Anti-counterfeiting and Authenticity Verification Technique for Molded Synthetic Resin Products

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Abstract - Authors propose anti-counterfeiting and authenticity verification technique for molded resin products. Each product has unique characteristic information formed by “liquid turbulence” which is caused when liquid resin is poured into a mold. The appearance of the product is not affected by this information as it can be covered by IR transparent paint. We confirmed that (1) Feature information could not observed by naked eyes, (2) This information could be extracted from samples without contact, and (3) extracted information differed from each sample.

I. Introduction
A. Background and Target

Synthetic resin products are common artifacts in our daily life. Synthetic resin can be obtained with affordable price. It is easy to form and resists acid and alkaline corrosion. Furthermore, it is used to add features and characteristics to products in order to make them fit for use. In general, there is an image of being non-conductive, flammable, and non-biodegradable, new types of synthetic resin with electro-conductive, flame-retardant, and biodegradable features have been developed. It can also be recycled.

Counterfeit products that mimic genuine synthetic resin products are being sold by abusing the resin’s characteristics, in particular, the ease with which it can be obtained and formed. Currently, the most valuable synthetic resin products are targeted for counterfeiting, but we predict that security devices (such as SIM cards and hardware tokens) and value-added products created by renowned brands (such as limited edition items) will be copied and sold in the near future.

Counterfeit products not only violate the intellectual property rights of brand holders and cost them income that they could have otherwise obtained but also cause financial and psychological damage to consumers. In addition, as copied products are of low quality, accidental injuries and health problems could occur due to structural weakness and the chemicals they contain. The existence of copied products cannot be overlooked, and thus, as with other items, it is important to distinguish between real and fake synthetic resin products and make counterfeiting difficult. In this paper, we propose a technique for automatically verifying a product’s authenticity and applying “artifact metrics,” which is a technique for making counterfeiting more difficult. We mainly focus on molded synthetic resin products.

B. Overview of Artifact Metrics

In artifact metrics, authenticity is verified using unique information (characteristic information) present in each artifact. Hence, this technique is conceptually similar to biometrics. Counterfeiting is more difficult because copying the genuine product’s characteristic information is quite difficult. This information is spontaneously and randomly created during the manufacturing process and cannot be deliberately engineered even by the manufacturer. Thus, counterfeiting remains difficult even if the method used for deriving the characteristic information is publicly available.

Microscopically, the characteristic information is different for each individual artifact. These differences can be seen through a microscope as very small changes in roughness or/hue across its surface. However, we assume that it takes some time to specify “the area photographed when registering” and “the area to shoot when verifying” because the area shown by the microscope is extremely small [1].

Hence, in artifact metrics, a method is adopted to create unique characteristic information for the artifact. It can also easily extract this information from the artifact. In concrete terms, a material with particular physical characteristics is added during the manufacturing process. Particles from the added material randomly and spontaneously spread and become fixed in the artifact. The degree of dispersion of the particles is determined and used as characteristic information. A sensing device that can identify the material’s physical characteristics is used when extracting characteristic
information from the artifact.

A system utilizing artifact metrics is called an artifact metrics system, a schematic for which is shown in Fig. 1. The two phases depicted in this figure are similar to that of a biometrics identification system. In this system, characteristic information is extracted from each artifact before shipping and stored in a secure database. On verifying the authenticity of a particular artifact, its characteristic information is extracted and compared with the information stored in the database.

II. Requirements and Prerequisites

A. Requirements

In this section, we describe the artifact metric requirements for our study. First, the material added to the products to create the unique and easy-to-extract characteristic information should present minimal risks to the human body and the environment. Second, the amount of material added should be as low as possible to avoid affecting the product’s moldability (so it can be formed as intended) and strength. Third, if the material added to the product affects the product’s appearance, a method should be adopted for concealing it and making confirmation of its existence by naked eye difficult (meaning that an artifact metrics technique for transparent synthetic resin products is out of our scope). However, this method should avoid affecting the extraction of characteristic information and not create a situation where the verifier cannot extract enough feature information from the artifact. Lastly, to avoid physically damaging the product while verifying its authenticity, such as scratching its surface, the characteristic information should be extracted without any contact. Hence, we set four requirements for the artifact metrics in our study.

Requirement 1: The material added to the product should present minimal risk to the human body and the environment.

Requirement 2: The amount of material added to the product should not exceed 20 wt %. This value was obtained from a technical reference [2] regarding the amount of additives required to improve a synthetic resin product’s strength or antistatic properties.

Requirement 3: It should be possible to extract sufficient characteristic information from the artifact (compared with the registered information) even when the method for concealing the material’s existence from naked eyes is applied.

Requirement 4: Characteristic information should be extracted without contact to avoid physically damaging the product.

B. Prerequisites

In this section, we set prerequisites to clarify the scope of discussion in this paper.

Condition 1: We focus on products that are currently being manufactured. This means that products that already exist in the market (such as antiques) are outside the scope of our discussion.

Condition 2: We discuss the feasibility of our artifact metrics technique for verifying a product’s authenticity and increasing the difficulty of counterfeiting. We do not discuss the actual performance of the artifact metric system (for example, in identifying characteristic information or counterfeit products) as our system has not yet been implemented.

Condition 3: We focus on completely painted synthetic resin products. Hence, transparent unpainted synthetic resin products are outside the scope of our discussion.

Condition 4: There are several types of synthetic resin. In this paper, we verify our approach’s feasibility using epoxy resin. This is because it has high moldability and strength, is easy to obtain and color, and allows to make products such as accessories without having expertise about synthetic resin. We will apply our method to other synthetic resins, such as silicone, in the near future.

III. Our Method

A. Concept

We often see liquid flows and the patterns made by them in our daily life. Some examples are shown below.

1. Liquids exhibit three-dimensional flows when they are poured into containers.

2. When two types of liquid, one dyed with color A and the other with color B, are simultaneously poured into a container, marble-like stripe patterns form throughout the container without the different liquids mixing.

In general, liquid flows and the marble-like stripe patterns formed by them are three-dimensional and random. This is because in hydrodynamics, such flows are defined as “turbulent” and are complicated and unsteady (changeable liquid flows affected by the passage of time) [3]. As with the decay of radioactive isotopes, turbulent flows are random [4]. A container called a mold is used when forming epoxy products. In general, liquid epoxy (the main agent) and a curing agent is poured into it. At that time, the flow of the epoxy is turbulent. Our idea is derived from the two examples mentioned above and uses the marble-like stripe pattern formed throughout the artifact as characteristic information. Thus, single or multiple information features can be extracted at any point in the product.

B. Creating Characteristic Information

This section describes the creation of characteristic information. First, two powders, A and B, with different optical characteristics are prepared. Powder A reflects near-infrared light while powder B absorbs near-infrared light. Using these materials, near-infrared images with high contrast can be obtained when photographing samples with stripe patterns. Although we used titanium oxide powder as powder A and carbon fiber powder as powder B in this paper, other materials could also be used as long as they have the
same optical features and minimal risk to the human body and the environment.

Next, two types of epoxy liquid were made (epoxy A with a small amount of powder A and epoxy B with a small amount of powder B). The same amount of curing agent was added to both epoxy liquids and evenly mixed. After that, the same amounts of both epoxy liquids were simultaneously poured into the same mold. As both powders are chemically stable, no chemical changes occurred after mixing the two epoxy liquids.

Marble-like stripe patterns formed in the mold due to the above-mentioned combination of physical and chemical characteristics and turbulent flow. The epoxy liquid gradually hardened owing to the presence of the curing agent and turned solid after a certain time period. The stripe pattern, formed throughout the artifact, could be observed after removing it from the mold.

C. Concealing Characteristic Information

Most of the synthetic resin products in our daily life are dyed or painted using pigment or paint and do not have marble-like stripe patterns. The patterns formed in the previous section could impair the product’s appearance, so it was necessary to conceal them in an appropriate manner. However, the method used had to satisfy Requirement 3, which is described in Section 2.

To be able to observe the reflection and the absorption of near-infrared light while still concealing the artifact’s stripe pattern, we used a special paint that transmits near-infrared light to paint the entire surface of the epoxy objects. As shown in Fig. 2 (Left), this paint reflects visible light; hence, the naked eye can see the paint’s color but cannot recognize the stripe pattern covered by the paint. On the contrary, near-infrared cameras can observe stripe pattern as the paint transmits near-infrared light.

D. Extraction of Characteristic Information

Characteristic information (the marble-like stripe pattern) can be extracted by the optical system shown in Fig. 2 (Right). First, the target product was placed on the stage and a near-infrared camera was prepared, with a ring-shaped near-infrared light source attached in front of the lens. Next, observation areas were shot by the camera while being irradiated with near-infrared light. A ring-shaped light source was used so that the surface of the observation area was evenly irradiated.

As the stripe pattern was formed throughout the product, multiple pieces of characteristic information can be extracted from the artifact by using multiple observation areas. Likewise, in biometrics, multiple pieces of biometric information can be obtained from multiple parts of the body, such as fingerprints and vein patterns.

VI. Experiments

A. Making Samples

We made three different types of samples in order to determine two things: (1) whether characteristic information can be formed by using the method described in Section 3.2 and (2) the appropriate amount of material to add to the sample. We made five samples of each type. Samples of Type 1 were made by mixing two types of epoxy liquid, one containing 5 wt % of titanium oxide powder while the other had 5 wt % of carbon fiber powder. Samples of Type 2 were
made by decreasing the amounts of each material by 2.5 wt %. Samples of Type 3 were made by reducing the amounts of each material by 1 wt %.

The two above-mentioned types of epoxy liquids (titanium oxide and carbon fiber) were poured into a mold using a syringe. To easily make marble-like stripe patterns (characteristic information), we adopted a pouring method where the tips of the two syringes were brought close enough to one another (see Fig. 3) through trial and error. We used a silicone mold, used for making accessories made from synthetic resin (see Fig. 3). The sample shape was an ellipse of height 5.5 cm and width 3.4 cm.

Visible images of the surfaces of each type of sample are shown in Fig. 4. The white color comes from the titanium oxide powder, and the black color is due to the carbon fiber powder. Each sample has its own unique characteristic information. However, the contrast between the black and white characteristic information in the Type 3 samples is lower than for the other types. On the contrary, on comparing Types 1 and 2, the contrast seems almost the same and no significant differences in the sharpness of the characteristic information can be seen. From the viewpoint of moldability and strength, a lower percentage of material added to the product is preferable. Hence, in the following experiments, we used samples containing 2.5 wt % of the material.

B. Visibility of Characteristic Information

To confirm that the characteristic information could be concealed using the method described in Section 3.3, we painted the surfaces of the Type 2 samples (2.5 wt %) selected in the previous section with black near-infrared-transmitting paint using a brush. Fig. 5 shows visible light images of the samples after painting. These show that the characteristic information, hidden under the paint layer, could not be seen by the camera as the paint reflects visible light. Next, we conducted the following experiment on 20 examinees to test whether the characteristic information was visible to the naked eye.

1. The sample ID number was pasted on the reverse side of each sample. Next, a visible-light image of the front side of the sample was printed on paper and its identification number added in the margin.
2. The visible-light sample images and their ID numbers were placed in numerical order on a table.
3. The samples were randomly placed on the table with their painted front sides up (see Fig. 5).
4. The examiner gave the following directions to each examinee. “Each sample has marble-like stripe patterns. Take each sample in your hand and observe the surface of it carefully. If the stripe patterns on a sample and those on a particular printed stripe pattern seem to be equal, put the sample onto that print. You are not allowed to see the reverse sides of the samples.”
5. After the examinee has moved all the samples, the examiner compared the identification numbers on the reverse sides of the samples with the corresponding numbers on the prints, adding 1 point if they matched.

The examiner did not inform the examinees whether their decisions were correct.

6. The examiner and examinee then repeated steps (3) to (5) ten times in sets of two. After that, the examiner calculated the examinee’s correct answer rate.

Fig. 6 shows the score achieved by each examinee. The vertical axis shows the score, and the horizontal axis shows the examinee number. The gray line shows the average score of 1st set and the yellow line shows the average score of 2nd set. The average score was nearly 10 points.

In order to evaluate the difficulty level of this experiment (Visibility of characteristic information) based on the average score, we set a scenario shown below and calculated the minimum score obtained by examinee.

Examinee puts a sample arranged at the most left on the table (by examiner) on the paper with sample number one every time with no careful consideration. Fortunately, the sample’s pattern and the printed pattern match every time.

In this situation, examinee can obtain at least 10 points in one set. In our experiment, two average scores were close to the above mentioned points. Although the scenario is advantageous for examinee, but we could say that the visibility of characteristic information by naked eyes was quite low through the experiment.

C. Extraction of Characteristic Information

To confirm that the characteristic information could be ex-
In Section 3.4, we proposed a method for extracting characteristic information from the artifact by photographing it using our optical system. In our experiment, we were able to extract characteristic information without making contact with the samples, and hence our method satisfies Requirement 4.

B. Difficulty of Counterfeiting

We consider the difficulty of counterfeiting characteristic information from an optical viewpoint. First, the optical characteristic information created by particles of the materials is uniquely determined by the particles’ shapes. Next, light reaching a particle reflects or refracts at the particle’s boundary. The particles’ refractive indices differ based on their composition, and the angles of refraction differ based on the particles’ shapes. Fig. 8 shows the image of reflection and inflection of titanium oxide and carbon fiber particles. Each particle is depicted as spherical shape for convenience of explanation. In carbon fiber particle’s case, the light intensity is gradually weakened when the light enters and moves the inside of the particle due to the light absorption. The intensity of the light comes out from the particle is weaker than the light enters to the particle.

Hence, to make a copy with the same optical characteristic information as the genuine product, forgers would have to do the following:

1. Use the same materials as were used to make the genuine product.
2. Choose particles of these materials that have the same shapes as those in the genuine product.
3. Place these particles in the same three-dimensional positions as the particles in the genuine product.

For manufacturing, step (1) is easy. However, step (2) seems to be more difficult as, in reality, the particle shapes are not spherical, as illustrated in Fig. 8. In addition, placing particles at designated three-dimensional positions in a physically unstable liquid resin (step (3)) would be very difficult. Hence, creating a counterfeit product with the same optical characteristic information as a genuine product seems to be
Difficulty of counterfeiting could be proven even if the samples were made adding only titanium oxide powder or carbon fiber powder based on the above mentioned reasons. Difficulty of making copied products could be heightened as we use two materials in this paper.

C. Correlation ratio between samples

We conducted the following experiment in order to confirm the fact that the unique characteristic information could be formed (it means that large difference of correlation ratios between samples could be observed) by using a method described in Section 3.2.

1. Make 50 samples with 2.5 wt % of additives and cover the front side of each sample by painting an infrared transparent paint.
2. Shoot infrared image of each sample by using a method described in Section 4.3. Calculate correlation ratio between two images of sample no. 1 by using Phase-Only Correlation (POC) method. Correlation ratio between sample no. 1 and the rest of 49 samples are also calculated. The reason of using POC method could be described as follows: This method is widely known to evaluate correlation ratio of two images and has good results for biometrics identification systems, such as fingerprint, iris, palm print, and dental X-ray images.

Fig. 9 shows correlation ratio between two infrared images of sample no. 1 and the ratios of infrared images between sample no. 1 and the rest of 49 samples. The differences are clear: The former correlation ratio is high as 1.0 while the latter ratios are low. From this result, unique characteristic information could be formed and used as identification information because the correlation ratios between different samples were low.

VI. Summary and Future Works

To automatically verify the authenticity of molded synthetic resin products and make manufacturing counterfeit products difficult, we have proposed an artifact metrics technique. This technique utilizes the phenomenon where poured liquids flow to form three-dimensional, random marble-like stripe patterns throughout the artifact. To create this characteristic information (stripe pattern) throughout the product, we proposed a method where two types of epoxy liquids with different optical materials added are simultaneously poured into the mold. We also adopted a special paint that transmits near-infrared light and proposed painting it onto the surface of the product to conceal the stripe patterns. The patterns cannot then be observed by the naked eye, but near-infrared light cameras can still detect them.

In our experiments, we made samples using epoxy, titanium oxide powder, and carbon fiber powder. We confirmed that the characteristic information could not be observed by the naked eye, that the near-infrared camera could extract feature information, and that the information differed in each sample.

We plan to conduct the following experiments to verify our method’s feasibility. In this experiment, we used black-colored paint that transmits near-infrared light. Aside from black, several other different-colored paints with the same ability are available. We will test whether sufficient characteristic information can be extracted from samples coated with these paints. We will use other synthetic resins, near-infrared reflecting and absorbing materials to test whether the same results can be observed.

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References


