Physical Tags: Fingerprints Embedded in Objects and Materials for Ubiquitous Sensing and Seamless Interactions

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1 ABSTRACT

Physical tags, i.e., metadata attached to objects for identification, are an essential component of manufactured goods and raw materials. Conventional means of tagging these without electronics involve sticking separate labels (barcodes) to objects or engraving/carving patterns on their surfaces. However, such tags do not subtly blend into the objects and are often visually distracting or prone to damage and degradation. I propose to replace this synthetic "tagging" process with improved and robust approaches that use unobtrusive physical features of objects and materials as tags.

I focus on two types of unobtrusive, machine-detectable tags: Natural tags and engineered tags. The former allows us to leverage objects' natural properties as an ID, e.g., their micron-scale surface texture. For my project SensiCut (*ACM CHI'21* [1]), I use laser speckle imaging to sense material sheets in laser cutters without any pre-labeled stickers. Differences in surface structure result in unique speckle patterns for each material, which I use to classify its type with a convolutional neural network. I trained the network with more than 38k images, resulting in an accuracy rate of 97.97%. I ran a technical evaluation to determine the accuracy for different types of materials under different conditions, such as illumination and sheet orientation. SensiCut can be attached to existing laser cutters with a compact attachment I designed, enabling a new workflow for using laser cutters and applications, e.g., enhancing user safety against hazardous materials, facilitating rapid prototyping, and engraving multi-material objects.

Second, engineered tags enable us to define the type of information or pattern we want to embed on an object during the fabrication process. For instance, by manipulating a 3D printer's path, we can create unique and subtle surface textures for each copy of the same 3D model, which can be distinguished from a single photograph (*ACM CHI'20* [2]). For this approach that we call G-ID, I evaluated how finely these texture-related parameter differences can be differentiated between, built a user interface for slicing multiple copies with unique parameters, as well as a mobile application that uses image processing techniques to retrieve these parameters from photos and their associated labels.

Together, these two techniques provide effective ways of how to include identifiers in objects without disrupting their look and feel. I will also demonstrate two more recent projects which allow for embedding data (i.e., 0 and 1 bits) into physical objects.

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