INHERENT ID: A NOVEL APPROACH TO DETECT COUNTERFEIT
CONSUMER GOODS USING PRODUCT INHERENT FEATURES

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ABSTRACT

Product-Piracy or counterfeiting is a well known problem which leads to economic damage that affects in particular countries that use advanced production and manufacturing processes based on intensive research and development to produce high quality goods. The existence of counterfeiting leads to the development of methods and technologies to secure high-quality products. The present way to secure top-quality products is often followed by an application of artificial security features.

In this text we show a novel approach in detail to secure products against counterfeiting using features of the product itself instead of additional labels. The specific conditions of production, manufacturing technologies and materials generate specific features, which identify the product uniquely.

KEYWORDS

Automated Counterfeit Detection, Product Fingerprinting, Pattern Recognition, Sensor Fusion, Classification

1 INTRODUCTION

The annual "Report on EU customs enforcement of intellectual property rights" of the European Union in 2012 [1] shows a continuous upward trend in the number of shipments suspected of violating intellectual property rights. As for the Year 2011 the value of detained articles and their equivalent genuine products is estimated to be over 1.2 billion euro. This number only includes the value of products actually detained only at the European border. The OECD report "The Economic Impact of counterfeiting and piracy" [2] of 2008 estimates a total loss of 250 billion dollars in the year 2007 worldwide. In comparison the EU-Report [1] states 43.671 cases in 2007 and 91.254 cases in 2011. The OECD report covers the analysis of international trade in counterfeit and pirated products. These estimates do not include domestically produced and consumed counterfeit and pirated digital products being distributed via the Internet. If these were also considered, the magnitude of counterfeiting and piracy worldwide could be several hundred billion dollars more than previously thought, and this increasing trend is quite alarming.

It is self-evident that counterfeiting and piracy are businesses from which criminal networks thrive. The OECD report shows further that the items counterfeiters and pirates produce and distribute are often of minor quality and can even be dangerous and health hazards.
With the magnitude of counterfeiting and piracy in mind, these reports emphasize the need for more effective enforcement to combat the counterfeiting and piracy on the part of governments and businesses alike. A key component for this enforcement is the development of new methods for automated counterfeit detection.

The effect of counterfeiting and piracy is an intermission of innovation and thus impairment of economic growth. The economic damage affects in particular countries that use advanced production and manufacturing processes based on intensive research and development to produce high quality goods. The review of copyright infringement of registered trademarks and products is not easy to implement. Due to the high number of pending trademarks and constantly added new applications it is very difficult for the executive bodies, such as customs, to register violations of trademark rights immediately and in a comprehensive manner. The awareness to all registered brands and products is for the executive organs not possible and therefore necessarily, trademark infringement remains unnoticed. The way to secure top-quality counterfeit products is often followed by an application of artificial security features. The issues of such security labels are in part the high cost, and additionally the integration into the product. High-quality branded products, as the target of counterfeiting, have usually, due to the production processes and materials used, and in view of its processing machinery and equipment, a grade of high quality. The specific conditions of production, manufacturing technologies and materials generate specific features, which identify the product uniquely. These features may be detected multimodal by man, including tactile (plasticity, elasticity, thermal conductivity, surface structure), visual (shape, colour, surface texture, transparency), olfactory (smell) or acoustic (sound) perceptions. In general, only the person familiar with the manufacture of the product can combine these inherent characteristics in their entirety so that it can differentiate the genuine product from a clear counterfeit. In the project Inherent-ID two properties of a product have been identified as the most promising ones suitable for identification: the olfactory and the optical features.

2 STATE-OF-THE-ART-TECHNOLOGY

Common automated counterfeit detection methods require nowadays additional security features at the product itself. Several methods have been developed, but main advantages and disadvantages remain similar. Additional security features require further steps in production to add these features to the product. This raises expenses, manufacturing time and development efforts, which is clearly a disadvantage. On the other hand the security is enhanced and an original brand is easy to detect in an automated fashion, since there is a specific feature to look for. But this could also be a main disadvantage, if the security feature itself is easy to reproduce and could be added to any forged product. Another challenge is to link the security label to the brand product in a way it cannot be removed or stolen. This way product pirates could label their counterfeits easily as an original with an original security label.

Figure 1 shows examples of different labels which are commonly used on products for different purposes. One purpose is the use as a logical security feature where the security label contains unique information and cannot be copied. Counterfeit detection without artificial security tags is a solution to these problems, if the counterfeit is distinguishable from the original brand.
2.1 Security Labels

The Anthology [3] gives a comprehensive overview of the latest efforts in product protection. A reasonably well studied approach is the extensive supervision of supply-chains. Here the application of RFID tags plays a significant role, as the latest form of artificial security tags, which can easily be integrated with existing logistic chains. The application of Data Matrix Codes (DMC) is discussed as well as a cost-effective alternative. Much work has been done to link these tags inseparably with the corresponding product to hinder product pirates from transferring these tags to their counterfeits. But in general it is observed that this protection method holds only with tremendous logistic implications, since todays products cover various stations during the distribution process. Up to now there has been no standard available and the customs authorities’ integration is still open. Even when the cost of these artificial tags could be reduced by advances in the production process, as e. g. the introduced direct printing of RFID antennas onto packaging, additional expenses with no direct use for the customer will arise. Security Tags like holograms found attached to various consumer goods give nearly no protection against counterfeiting since machine readability is poor and knowledge of the correct appearance is scarce.

2.2 Product-Inherent Features

The Inherent ID Project adopts a novel approach to protecting high-value products from counterfeiting. The approach is based on the stationary and mobile capture of key product features indissolubly linked with the product which enable its production process to be traced. This not only renders obsolete the application of security tags but also gives enhanced protection against counterfeiting as the inherent characteristics that the high-quality production process impregnate in the genuine product are combined with one another to serve as proof of product identity. They form the basis on which electronic certificates of authenticity can be issued without the need for complicated explicit security markings. Methods for the capture and control of identity characteristics are being elaborated in the Inherent ID project for system integration using intelligent cameras and an electronic nose. The identity characteristics captured by this range of sensors serve both for the product identification and product authentication. At the same time this also offers opportunities for improving documentation of product flows in the supply chain. Full documentation serves as a complement to the inherent characteristics of the authentic product and offers valuable information of verification of the genuine article, thus serving to safeguard against counterfeits. The Project aims to answer the question: Which inherent features allow separation of genuine products from counterfeits in an automated fashion? The motivation of this question is the assumption that genuine products must differ in its properties from its counterfeit, since the product pirate tries to maximize its profit by using material of inferior quality and misusing a trademark of a genuine man-
ufacturer to feint the customer. One result of the project is that only a combination of features can detect counterfeits at a decent rate for different products.

3 INHERENT ID IN DETAIL

Optical 2D and 3D characteristics as well as olfactory characteristics are combined with one another to serve as proof of product identity, as shown in figure 2. They form the basis on which electronic certificates of authenticity can be issued without the need for complicated explicit security markings. The identity characteristics captured by this range of sensors serve both for product identification and product authentication. At the same time this also offers opportunities for improving documentation of product flows in the supply chain. Within the scope of Inherent ID is the successful establishment of a laboratory providing multi-modal measurement equipment comprising multigas sensor array for olfactory analysis, high resolution camera for texture analysis and stereo vision, as well as range cameras for 3D feature extraction. Further research is conducted with the aim for increasing robustness of the sole test methods especially under ambiguous environments, integration into portable devices, implementing sensor data fusion for increased detection ratio, effortless integration into supply chains and developing efficient data models for storage of various features depending on the regarded product.

3.1 Texture Features

The ability to characterise visual textures and extract the features inherent to them is considered to be a powerful tool and has many relevant applications. A textural signature capable of capturing these features, and in particular capable of coping with various changes in the environment would be highly suited to describing and recognising image textures [6]. As humans, we are able to recognise texture intuitively. However, in the application of Computer Vision it is incredibly difficult to define how one texture differs from another. In order to understand, and manipulate textural image data, it is important to define what texture is. Image texture is defined as a function of the spatial variation of pixel intensities [5]. Furthermore, the mathematical description of image texture should incorporate, identify and define the textural features that intuitively allow humans to differentiate between different textures. Numerous methods have been designed, which in the past have commonly utilised statistical models, however most of them are sensitive to changes in viewpoint and illumination conditions [6]. For the purposes of mobile counterfeit detection, it is clear that this would be an important characteristic for the signature to have, as these conditions can not be entirely controlled. Recently a description method based on fractal geometry known as the multifractal spectrum has grown in popularity and is now considered to be a useful tool in characterising image texture. One of the most significant advantages is that the multifractal spectrum is invariant to the bi-
Lipschitz transform, which is a very general transform that includes perspective and texture surface deformations [6]. Another advantage of Multifractal Spectra is that it has low dimension and is very efficient to compute [6] in comparison to other methods which achieve invariancy to viewpoint and illumination changes such as those detailed in [7], [8]. One of the key advantages of multifractal spectra, which is utilised here is that they can be defined by many different categorisations or measures, which means that multiple spectra can be produced for the same image.

This is achieved through the use of filtering, whereby certain filters are applied to enhance certain aspects of the texture, to create a new measure. Certain measures are more or less invariant to certain transforms, and the combination of a number of spectra achieves a greater robustness to these. The workflow is depicted in Figure 3 and an example is given in Figure 4.

3.2 Shape Features

Since manual detection is often done visual by customs officials, visual features are also important for any automatic detection mechanism. Besides detecting features through two dimensional image processing, three dimensional data capture is necessary for counterfeit detection, because it provides important additional information.

To capture a real-world object in three dimensions a 3D scanner, or range camera, can be used. The basic principles of 3D scanners available on the market are triangulation, time-of-flight or interferometric approaches, whereas each principle has its advantages or
disadvantages. For a profound insight into that topic refer to [9]. We use a mobile structured-light 3D scanner for our application, but in general any three dimensional data acquisition method can be used to capture a real-world object. But using different kinds of scanning techniques results may vary.

One distinguishable feature of brand products is the shape itself. Shape matching is a well studied topic and several publications can be found over the last 15 years. Feature-based approaches have become very popular since some years in image analysis (2D) due to robustness and less computational effort compared to other approaches. In shape matching (3D) feature-based approaches have been introduced more recently and are gaining popularity in shape retrieval applications for the same reasons. The major difference is whether the approach uses global or local features. In [10] an overview of shape matching principles and algorithms can be found.

Many shape matching approaches use digital human made data like the Princeton-Shape-Benchmark [11] or the SHREC datasets [12] to evaluate their algorithms. Scanned data from real world objects is different in a sense that holes and variations between two scans of the same object can appear.

For that reason most approaches are not suitable for counterfeit detection, where minor details of an object can be highly important. Therefore only approaches detecting local features were taken into consideration. Figure 5 shows the required steps for our shape matching algorithm using real world objects. The shape matching algorithm requires a three dimensional model of the product as input which can be matched to an abstract model of the brand product. The abstract model is a description of features that render the brand unique.

Figure 5: Workflow for generating a Shape-Signature

One major challenge for three dimensional object capture is the huge amount of data that has to be processed. The 3D scanner we use has an accuracy of 20 to 50 µm and generates around 300,000 vertices per object. Assuming a point per point matching algorithm with $O(n^c)$ and $c > 1$ growth rate and a calculation time of 1ms per point match, it would take nearly 3 years to calculate a match of two objects. This simple example demonstrates the challenge. Optimized algorithms, data reduction, parallel processing or transformation is necessary to achieve acceptable results.

In our approach the concept of Key-Points or Points-Of-Interest in combination with transformation is used. To do so, a feature detector [12] has to be applied and the area surrounding the detected Key-Points is transformed into a

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1Holes are areas on the scanned object where the used scanning technique has troubles to capture data.
meaningful descriptor. Figure 6 shows a transformation of the area surrounding Key-Points into a 2D dense map using Spin Images [13]. A set of Spin Images is then transformed into a description of the object that can be matched to the abstract brand model.

### 3.3 Odour Features

Much effort has been spent on how odour could be measured. The European Standard EN-13725 [14] defines a method for the objective determination of the odour concentration of a gaseous sample using so called dynamic olfactometry. It is currently the only standardized method for the evaluation of odour impressions.

The dynamic olfactometry is a method where a panel of human assessors evaluates the concentration of odour in a series of standardized presentations of a gas sample. Here the emission rate of odours emanating from point sources, area sources with outward flow and area sources without outward flow are considered. The primary application of this standard is to provide a common basis for evaluation of odorant emissions in the member states of the European Union. Every method claiming the ability to detect arbitrary odour emissions has to benchmark against this standard. An overview of the development and application of electronic noses is given in Gardner and Bartlett [15].

In general it was observed that electronic noses do not react to human inodorous gases and were also unable to detect some gases humans are able to smell naturally. Beginning with the working principle of specific gas sensors the concept of electronic noses as a combination of sensor array and diverse pattern recognition algorithms for classification is introduced. In principle the sensor concepts could be divided into three categories. The commercially available electronic nose Artinos basing on the KAMINA (KArlsuher MIkroNase) [16] is a representative of metal conductance sensors. Here the sample gas flowing alongside the sensor surface is changing the concentration and configuration of oxide containing compounds, thus changing the conductance of the metal-oxide, which is then used as a measurement signal. The sensor elements differ by the thickness of silicon dioxide coating. Additionally the temperature is changed over time producing 38 analogue channels containing also transient responses, which are to be analysed. Due to its working principle these sensors deliver the most unspecific data, which is both an advantage and a disadvantage at the same time, since the sensors are suitable for a broad variety of samples, but the signal processing is harder to realise. A metal-oxide conductance sensor using 16 channels was utilized in the project Inherent-ID [4].

A similar sensor setup is used in [17], the
difference being that the sensor elements are coated with different polymers, which induce a change in conductance to specific gas components. It was shown that with four different sensor types held at four different temperatures, so a total of 16 channels and following linear discriminant analysis ovarian cancer could be detected from tissue samples. There are still some issues with falsely rejected samples, but the results were quite impressive with respect to the use of ad-hoc methods. Another sensor concept utilising polymer coatings are the quartz microbalance sensor arrays as described in [18]. These sensors detect the change of frequency when a gas is flowing over the sensor surface. In principle these arrays are very sensitive but also very susceptible to disturbances. Most of recently published results in odour detection are based on linear discriminant analysis and derivatives thereof. These methods are efficient in classification of complex sensor data, but with a manageable number of classes. And these methods need a significant amount of data present and are therefore not suitable for the here elaborated problem of one to many matching, as needed for the application in counterfeit detection. An additional obstacle is the sensitivity to ambient conditions which result in wide variance of measurement data from the same class of samples. Effort is made in the extraction of relevant features for the purpose of reducing the dimensionality and the suppression of ambient influences which was done by independent component analysis. An attempt of designing a general odour model was made in [19], but was not successful due to the sensors used and the fact that nonlinear behaviour was excluded in advance. So the usage of specific models is more promising.

4 WORKFLOW

With the features described above there is a strong basis for automated classification of patterns. The key point for a robust and reliable counterfeit detection is the combination of these features and additional user information with the aim to derive a decision whether the probe is likely to be a counterfeit. An advantage of the proposed algorithms for feature extraction is the possibility to utilize statistical frameworks since the features are represented by probability distributions. In general there are various approaches possible. Starting with a direct fusion of the features as proposed in [20] and shown in figure 8, or a more sophisticated approach which is taking the process of probing into account. Such a workflow is depicted in 9. Here the decision process is not necessarily based on the utilization of all features, since some of them are dispensable or could be misleading. Think of the probing of shirt, obviously the 3D geometry cannot give a relevant contribution to the decision process and the 3D scanning can therefore be omitted. The classification itself is done with an adjusted Bayesian approach where special account was given to the detection of novel and therefore unknown patterns. This was done with estimation of the Level of Significance distribution,
Figure 9: Sophisticated Workflow for Counterfeit Detection

which gives a decision information and an additional value of the plausibility of this decision, cf. [21].

5 CONCLUSION

It was shown that the Inherent-ID Project adopts a novel approach to protecting high-value products from counterfeiting. The approach is based on the stationary and mobile capture of key product features indissolubly linked with the product which enable its production process to be traced. This not only renders the application of security tags obsolete but also gives enhanced protection against counterfeiting as the inherent characteristics that the high-quality production process impregnate in the genuine product are combined with one another to serve as proof of product identity. They form the basis on which electronic certificates of authenticity can be issued without the need for complicated explicit security markings. Methods for the capture and control of identity characteristics are being elaborated in the Inherent-ID project for system integration using intelligent cameras and an electronic nose. The identity characteristics captured by this range of sensors serve both for the product identification and product authentication. At the same time this also offers opportunities for improving documentation of product flows in the supply chain. Full documentation serves as a complement to the inherent characteristics of the authentic product and offers valuable information of verification of the genuine article, thus serving to safeguard against counterfeits.

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The authors are working at the department of Industrial Automation Technology, which is an integral part of the Institute for Machine Tools and Factory Management at the School of Mechanical Engineering and Transport Systems of the Technische Universität Berlin. Main tasks are fundamental research and lecturing in a broad band of topics regarding industrial automation such as process automation and robotics, process monitoring...
and simulation, image processing and pattern recognition.

8 REFERENCES


