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VISUAL ART ASSEMBLY
GUIDED BY TAG-LESS IDENTIFICATION OF COMPONENTS

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ABSTRACT

This paper proposes an interactive system that enables visitors to enjoy assembling a visual artwork from its decomposed components. "Assembly" here means the alignment or placement of the components, which challenges the visitors like a jigsaw puzzle. It is inadequate to mark numbers or attach tags onto the components, because it invades the visual appearance of the art. Thus, we employ a non-invasive identification system using "Fingerprint of Things" to identify each component without marking or tagging. In the experiments, our system successfully identified 90 components of the artwork, each of which exhibits too small piece to retrieve its original position in the whole artwork. The system is easy-to-use and responds quickly, thus visitors can enjoy assembly of the artwork. This digital system provides analogue taste like a traditional jigsaw puzzle, with the portability of the artwork. It is also a prototype to explore future applications including cultural property preservation and industrial assembly.

1. INTRODUCTION

In construction or manufacturing industry, there are often a large number of components which have to be assembled. Therefore, the construction or manufacture often requires special skill or craftsmanship. For example, in manufacturing industry, workers have to handle numerous components, such as bolts, chips etc. Those components are similar-looking and hard to distinguish at a glance; however misuse of those parts having different specification is critical damage to the whole product. Therefore, the workers are struggling to achieve the contradiction of fast but secure work;

In such a situation, a work-assistance system by identifying those components will be a way to assist efficient manufacturing work. If the workers can get instructions directly from those components in their hand, they will be able to assemble components without skilled labor. Furthermore, such an instruction system may enable robot hands to do such a manufacturing work without any teaching. Since attaching markers or barcodes to all the components is difficult because of lack of mounting space, surface functionalities or aesthetics, a tag-less identification method is demanded to fit such industrial needs.

In this paper, we present a tag-less assembly system by identifying each component without applying numbering or tagging. We employ a non-invasive identification technology using "Fingerprint of Things" [1] to identify each component.

As a proxy for a more practical problem in construction

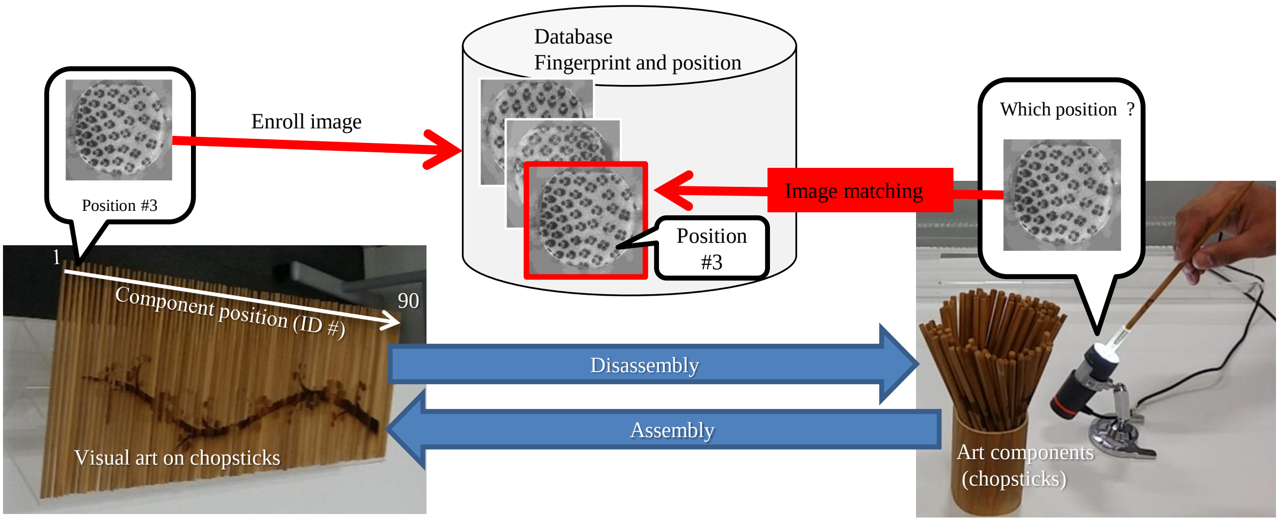

Figure 1: Proposed tag-less assembly guidance system using "fingerprints" of bamboo chopsticks.

or manufacturing industry [3], we construct a visual art that is constructed by assembling chopsticks in the designated order. Anyone can assemble the art at first sight, which is analogy of situations where workers construct a sophisticated structure e.g. a log-house without a long parts list. Our smart guidance system demonstrates that the annoying assembly task can be changed to enjoyable interactive artwork.

2. PROTOTYPE SYSTEM OF ASSEBLY ART

Figure 1 shows an overview of our prototype system using tag-less identification of artwork components. We demonstrate a multi-view art that is assembled by placing chopsticks in the designated order (Fig. 2). Each chopstick is laser engraved to show a little part of the art (Fig.3). Once the art is disassembled, it is quite hard to identify the individual component solely on the basis of its appearance and retrieve its original position. At the beginning of our demonstration, the art is disassembled and the chopsticks are assorted randomly into a holder. Our proposed system can identify each chopstick through image matching of the “fingerprint” of chopsticks, i.e. the natural micro pattern of bamboo fibers. The visitors can enjoy assembling the art, while guessing by themselves or being assisted by our system (Fig. 4).
The proposed system consists of the following three steps:
1. Fabrication of the multi-view art composed of chopsticks
2. Enrollment of the “fingerprint” images of the chopstick heads into the matching database
3. Image matching for identifying an individual chopstick

2.1. Fabrication of Visual Art

Figure 4 shows a photo of the fabrication process of the chopstick art for our demonstration. The art on the chopsticks (shown in Figure 2) was created by using a laser engraving machine. The chopsticks were held in a custom designed holder, so that the sides of all the chopsticks were aligned to be flat. Then, the left image, branch of a cherry blossom tree, was engraved. Next, all the chopsticks were turned 90 degrees and then put back in the holder. The right image, the emblems of our institutes, was engraved on the side of the chopsticks (Fig. 4).
Note that we do not apply any process for identifying the chopsticks. Each chopstick is given only a small portion of the visual art, so its original position is hard to identify by just looking.

2.2. Database of Fingerprints

To identify the original position of each chopstick in the art even after disassembling it, we created a database with the “fingerprint” (natural micro pattern of bamboo fibers) images of all the chopstick heads. An attachment for the microscope was 3D printed, so that anyone can easily capture the microscopic image of the chopstick head by just putting it into the attachment. Figure 5 (a) shows the attachment and a captured image of a chopstick head. The captured images are registered in a database with their position number (ID: 1-90) in the artwork.

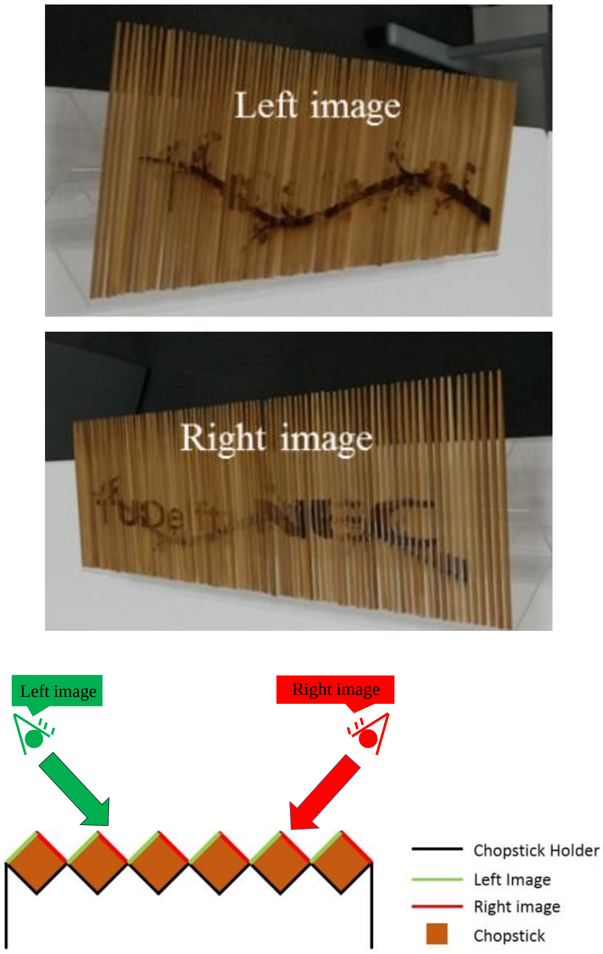

Figure 2: Overview of our multi-view art on chopsticks and its schematic view of cross-sectional geometry.

Figure 3: Laser engraved art on chopsticks.

2.3. Identification of Chopstick by Image Matching

To identify each of the chopsticks, we use the "fingerprint" of things matching approach proposed in [1]. We use the ORB [2] algorithm to obtain corresponding feature point pairs from two images. Figure 5 (b) shows a result of local feature matching using ORB. An image-pair captured from identical chopsticks has many corresponding feature points that are successfully matched. On the other hand, an image-pair captured from different chopsticks has only a few points that are accidentally matched. On the basis of how many feature points are matched, we determine whether the matched images are of the identical chopsticks or not. Thus the system can identify the query image by matching it with all the images in the database, after which the ID is selected with the largest score above a fixed threshold.

3. EVALUATION OF IDENTIFICATION

To evaluate the accuracy of identification, we captured 90 images of the chopstick heads as the database registration, then we again captured 90 images as the queries. Figure 6 shows the example of the images of chopsticks No.1 to 4, from left to right. Note that the orientation of the chopstick are randomly changed each time of capturing, because the user does not aware of it and just puts it into the microscope.

We matched 90 pairs of the registration and query images of the identical chopsticks, which we call "genuine" pairs, and 89x90=8,010 pairs of different individual chopsticks, which we call "imposter" pairs. In this experiment, we set the ORB feature detection algorithm to extract up to 1,000 keypoints from an image, and the number of the successfully matched keypoints by the ORB descriptor matching algorithm is used as the matching score.

Figure 7 shows the cumulative distribution ratio of the genuine and the imposter pairs. For the imposters, the portion of the pairs whose score were smaller than the value of x-axis is plotted. For the genuine pairs, the portion of the pairs whose scores were larger than the value of x-axis is plotted. All the matching scores of the genuine pairs were much larger than those of all imposter pairs. It concludes that we can determine which chopstick in the database is identical to the query chopstick at hand by simply thresholding the matching score. For example in this experimental setup, the threshold can be set to 50, which induces no identification error, i.e. no false acceptance or no false rejection. Consequently, we obtained the perfect identification results i.e. all 90 chopsticks were identified correctly without error.

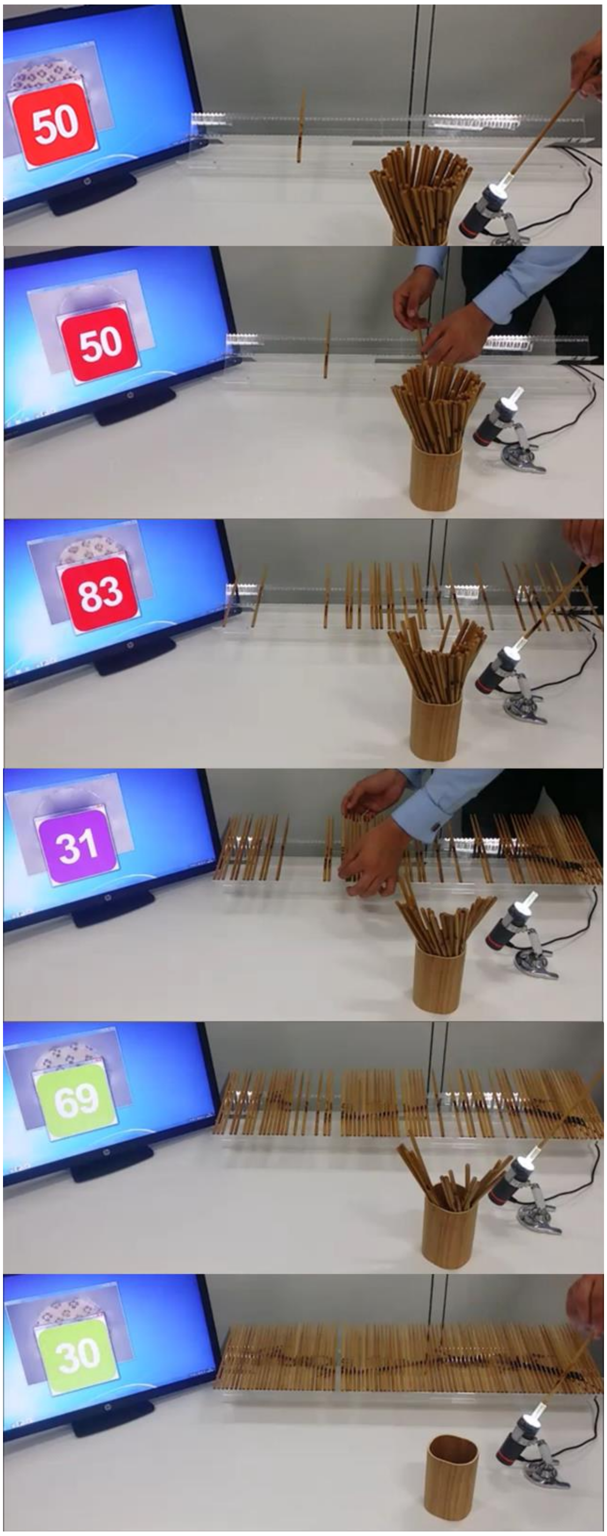

Figure 4: Demonstration of the assembly guidance. The user put a chopstick into the camera, then the display guides the designated position of the chopstick.

4. CONCLUSION

In this paper, we presented a tag-less assembly system by identifying each component without applying numbering or tagging. As a proxy for a more practical problem in construction or manufacturing industry, we developed a visual art that is constructed by assembling chopsticks in the designated order. Through the experiments using the components of the artwork, we revealed that all the components are perfectly identified. In the future, a method which assists assembling a more sophisticated structure should be developed. This makes it possible to deploy the proposed system for practical applications.

Our system is applicable to such visual arts as mosaic paintings and multi-view arts we demonstrate and contributes to make the visual arts more interactive and fun. There are two main substantial benefits, especially in situations where writing a number or putting a tag onto each component is inadequate.

The first benefit is gamification of the art. Any visitor can perfectly assemble the multi-view art while being guided by our identification system. The art is assembled like a jigsaw puzzle: visitors try to place each chopstick in its correct position, and the identification system is useful for checking the answer. Such characteristics make the visual art a type of hands-on entertainment.

The second is portability of the art. Sometimes tagging and numbering are inadequate because of aesthetics. For such visual art, our tag-less identification system can offer portability and storability by enabling disassembling and assembling of the art. This usefulness can make art easy to demonstrate all over the world.

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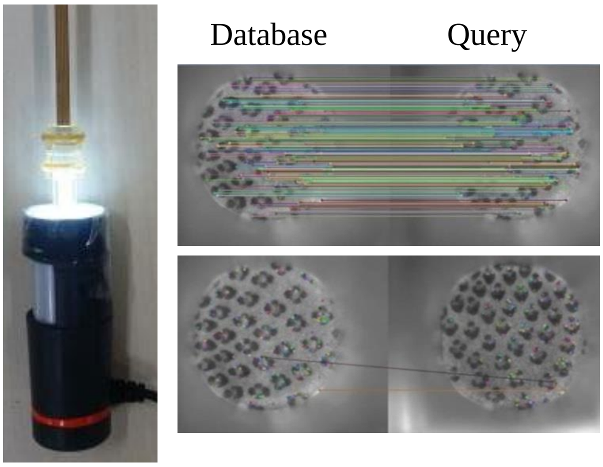
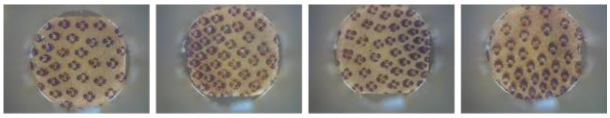
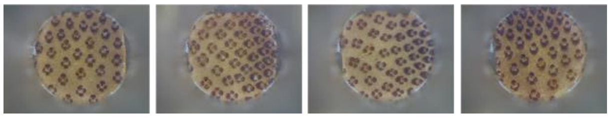


(a) (b)

Figure 5: (a) Registration of chopstick head images. (b) Image matching results.



(a) Database images



(b) Query images

Figure 6: Examples of database and query images used in identification experiments.

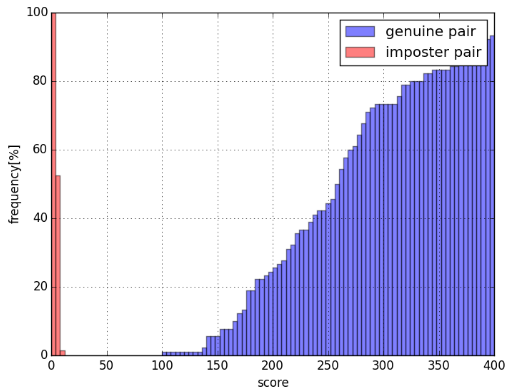


Figure 7: Experimental results of identification of chopstick head images.