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MICROSERVICE BASED SYSTEM FOR PAPER DOCUMENTS COUNTERFEIT DETECTION

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Abstract. The anti-counterfeiting is an ongoing problem whose solution requires significant human and financial resources. Eventual additional expenses are reflected in the final price of a protected product that means the customers pay for anti-counterfeiting. Simple and inexpensive method for document authenticity verification development and implementation, aimed to discourage documents counterfeiting in general and as a consequence guarantee authenticity of accompanying documents, bring the customer confidence in a product quality, reducing the product price. The article represents a novel method of paper document validation using modern smartphones. The proposed paper document validation method is based on paper surface structure comparison of the registered reference document and the candidate document under validation. The method allows regular owner of a smartphone to quickly validate the paper document without having any knowledge about the validation process itself. The proposed solution is characterized by high availability and scalability, which are dictated by wide popularity of smartphones and high demand for tools from this category. To achieve stable and effective work of such system the special technical design approach is required. The usage of microservice based approach for system design and implementation allows to solve mentioned problem and to allocate the hardware resources efficiently to make the system work under high load stable.

Keywords: *anti-counterfeiting, document protection, microservices architecture, paper surface structure, system design.*

Introduction

Organization for European Cooperation and Development (OECD) and the European Union Intellectual Property Office (EUIPO) shows that international trade in counterfeit and pirated goods represents up to 2.5% of world trade, or as much as EUR 338 billion [1]. The purposes of counterfeiting are various official documents, goods with labels and packaging with famous brands logos, medicines, etc.

There is a need to develop document authentication method and to build a system on its basis, which would allow to identify counterfeited products and the most important would allow to make it publicly available. The requirement of public availability of document authentication system includes low price of each verification, high speed of verification with no binding to concrete moment of time and no need for special equipment and knowledge in security domain for document counterfeit detection. Modern smartphones are well suited to be used for documents authentication, because their photo camera capabilities are high enough, have relatively big sensor size with consequent benefits in image quality, and usually are equipped with a flash, which can be used as a constant light source [2].

Problem definition

A content of any paper document can be copied, including information, which identifies this document. This information can be corrected and presented as the original. A drugs package, packages and labels of different types of goods, for example electronics, tableware or closes, can be considered as a document. Barcodes and QR-codes, which a printed on the surface can be used to identify a document or a product, but as any other information printed on the document they can be copied. Only more advanced and usually expensive security features can make counterfeiting difficult or inexpedient, because of disproportionate cost of document counterfeiting. Such methods as watermarking, hologram and microtext application, use of fluorescent paint and others can increase the document security [3]. The usage of additional security features is hampered by the fact that their application can complicate the production process and increase the cost of the document or product, while the increase in the cost of product can negatively affect the manufacturer competitiveness and consumers purchasing power. From other side the absence of security features is also not acceptable as almost unhindered production of counterfeit will increase the number of products, which don't meet the quality standards and potentially can be hazardous to customer health. Such cases may affect the reputation of original manufacturer, under whose labels the counterfeit products were sold.

The most counterfeited goods are:

- medicines;
- electrical engineering;
- food products;
- car parts;
- kids' toys;
- footwear;
- clothes.

The list of the most counterfeit goods is not limited to the presented list.

Usually it is required to have certain knowledge and special equipment to identify a high-quality fake. It is not known about the existence of a system that would allow automation of the document authenticity verification, while not imposing certain requirements on security knowledge.

Proposed solution

All the surface types are characterized by different structure and all the surface areas have unique features, which distinguish them. The paper surface is characterized by visible interwoven cellulose fibers if it was not specially treated. Paper surface structure is an

integral part of the paper document, each its region is unique, and it unequivocally confirms the document authenticity, in addition, there is no need for any additional costs. Besides this the majority of product packages and labels are produced from a paper because of its low price and reduced use of plastic in connection with the fight against environmental pollution.

The development of technologies, the ubiquity of portable personal devices and their high technical characteristics allow to apply them in various areas of human activities.

It is proposed to use smartphones for cheap, reliable and the most importantly widely available methods for documents authenticity verification. The method of the document authenticity verification should be based on paper document surface structure characteristics and features analysis.

The proposed method of paper document counterfeit detection includes two main steps:

1) Document registration.
2) Document verification.

A device, which may be used for document registration and verification should have a camera to register the paper document surface, a source of a constant light for high quality surface photographs and an Internet connection to interact with the server part where the registered document information is stored and the document authenticity verification is happening.

Modern smartphone is a good candidate for a device to be used for paper document registration and verification, but it could be possible to use other types of devices, which meet the requirements.

A smartphone, which can be used for paper documents counterfeit detection, should have preinstalled software application, which allow to capture paper document surface and to communicate with the centralized system through web services for document registration and authenticity verification.

Web services should store photography of original registered document surface and extracted surface features.

This information should be hidden from a client to prevent potential surface reproduction.

Public information about the document and its author should be accessible to the user, who successfully verified the document. The document authors should also have a possibility to manage their documents.

A paper document surface analysis and a comparison of original and candidate documents can be based on following methods:

1) Surface features can be extracted by image feature detection algorithm. Fast robust local features detector and descriptor ORB [4] can be used for this purposes. Features matching algorithm can be used for paper surfaces images comparison.
2) Gabor filtration based algorithm can be used for paper surface structure extraction. Extracted paper document structures can be matched by binary images correlation.

The figure 1 shows the enhanced image of paper surface, the paper surface features obtained by ORB detector applying and paper structure extracted by Gabor filtration.

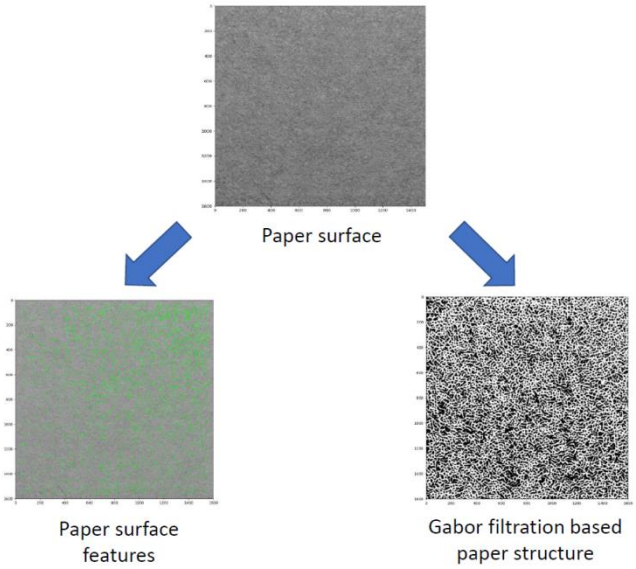

Figure 1. Paper surface features and structure extraction.

Document identifier

Each document to be registered in the system for future verification should have an identifier, which would link the document surface features and document description. In addition it should univocally specify which document authenticity should be verified on a document verification request. It is proposed to use QR-code for this purpose, because QR-code can easily be read by the scanning device even in case when it is rotated. The redundancy used for errors correction in QR-code allows to decode the identifier even in case when the printed QR-code is damaged [5]. To simplify user interactions with the system and to speed up the process of document authenticity verification the image of the surface should include both document identifier and the paper surface region, which should be used for original and candidate documents comparison. The paper surface region should be limited by printed square border with the QR-code identifier in the middle of this area. This printed square with encoded identifier is called a document label. Square region allow to simplify the distortion correction, but the QR-code fixed patters allow to identify image orientation. QR-code location in the middle of the region of interest simplifies the camera focusing on a surface and also helps to achieve near the same sharpness in the whole marked surface area. The document label with encoded document identifier example is presented in figure 2.

Figure 2. Document label identifier encoded in QR-code.

Requirements for surface capturing devices

Paper document surface capturing is very important step of document registration and verification as the captured image quality and detail have a very high impact on the result of algorithms, which process the image and verify the document authenticity. Taking into account the fact, that the proposed document counterfeit detection system should interest manufacturers and simple customers, two types of surface capturing devices are selected. These surface capturing devices are:

1) Industry camera

Industry camera can be used to register a document on a production stage, for example when product labels or packages follow the conveyor. The document surface must be evenly lit on the document registration step. The minimum requirements for camera sensor resolution depends on the camera lens focal distance and a distance between the camera and the paper surface. Camera sensor resolution should equal or higher than 16 megapixels, taking in account that document identifier label must not be less than 80% of the smallest frame side when frame aspect ratio is 3:2. This requirement is based on a high importance of surface structure detail. It is also recommended to use high frame rate and global shutter camera sensors, otherwise captured paper surface images can be not sharp enough.

There is a number of camera sensors on the market, which could be used to register the paper document surface in production:

– NOIP1FN025KA-GTI – 26.2 MP (5120 x 5120 pixel) 10-bit CMOS image sensor in APS-H optical format, supporting up to 80 frame per second readout at full resolution. Manufacturer: ON Semiconductor. [6]

– NOIP1SE016KA-GTI – 16.77 MP (4096 x 4096 pixel) 10-bit CMOS image sensor in APS-H optical format, supporting up to 120 frame per second readout at full resolution. Manufacturer: ON Semiconductor. [6]

– IMX387LQA – 6.88 MP (5472 x 3084 pixel) 8-bit CMOS image sensor in Type 4/3 optical format with global shutter and 61.3 frames per second readout. Manufacturer: Sony Semiconductor Solutions Group. [7]

2) Smartphone camera

Smartphone cameras in the most case will be used for document authenticity verification, but they can also be used for documents registration. Smartphone camera sensor resolution should be at least 12 MP and it should be possible to take RAW images, which are not processed by image enhancement algorithms. Big sensor size, optical image stabilization and phase detection autofocus are recommended for smartphone cameras used for paper document counterfeit detection, as these camera characteristics can have a positive impact on image quality and respectively on counterfeit detection algorithm results.

Requirements for surface registration conditions

Successful document registration and quality of document counterfeit detection depend on paper surface registration conditions. It is required to adhere the following rules to minimize a negative impact of external factors on the document registration:

a) Camera orientation should be perpendicular to the document surface. Small tilt angle can be corrected by early proposed region of interest extraction algorithm [8], nevertheless the camera tilt will result in reduced resolution of one of the surface image part, but insufficient depth of field will reduce sharpness of some image areas. Camera characteristics, and namely sensor size and lens properties, and external conditions of surface capturing can influence on image sharpness in the mentioned case.

b) Document surface to be captured should be evenly lit. Most modern smartphones have a led flash, which can be used as a constant light source, which can improve quality of document surface image and have a positive impact on autofocus accuracy and speed.

c) Camera should be fixed as much as it is allowed by the conditions of document registration or verification. Camera shake on surface capturing may cause the surface image to be blurry. Surface image blur can be caused by camera movement when it was already focused or when the exposure was long enough.

Document registration

A document registration step has a goal to collect and save document information to make possible its authenticity verification in the future. The document registration step starts with document registration initiation, which also includes document description introduction. The system generates unique document identifier, which will be stored together with introduced document description in the paper document counterfeit detection system. The generated identifier is encoded in QR-code, which is being printed as a part of a label on the paper document surface. It is required to capture the document surface in the area marked by the label to finish the registration step.

The document identifier decoded from the QR-code in the image will be used to link extracted paper surface features with the document information introduced on label generation step. Paper surface image processing and analysis will only be performed when the identifier is already registered in the system. When the identifier is verified and it is valid it is required to preprocess the image to extract the surface structure and features. In case if their quality is not high enough for the document registration then surface capturing should be repeated. The user will be informed about successful document registration, but the registered document will be associated with the author or the company on whose behalf the document is registered.

The process of document registration is shown in figure 3.

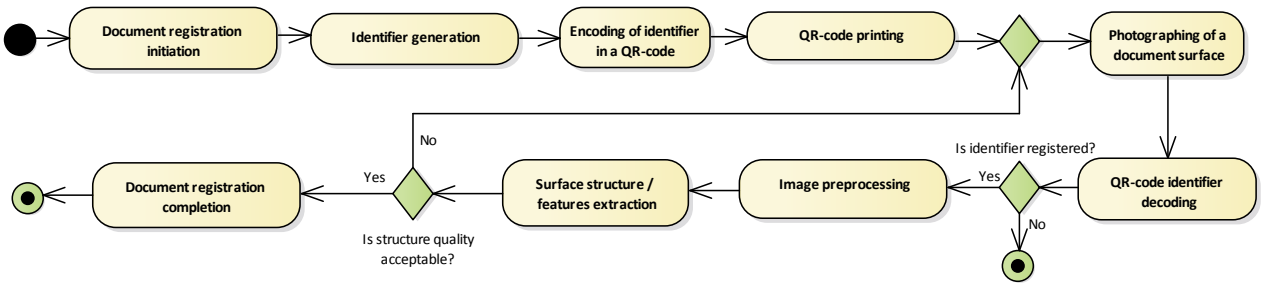

Figure 3. Document registration process.

Document verification

A document verification step starts from photographing a document area marked with a label. An identifier is being decoded from QR-code. If the decoded identifier is not registered in the system then the document verification process will be stopped. If the identifier is valid then the image of documents surface will be preprocessed for more robust surface structure and features extraction. If the extracted paper structure and features quality is low for document validation then the user should repeat the verification process. Valid document identifier is used by the system to get the original document paper structure features, which will be compared with the paper structure features extracted from new document candidate surface photograph when their quality is acceptable. The decision about document validity is based on the documents comparison result. Successful document authentication allows document information displaying. The process of document verification is shown in figure 4.

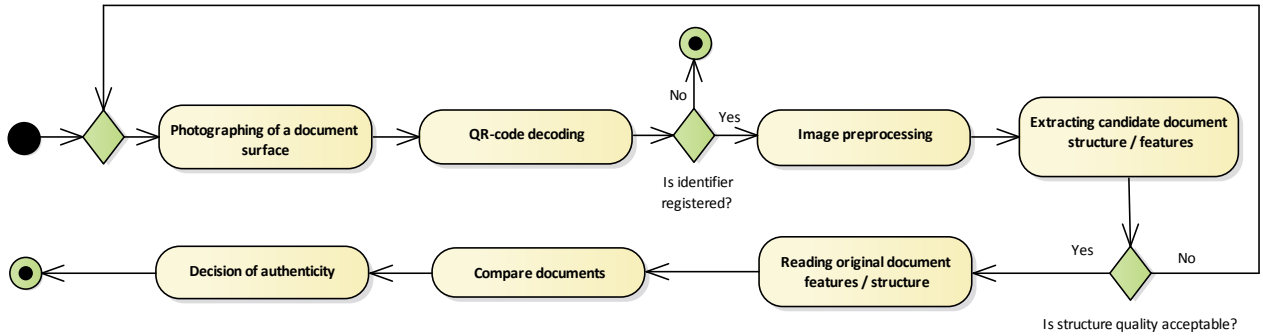

Figure 4. Document verification process.

System requirements

The system for paper counterfeit detection can be interested for product manufacturers, who want to minimize financial losses caused by counterfeit production. Counterfeited products are usually more attractive for some categories of buyers by lower cost, but can have bad quality, which can impact on original brand reputation or on the buyers' health. Many manufacturers pack or could pack their products in paper pockets and boxes or use paper labels. This allows to apply proposed method of paper documents counterfeit detection for their needs. Final consumers are interested in product quality and need a quick, chip and simple solution to verify product authenticity.

The proposed system is based on the following principles:

1) System user can be an individual or company.
2) System users, who are a document author, should specify information about themselves, for example: name or company name, address, email address, site, etc.
3) Each document has linked information, which describes it or an associated product.
4) A label, which is printed on a document, identifies the document and links the document with the document paper structure, which is stored in the system and can be used for candidate document verification.
5) Identifier encoded in QR-code and the marked area of interest, which paper structure identifies the document, should be captured in the same photograph.
6) The same label cannot be registered twice in case if one successful registration of this label is already present.
7) A user or an organization, who registered the label, is considered a document owner and has rights to manage it and to track its successful and failed validations history in the document counterfeit detection system.
8) A document scan session can include a sequence of photographs. The best photograph will be used by the system for paper structure analysis.
9) Document information, including the document author details should be displayed when the document verification is passed.
10) Each attempt to verify the document authenticity should be registered in the system and should include the date and also may include details of the user, who scanned the document, but only in case when the user accepted this and wants to assist in a fight against counterfeiting.

11) The document can be removed by its author. This may mean that the document lost its value, but in case of the product it can happen when the product is recalled or it is unsafe for use and respectively its sale must be stopped.

System users can have access to three main functionalities: document registration, document verification and document management.

Document registration includes introduction of document information, document identifier generation and encoding of the identifier in QR-code, which should be printed on the document surface. To finish the registration user should capture the labeled area of the document surface.

Document management includes documents information displaying. Verification statistics can be shown for selected document. Documents can also be deleted.

System users can be divided into four types:

1) Administrator – can manage system users.
2) Web application user – can register an account and manage own documents.
3) Mobile application user – can register an account, register and verify documents, and manage own documents.
4) Organization – a manufacturer. It can register documents, for example on a conveyor.

Use cases of paper document counterfeit detection system is presented in figure 5.

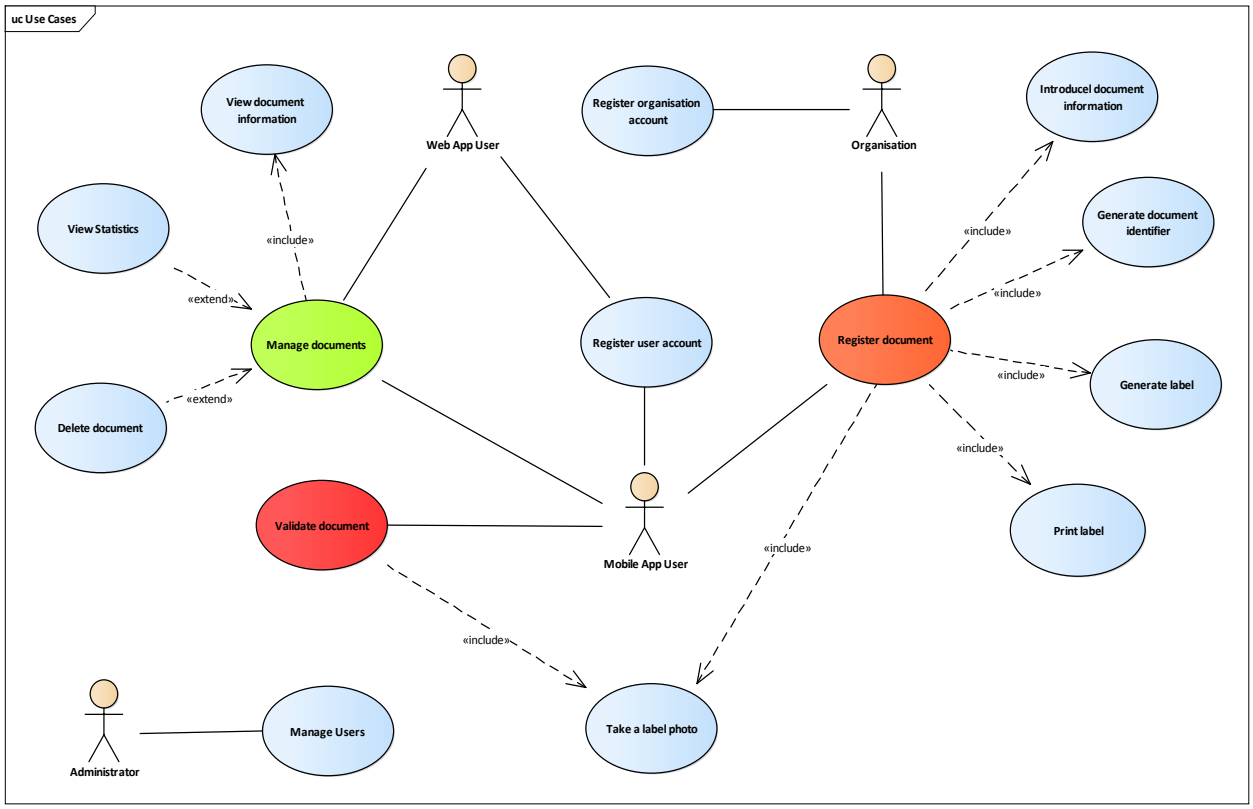

Figure 5. Use cases of paper document counterfeit detection system.

Proposed paper counterfeit detection methods and the system based on these methods are suggested to be used by paper manufacturers and buyers, who want to verify product authenticity. The proposed system is characterized by relatively high requirements for computing resources, which should be taken in consideration on a system design step.

The load on the paper counterfeit system may be not constant and it may vary depending on a time of a day, a day of a week, a season and other predictable and unpredictable factors. It is required to guaranty data security and integrity.

Taking above in consideration, the paper document counterfeit detection system should meet following technical requirements:

- security;
- high maintainability;
- high availability;
- ability to handle a variable load;
- high scalability;
- fast response;
- fault tolerance;
- versioning.

Microservice architecture

Traditional monolith approach in building software system is based on idea of system functionalities implementation grouping in a single application module, which is being deployable as a single software module and executed as a single process. Although seeming simplicity and reliability this architectural approach sets a group of limits on a software system. Monolith architecture of software system substantially restricts possibility to deploy different parts of the system independently. A deployment of a big system is not instantaneous and always there exists a risk, that changes in one system area or functionality can impact on another system area and potentially can break it or in some case can have an impact on an entire system, which is highly undesirable. Effective application scaling is also not possible in this conditions as different functionalities or processing steps, which should be scaled, may require various resources. System scaling without these considerations may have a negative impact on the system stability and the most importantly its development and operating cost. There is a need for a different system architectural approach, which would allow to design and to build effectively scalable system for paper document counterfeit detection, which is also characterized by low operational costs. It is very important as this factor is much related to profitability of the proposed paper counterfeit detection method. Microservice based architectural approach could solve the problem and to remove the limitation of the traditional monolith approach.

There are various definitions of microservice based architecture. James Lewis and Martin Fowler defined this software architectural term as: “The microservice architectural style is an approach to developing a single application as a suite of small services, each running in its own process and communicating with lightweight mechanisms, often an HTTP resource API. These services are built around business capabilities and independently deployable by fully automated deployment machinery.” [9]

It is proposed to organize the system as a set of small services also called microservices to meet all technical requirements for paper document counterfeit detection system. Each small service will have own responsibilities and can be deployed and scaled independently. A microservice should be deployable in independent environment – container, which will isolate it from other system parts, increasing system reliability [10]. All the containers should be centralized managed by container orchestration system, where one of the main responsibilities is containers placements on physical machines and scaling

based on instantaneous system loading, users' activity, free resources available on a physical machine and estimated resources required for microservice to be scaled. Virtual network connects all the microservices to allow interservice communication. Microservices can interact with each other by direct API calls or by sending a message to an event bus, which guaranty message processing and makes processing asynchronous. The type of each interservice communication is dictated by concrete functionality. Big advantages of asynchronous message processing using message bus are non-blocking calls, which free microservice-caller for other processed messages, and guarantied message delivery even in case if receiver is temporary unavailable. The processing of all the microservices requests is being performed on the user behalf to restrict the access to other users' data and to have possibility to restrict user access permissions where it may be required. Gateways are used to minimize the number of publicly accessible points [11]. They are build based on Web API design principles [12] and work like reverse proxies. Each gateway is dedicated to concrete client type and all the client requests are being transmitted to microservices. Usage of gateways is an application of backend for fronted pattern [13] and minimizes the number of dependencies for each system client, simplifying future system changes. Connection security between clients and gateways is guaranteed by SSL.

Proposed paper document counterfeit detection system architecture, based on microservice architecture is presented in figure 6.

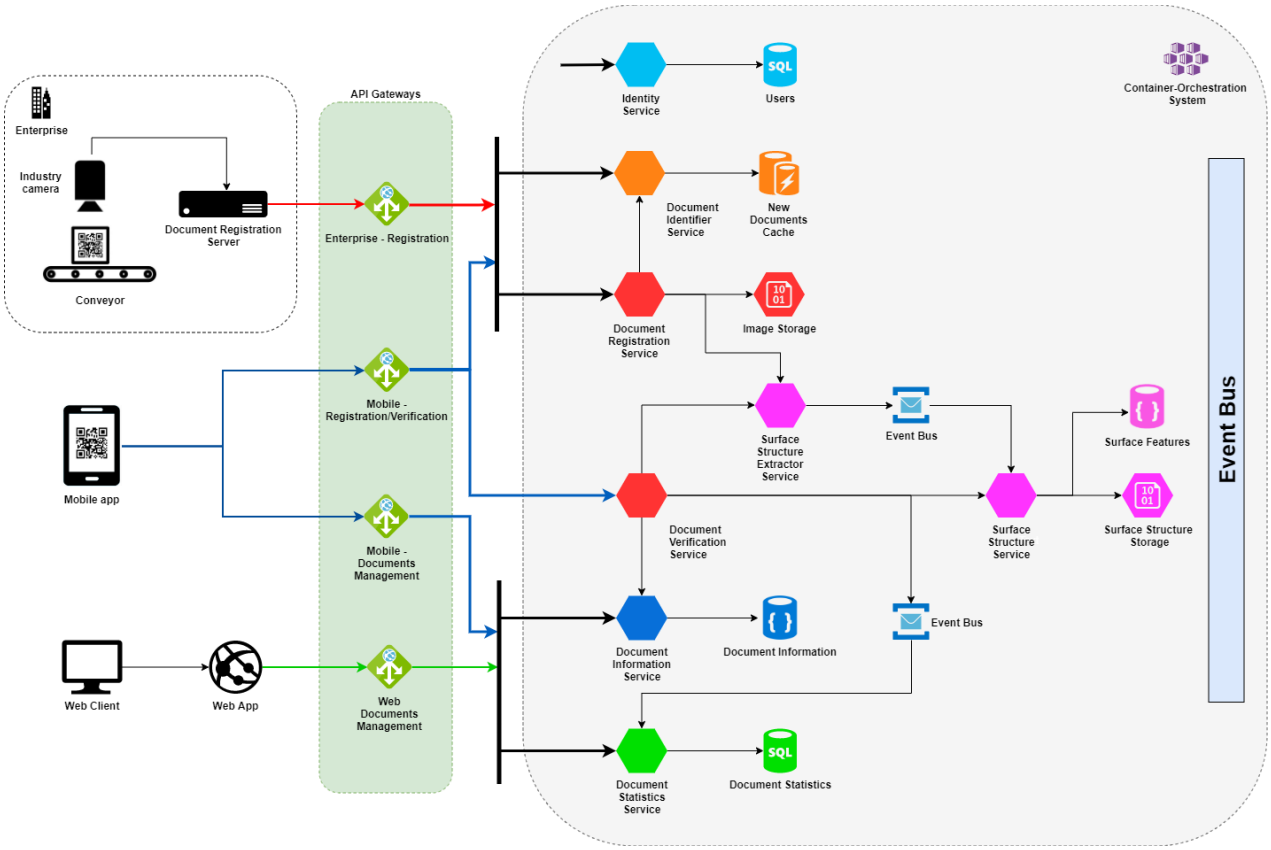

Figure 6. Microservice based architecture of paper document counterfeit detection system.

Proposed paper document counterfeit detection system is oriented on three client types and namely:

a) **Enterprise system**, which registers the documents when they pass a conveyor. Industry camera captures the document surface, but document registration service with

installed enterprise client application interact with Enterprise-Registration API gateway to register document in the counterfeit detection system.

b) **Smartphone** with preinstalled mobile application, which allow to register and to verify the documents and to manage the documents associated with the account the user is logged in with. It accesses two API gateways for mobile client: Mobile-Registration/Verification API gateway and Mobile-Document Management API gateway.

c) **Web client**, which interacts with a web application and Wed Documents Management API Gateway. Web client user can manage documents associated with their account.

Proposed paper document counterfeit detection system consists of following microservices managed by container orchestration system:

a) **Identity Service** is service responsible for authentication and authorization. System user can use their identity to access the services of document counterfeit detection system. Identity Service implements OAuth 2.0 authorization protocol [14] and OpenID Connect 1.0 authentication protocol [15]. Identity service has access to Users relational database and it is accessible for all the microservices and gateways in the system.

b) **Document Identifier Service** is a service, which has access to New Documents Cache in-memory database. It is non-relational database, which relies on RAM memory for data storage and respectively is characterized by a high data read/write speed. Document Information Service is called on the document registration initiation step to save the document details to be registered, generates a unique identifier for the document, links the document identifier with the information associated with it and stores them in New Document Cache. The generated identifier should be encoded in QR-code and printed on the corresponding document surface for subsequent surface registration. The time interval between document identifier creation and full document registration should usually be short and respectively all this information can also be stored in New Documents Cache for a short period of time before the document generation process is finished and the document information can be saved to persistent storage – Document Information database. The document information, which is stored in New Documents Cache for a long time, can be deleted. In case if the registration process for that identifier will be still requested and the document information is already not available then user will be prompted to repeat the process starting from the document details introduction.

c) **Document Registration Service** is a service, which is called on document registration finishing. The service receives surface image and saves it in Image Storage. This image can be used in future for more advanced surface structure or features extraction. Document Registration service transmits the document surface image to Surface Structure Extractor Service.

d) **Surface Structure Extractor Service** is a service, which responsibility is surface structure and features extraction for provided paper surface image.

e) **Surface Structure Service** is a service, which manages already extracted surface structure and features. Surface Structure Storage is responsible for surface structure image storage. Features are stored in Surface Features document oriented database.

f) **Document Verification Service** is a service, which is called when document verification is initiated and a client sends an image of a document surface, which authenticity should be verified. Document Verification Service provides surface image to

Surface Structure extraction Service, which extracts surface structure and features from the document candidate image. Surface Structure Service provides the surface structure and features of original image. Document Verification Service compares surface structure and features of original and candidate documents. Details about document verification are being sent to Document Statistics Service. In case of successful document verification information about the original document is being requested form Document Information service. It will be sent to the client.

g) **Document Information Service** is a service, which manages registered documents information. This information is stored in Document Information document oriented database.

h) **Document Statistics Service** is a service, which manage document verification statistics. Document statistics is stored in Document statistics relational database.

Directions for improvement

To improve the system work quality, efficiency and reliability of the method of paper document counterfeit detection it is required to continue research in following areas:

a) Smartphone camera displacement detection algorithm development. This algorithm should inform system user about oblique camera location, which can lead to false negative document authentication result, and prevent new document registration when quality of image for paper structure extraction is not acceptable. This algorithm development and its implementation in the system should simplify the system usage, increase the quality of proposed method for paper counterfeit detection by reducing the number of false negative document verifications.

b) It is necessary to study the image correction methods work when various devices are used. Smartphone models may differ in photo cameras. Each photo camera has own lens characteristics, sensor resolution and sensor size, which may influence on photosensitivity and depth of field. It is required to introduce new step of paper surface images preprocessing algorithm, which should depend on device type and should be based on the experiments results.

c) It is required to identify to localize damaged paper surface area in image and to exclude it form surface analysis and document verification, informing user about higher probability of false negatives.

d) Paper document scanning device IP address and GPS/GLONASS coordinated can be used to identify approximate location or geographical region where the scanning device and respectively the document under verification is located. This information can be used by document producer or document author to track product or document spread by regions. It can help to identify ways of counterfeit product distribution, analyzing failed document verifications statistics. Potentially this can even be used to localize counterfeit production.

Conclusions

In this paper we proposed a new method of document counterfeit detection and the system based on in. The proposed method can make document authenticity verification publicly accessible and easy to use, guarantying the quality of a product and protecting buyer health. The buyer, who wants to verify a document or a product authenticity, can do it on his own using only a smartphone that meets the defined technical requirements, pre-installed specialized software and an Internet connection. The proposed method can be

used to verify the authenticity of various kinds of documents, including goods with packaging and labels made of paper, such as clothing or medicines, by detecting the fact of copying a document or packaging. Moreover, a system based on the proposed authentication method is characterized by low cost as it doesn't require any special security features. We proposed an architecture for document counterfeit detection system. It is based on microservices and takes in account system work specific and potential conditions of the system use. This allows to use resources more efficiently and respectively to minimize costs. We defined the directions for the next researches, which should improve the proposed method reliability and intensify the fight against counterfeit production.

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