Implementing traceability using particle randomness-based textile printed tags

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Implementing traceability using particle randomness-based textile printed tags

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Abstract. This article introduces a random particle-based traceability tag for textiles. The proposed tag not only act as a unique signature for the corresponding textile product but also possess the features such as easy to manufacture and hard to copy. It seeks applications in brand authentication and traceability in textile and clothing (T&C) supply chain. A prototype has been developed by screen printing process, in which micron-scale particles were mixed with the printing paste and printed on cotton fabrics to attain required randomness. To encode the randomness, the image of the developed tag was taken and analyzed using image processing. The randomness of the particles acts as a product key or unique signature which is required to decode the tag. Finally, washing and abrasion resistance tests were conducted to check the durability of the printed tag.

1. Introduction

Textile and Clothing (T&C) industry is facing numerous challenges due to its complex and extensive distribution system with a vast geographical distance between various stakeholders [1]. Low labor cost and easier availability of raw material have made the production more dominating in the developing countries like Bangladesh, China, and retail in developed countries like the European Union and the United States [2]. Due to mass production of similar style, identification and differentiation of textile products in the supply chain based on their physical characteristics is almost impossible. Moreover, at each stage of production either the textile product is transformed, or the sub-industries do value addition. All these factors have paved ways for easy breaching of the supply chain and introduction of counterfeit goods, which are a serious concern for brands, authorities, and customs.

To resolve the above-mentioned issues, tagging of the product is one of the useful and widely used solutions [3]. Product identifier in the form of RFIDs, 2D, and 1D bar code are some of the existing technologies being used in product tagging in the supply chain [4, 5]. However, in the case of textiles, most of these attached tags can easily be cloned or are detachable from the product thus leading to loss and replace of original product with counterfeits in the supply chain [6-8]. In this context, the study aims to develop a random particle based textile tag for product authentication and traceability in the textile supply chain. The developed tag is anticipated to be of low-cost which can easily be manufactured via conventional screen printing process and authenticated using the camera based smartphone. These tags will be integrated (printed) on the garment during apparel production stage acting like an unclonable unique identifier for each product leading to the authenticity and traceability application, as shown in figure 1.

2. Proposed Tag and Traceability System

As aforementioned, T&C industry have a global supply chain with multiple nodes (stakeholder) like fiber manufacturer, yarn manufacturer, fabric manufacturer, apparel producer, sub-industry (dyeing, finishing, etc.) and retailer [9]. This complex network requires a uniform and secure information sharing and storing system through product data management (PDM) system to bring transparency, stop counterfeits and increase the visibility in the supply chain[6, 10]. To overcome all these challenges and to implement traceability, use of a time varying function integrated with a unique identifier code for each product can be a useful solution [11]. The unique code thus generated will act as a link or a secure key to stack or access product information at each stage of product life cycle. However, the proposed tag discussed in this study will be added to the product at final manufacturing/finishing stage, will incorporate time-based codes from the previous stages (fiber and yarn) and remain integrated to the textile product throughout the life cycle thereafter.

The methodology for the construction of proposed tag draws inspiration from Physical Unclonable Function (PUF) which is popular cryptographic technique involving encoding of randomness [12]. This randomness can be an optical random feature, random magnetic signal or quantum confinement. However, due to easy production, encoding and decoding purpose (using camera based smartphones) optical randomness is one of the widely used techniques. Therefore, in the proposed tagging system, to generate and integrate such randomness onto the textile surface, dark micron-scale particles were mixed with printable paste and printed on the light color textile surface using screen printing method. Since the particle distribution on each tag thus produced is random and uncontrolled, therefore, replicating them is practically extremely difficult if not impossible. In comparison to traditional tags like RFIDs and QR codes, the proposed tag has certain advantages. As mentioned above the most important being unclonability as a microparticle-based unique signature (randomness) is hard to reproduce for each textile product. Secondly, as the tags are printed directly on the textile surface, they are un-detachable and can last long and cannot be used with another product. Finally, the tags are cheap as they can be developed using conventional printing paste and microparticle with reusable printing screens. The printing method, encoding, and decoding are further explained in next section of the paper.

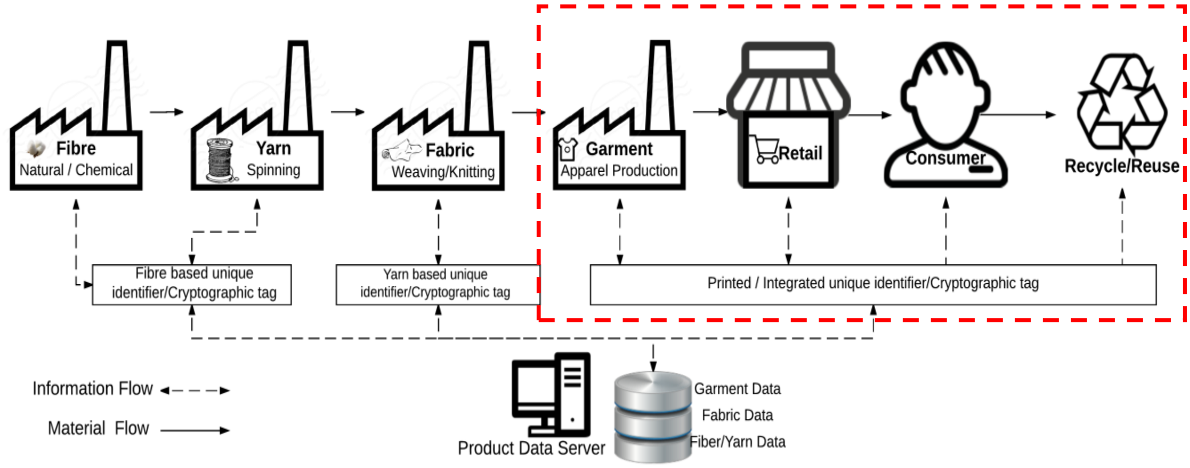

Figure 1. Proposed textile traceability system with area of implementation highlighted in red

3. Materials and methods

3.1. Screen printing of random particle

To generate these random distributions, a special paste comprising of micron-scale particles and binder in a fixed ratio is screen printed on the surface of the textile. These particles were black polyester glitter sourced from GEOTECH, International B.V, Netherlands [13] and widely used for textile coating and printing. The size of these particles was selected to be 200 microns to enable easy detection by mobile based cameras. For initial experiment styrene-acrylic based binder (8% w/w) sourced from Archroma, France [14] was mixed with 2.5% (w/w) thickener and (89.5% w/w) water along with 0.002 % (w/w) of glitter particles. The paste was thoroughly mixed to attend a homogeneous mixture and printed on a white 100% cotton fabric of 118 gsm. An 18 threads/cm screen was selected for easy passage of glitter particle along with paste onto the textile surface (figure 2).

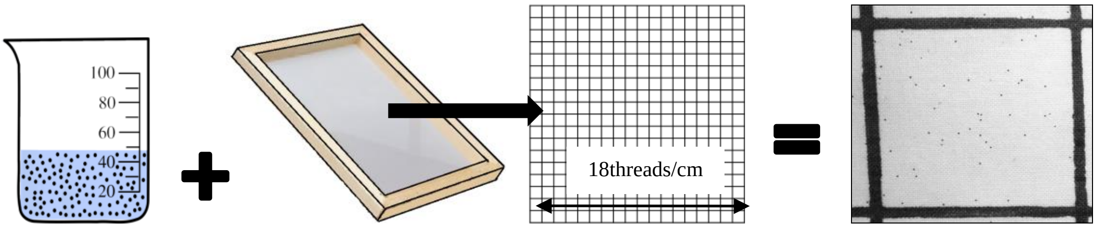

Figure 2. Equipment and material used for tag construction

3.2. Optical features extraction using Image analysis

The obtained randomness is extracted and characterized using image processing tools and encoded. The encrypted code thus obtained acts like a secure key to authenticate the product. To begin with, the algorithm for square box detection was applied to locate the area of interest (tag area) on the textile surface followed by image cropping, particle detection and finally distribution characterisation as illustrated in figure 3.

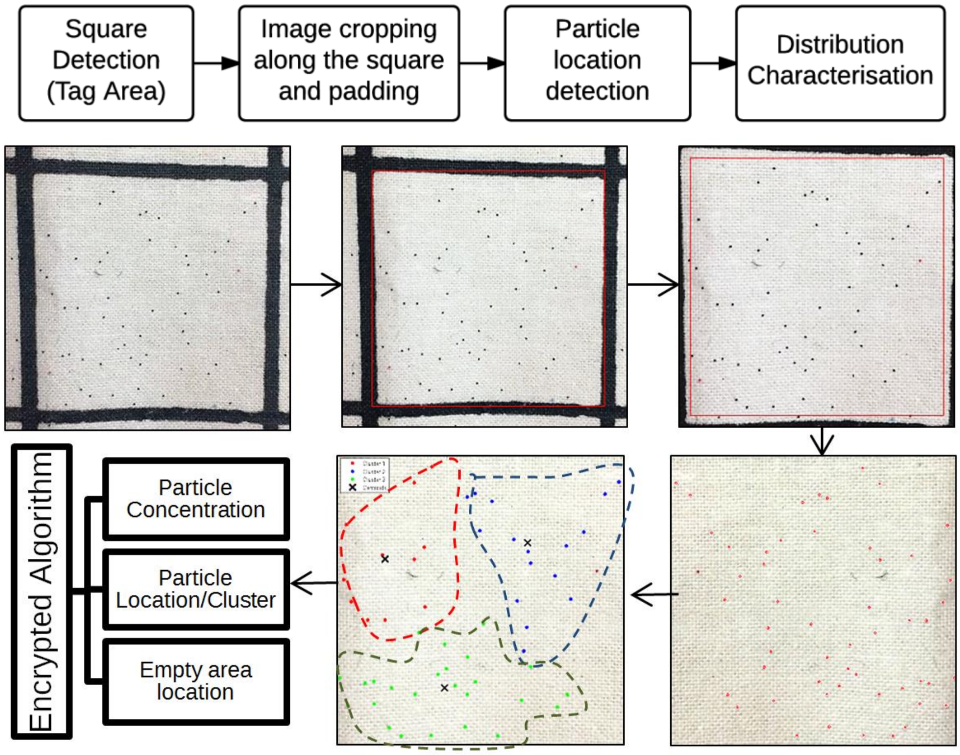

Figure 3. Image processing steps to extract and characterize the random distribution

3.3. Durability Test
To test the durability of the developed tags (printing paste along with micron-scale particles) three samples were printed with the developed paste and cured for different times (5, 7 and 10 mins respectively). This was done to observe the effect of curing time on the adhesion property of binder. Further, these samples were subjected to washing and abrasion fastness test. The number of particles in each tag of area 3x3 cm² was calculated through image analysis algorithm described above, before the test and subsequently after each cycle (wash and abrasion).
To test the washing fastness, samples were washed with ECE (European Colourfastness Establishment) normalized detergent and water mixture (0.5% w/w of detergent) for 20 mins at 60°C followed by hanger drying. This cycle was repeated for four times and image was taken after each wash. Martindale Abrasion Tester was used for abrasion resistance test of the three samples. The samples were abraded with standard wool abradant fabric (plain weave, crossbred, worsted wool) for ten cumulative intervals comprises of 100, 250, 500, 750, 1000, 1250, 1750, 2500, 5000 and 7500 cycles respectively. Images were taken and analysed after each interval.

4. Results and Discussion
The developed image processing algorithm efficiently extracts from the printed tag - the area of interest, correct alignment, detect particles location and encode them. From the abrasion resistance test, it was observed that after 7500 cycles, on an average less than 20% of the particles were only eroded (figure 4). Sample with high curing time displayed a good abrasion resistance; however, the difference was not significant. Weight after each interval remained same throughout.

It was further observed that the washing fastness of the binder was not good, resulting in almost 50% particles erosion after first wash. Moreover, approximately 10% of particles were only remaining after four washed (figure 5) which proves that the tags can withstand high abrasion during the daily usage, but further research has to be undertaken to make it wash friendly.

There can be multiple reasons for low washing fastness of the binder. Major being the solid content of the binder (which was low for the current binder), print paste viscosity, work of adhesion for binder and textile surface etc., and needs further experimental validation.

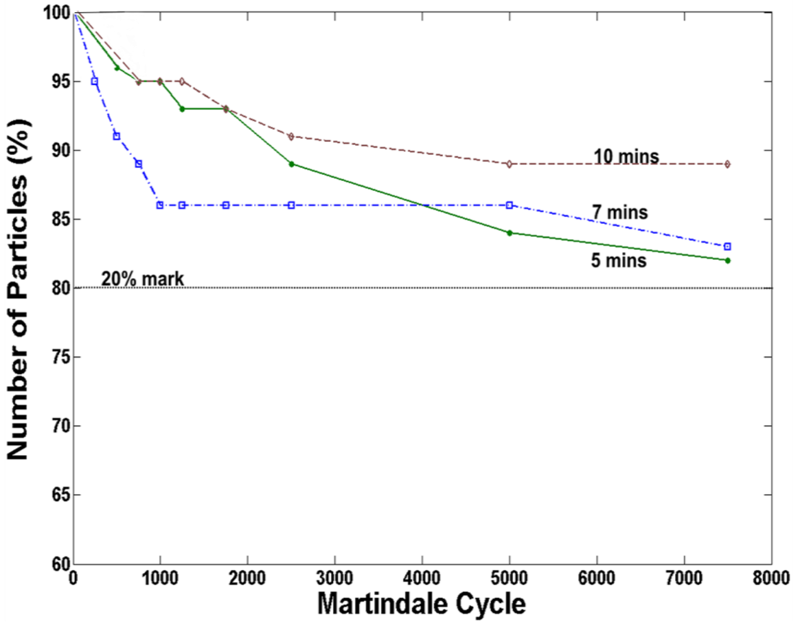

Figure 4. Results for the abrasion fastness test

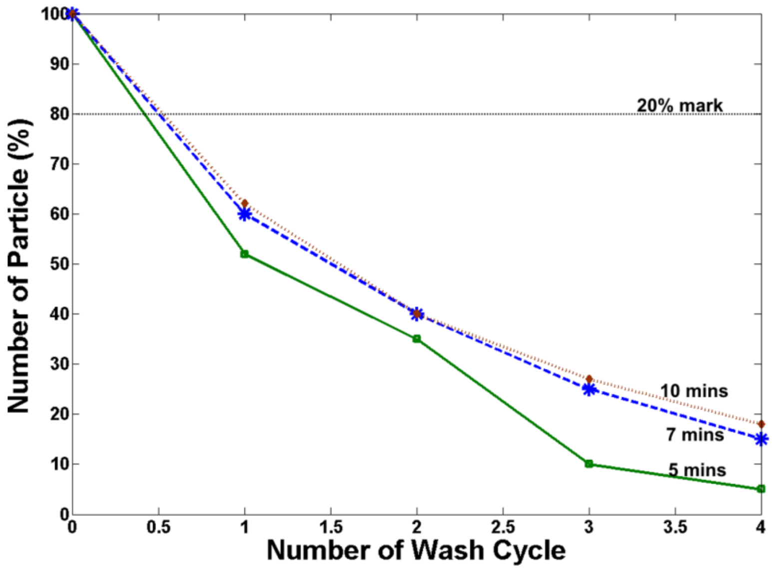

Figure 5. Results of the wash fastness test

5. Conclusions

The study presents a particle randomness-based tag for product authentication and traceability in the textile supply chain. The developed tag act like a unique signature for each product is low-cost and can easily be encoded and authenticated using a camera based smartphone. To overcome the problem of detachability, the developed tag is integrated into the garment by printing it over the fabric surface. Initial durability test proves that the printed tag has good rubbing but low washing fastness. Therefore, different binders need to be explored and tested to improve wash durability. Further research work is also undertaken to integrate these tags (which will act as a security layer) along with existing technologies to track the product, know its' composition, history, origin, carbon footprint and distribution processes.

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