reverse engineering process was finished, we prepared our own EURion constellation. This constellation was generated as an image that can be introduced in several kinds of documents. In order to test our results, we generated a Microsoft Word© document with this constellation. Then, we tried to copy and to scan this document in the multifunctional printer and we could not scan and copy it. We always achieved a black or white sheet of paper. Hence, this document was totally secure.

Regarding printing feature, the EURion constellations always can be printed. Hence, the document including at least one EURion constellation can be printed. Nevertheless, once printed this document, it cannot be copied or scanned by newest scanners or copiers. In this way, the achieved results confirm our original hypothesis. Documents can be protected against unauthorised copies by using this security feature. Note that, nowadays, not all the hardware and software packages support this feature. Nonetheless, we expect that most of them will, in the foreseeable future.

IV. Conclusion

The EURion constellation is an image pattern composed by symbols. It can be found in a large amount of banknote designs. Although this pattern is one of many security features in a banknote, its peculiarity is that it is kept secret. The EURion constellation appears in banknotes to allow the detection of a banknote by a copier, scanner or some software which works with images. If the correct EURion constellation is recognized and authenticated, the reproduction is stopped, i.e., counterfeiting is prevented.

Principles of security features against counterfeiting such as those realized by the EURion constellation have the potential to be useful not only for preventing the falsification of bank notes, but also for a wide range of other applications.

Currently, however the solutions for authenticating documents and for assuring their security are implemented by processing digital features. Moreover, the production process of digitally secured documents usually does not include any security feature that would prevent unauthorised document copies.

Hence, the provision of security measures for preventing illegal copies is a very important issue to be solved, in several domains, such as confidential documents, copyrighted books, non-transferable tickets, original art work, etc.

It can be expected that the future development of such security features for various kinds of documents will include the development of systems that make use of features analogous to the EURion constellation.

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