Acoustical measurements improve print flaw detection and authenticity checking

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Acoustical and physical measurements—like temperature, pressure, etc.—are combined with image-processing inspection methods in a new approach for print-flaw detection in printing machines.

Authenticity checking and inspection during the printing of highly-secure bank notes and securities is traditionally a labor-intensive process where every item is manually inspected. With the implementation of more-sophisticated security features (both visible and invisible), and the need to reduce the costs of printing, it is clear that automation is required. As more print techniques are employed and new security features established, total security, authenticity, and printing quality must be assured.\(^1\)\(^-\)\(^3\) We have demonstrated that sensor systems can be combined with optical printing inspection methods to enhance the stability of inspection, streamline authentication results, and improve the rate of false classifications.

During printed-product manufacturing, steps are typically taken to ensure a certain level of quality. This is particularly true in the field of security printing, where the standards that must be reached for end products (such as bank notes and security documents) are very high. In these cases, the quality control for printed products is conventionally limited to manual optical inspection. In general, these mono-modal systems have difficulties in detecting slow degradation errors that occur over time, such as those caused by the noise of the printing press. While experienced operators may be capable of identifying degradation or deviation in press behavior, we propose a concept for authenticity checking and inspection that is based on sensor fusion and fuzzy interpretation of data measures.

We have employed acoustical and other measurements—such as the temperature and pressure of the printing machines—to supplement optical printing inspection methods. Cepstrum methods, for instance, are used to monitor the pressure. All signals or combinations of signals are analyzed in the time-frequency (quefrency) domain\(^4\) with a fuzzy pattern classifier model.\(^5\)\(^-\)\(^7\) The monitored machine is provided with multiple sensors that are mounted on key functional components of the printing press. As these are intended to monitor the behavior of the printing press during processing of the printed substrates, the sensors must be selected appropriately.

Fuzzy pattern classification techniques are used in order to implement machine behavior analysis. In other words, sets of fuzzy-logic rules are applied to characterize the behaviors of the printing press and to model the various classes of printing errors that are likely to appear during the printing process. Once these rules have been defined, they can be applied to monitor the behavior of the press and identify a possible correspondence with any machine behavior that leads to (or is likely to lead to) the occurrence of printing errors. This is a particularly effective way to describe and the press behaviors and fit them into a limited number of classes.

In general, fuzzy pattern classification partitions the input space into categories (or pattern classes) and assigns a given pattern to one of them. If a pattern does not fit directly within a given category, a so-called ‘goodness of fit’ (membership function \(\mu\)) is reported. By employing fuzzy sets as pattern classes, it is possible to describe the degree to which a pattern belongs to one class or to another. Figure 1 is a schematic sketch of the ar-
Figure 2. The fuzzy pattern classifier can be used to detect printing flaws up to ten printing sheets or formats earlier than with optical-only inspection systems.

architecture of a fuzzy classification system for implementing the machine behavior analysis. The operational parameters $P_1$ to $P_n$ (sensed by the multiple-sensor arrangement) are optionally preprocessed prior to feeding into the pattern classifier.

We use the basic fuzzy classifier known as the Tagaki-Sugeno-Kang model (TSK model), which is usually applied to controls. However, in this case, it has been adapted and modified to use in sensor and data fusion. The first and second parts of the model are exactly the same as the Mamdani model, which is characterized by the definition of membership functions $\mu$, and the connection between the membership functions in the form of rules like ‘IF $<\text{premise}>$ THEN $<\text{conclusion}>$’. These are usually modeled as unimodal potential functions.

This new inspection and authentication approach for securities and bank note printing results in a robust and reliable detection of flaws and/or authentication markers. Based on expert knowledge of the relationship of machine parameters, rules can be defined that supply a goodness of fit value between one and zero at the output of the classifier. The system ‘observes’ the various machine parameters and then uses a classifier model with manually-tuned or learned parameters to decide whether the data is as expected or not.

Figure 2 shows where optical inspection, machine current, and acoustical signals (cepsrum per printed sheet, machine side 1: y3s1) are fused with the fuzzy pattern classifier. Print flaws were detected by an optical inspection beginning at printed sheet number 500. As errors occur sporadically from sheet 450 onwards, the fused score value gives better results as compared with the optical inspection only. Our research shows that with our method, printing flaws can be identified up to ten printing sheets or formats earlier than with optical-only inspection technique.

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