Print Quality Optimization Apparatus

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Abstract

Given the rapid evolution of printer technology and the ever-increasing demand for enhanced resolution, quantitative measurements of printer performances under different operating conditions are deemed necessary. To fulfill these requirements, two types of Print Quality Control Systems have been proposed in the past. The first one, based on high speed video and image analysis is typically used in research and development of inkjet print head. The second apparatus which also includes a lot of image processing is mainly based on the examination of printed test patterns.

Each device presents drawbacks and advantages, since one focuses on the characterization of an ink drop in flight, and the other one on the interaction of ink and media. In fact, an efficient print quality tool must control the process at each step, by following the drop from the exit of the nozzle up-to drop impact on the substrates. For this purpose, we have designed and built the automated Print Quality Optimization Apparatus (PQOA).

This system is designed to investigate more closely the relationships that exist between drop formation and drop impact. This is especially useful if one wants to monitor the printer as a global system (print head, ink, media).

In this paper, we will first discuss the general design requirements, then all possible measurements which can be performed with the PQOA and the methodology for each of them. Finally performance results and prospects are also detailed.

Introduction

Many Print Quality Control (PQC) systems for inkjet print head are capable of identifying and rejecting heads having printing problems. The required performances[1] from print-heads could be in terms of drop sizes, optical density, color gamut and uniformity and so on. It is well known in the existing literature that critical issues in print quality are the coalescence of ink on the print media[2,3] and/or imperfections related to the manufacturing of print heads[4]. The overall expected performance[5] is to precisely determine the relationships between ink and print head, and ink and print media.

With the two present types of PQC systems commercially available, one cannot really determine these relationships. Indeed, flying droplets and dry printed dots or line characteristics taken separately, will not provide the same conclusion for a given test print head. Moreover, the two PQC systems give their results at two different steps of the printing process, but none at the critical step, i.e. when the drop splashes on the media[6].

The first PQC system predicts size and location of the dot from volume and jet angle results on each drop in flight, without directly taking into account the physical characteristics of the media, the web speed and the ink chemical composition. The second one gives the two print quality metrics (size and location) from a printed test pattern, after drying and penetration effects have occurred. Furthermore, in this case, the dot size is directly linked to the media composition combined to the ink chemical behavior and this may lead to experimental artifacts. Certainly, the above two types of PQC systems have shown their capabilities for specific measurements, but one question remains still open. What is precisely the link between print quality and the entire drop ejection and splashing process?

To provide an answer to that question we have developed the PQOA. By this method, we show that the print results obtained using various commercial print heads reveal drastic differences, which may be ascribed to ink rheology and drop formation behavior [7,8,9].

In this work, we present the general design of this system. The measurements taken at each step of the drop on demand printing process will be discussed, as well as their methodology. We will dwell on accuracy, reproducibility of results, and on the automated modules of the PQOA. This system has not yet reached the maximum in its various possibilities and so we will discuss in the last section the prospects for this system.

Print Quality Optimization Apparatus

To reach the goals introduced in the previous section, we have first defined a versatile architecture. In fact, this apparatus proposes a classical design for the study of drop in flight and printed spot on the media, while nozzle plate visualization to check for pollution and drop impact have required special developments both in terms of the optical and illumination systems.

Hardware Architecture

At this time, the PQOA proposes three major locations for image acquisition : nozzle plate, drop in flight and dynamic drop impact.

To perform a control of the entire head, the first requirement is to precisely move the print head from one nozzle to another in front of the static image acquisition system. This requires a very high precision mechanical support for the head.

The basic form of the PQOA's architecture is the following.

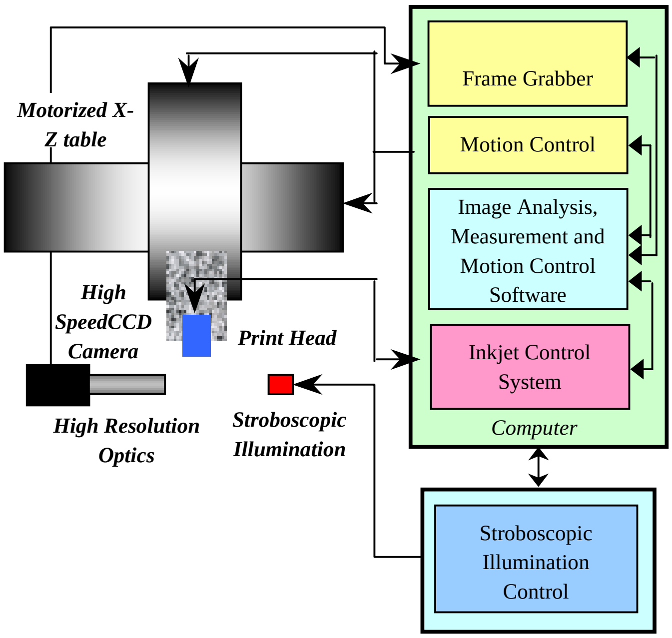

Figure 1. Print Quality Optimization Apparatus Hardware Architecture

Optical System and Image Acquisition

Depending on the configuration, the PQOA uses one, two or three CCD (Charged Coupled Device) cameras. Standard speed (50 images/sec) and high speed (larger than 300 images/sec) cameras are available with a frame grabber. The frame grabber acquires images with adjustable magnification, according to the target object.

The electronic stroboscopic illumination control includes two types of illumination sources, laser diode and high luminosity LED. The laser diode allows longer distance of work between the object and the illumination source, and furthermore, for shadowgraphy images a higher power diffused light. Our electronic device allows us to deliver regularly spaced flashes of 100 ns. The apparatus is also capable of providing pseudo-cinematographic movies of the entire drop formation. This is specially useful for rheological and instability studies[8-10].

Motion Control and Media Support

As said above, the X-Z tables must be very accurate for the print head positioning. Microstep motors combined with high mechanical precision displacement tables were chosen. The motion control is directly integrated in the software. For the impact study, a specific web was developed to control the speed of the media, and minimize vibration effects. A vacuum system holds tightly the media attached to the table.

Inkjet Control System

At this time, we are able to provide a control kit of the print head (electronic and ink circuit) for most of the presently commercially available print heads.

Measurements

This system proposes several measurements, some of which are automated whilst other still require manual handling. In table 1, we present some of the possible results. Those in italic characters are entirely automated at this time. Some of those which are not yet automated will probably become available at the time of the conference.

Table 1 : Possible Measurements with the PQOA

Location	Measurements
Nozzle plate	• *Distance between nozzle to nozzle* • *Nozzle diameter* • Nozzle plate pollution • Nozzle Erosion
Flying Drop	• *Volume* • *Average Speed* • *Jet Angle Measurement* • Speed, Volume, Physical characteristics for filament • Speed, Volume, Physical characteristics for a possible satellite • Follow-up of Drop formation
Impact	• Splashing • *Impact spreading* • Impact Classification

Measurements Methodologies

This apparatus provides two types of measurements, automated and semi-automated results.

We will start with the measurement methodologies of automated one.

The six automated measurement modules (see table 1) follow the same algorithm:

1. Snap and store the image of the object under consideration.
2. Once all the acquisitions are completed, the images are processed and the characteristics of the target object are determined.
3. Further mathematical analysis is performed to attain the expected result.
4. Predefined data sheets are performed with graphical results

As an example we determine the volume of a flying drop. Figures 2 and 3 are typical images obtained with the two first steps.

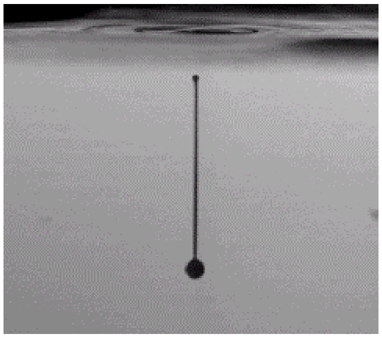

Figure 2.Flying Drop

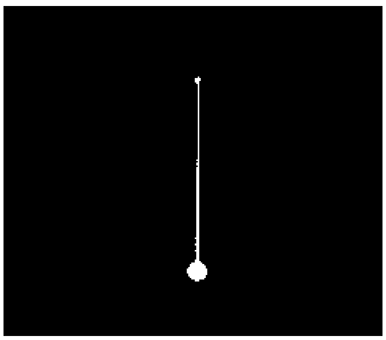

Figure 3. Processed Flying Drop

We apply a special mesh on this binary image, in order to discretize the entire jet. The volume can then be determined with an high accuracy. For this example, we find a volume of 82.3 picoliters which is close to the manufacturer specifications.

An another example, is the control of the distance from one nozzle to another one. For this purpose, according to the print head, some simple settings have to be done before starting the processing. In fact, the illumination is directly linked with the composition of the nozzle plate, as well as the nozzle fabrication process. Figures 4 and 5 are typical images obtained with the two first steps.

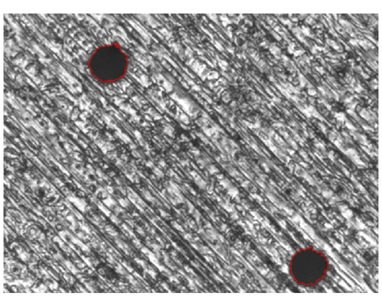

Figure 4. Nozzle Plate

Figure 5. Nozzles after Image Processing

In this case, the nozzle plate is clean and the apparatus has detected the two nozzles easily with this marked contrast. But in fact, on the nozzle plate multiple interference are possible (dust, dry ink spot, …). In order to filter those interference, each detected object is precisely studied.

The semi-automated measurements require manual intervention during the process. For example, to determine the speed, the volume and physical characteristics of a satellite, for one given time and for each nozzle, the user has to manually detect which is the satellite drop between the two (or more) drops present on the image which is under processing.

Generally, the satellite position is too uncertain as well as its speed, from one nozzle to the another one, in order to automate this process.

For our impact classifications (see figure 6), the same working steps as described above are required for these measurements.

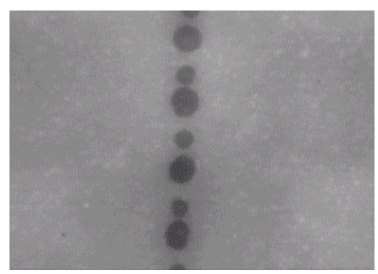

Figure 6. Dot on the Media with Presence of Satellites.

The reproducibility and the accuracy of each measurement is directly linked to the image cleanness and the contrast between the target object and the background. Mechanical and optical arrangements permit us to satisfy this requirement. An auto-calibration module is used for safety before each work sequence.

Conclusion

In this paper, we have presented a specific tool for print quality optimization. The main goal of this apparatus is to determine the relationships existing between the print quality and the formation and impact of drops.

For this purpose, we have shown that it is necessary to follow the entire drop formation process, from the ejection to the impact on the media.

The measurements taken at each step of the drop on demand printing process have been presented and discussed in detail and we have pinpointed the eventual pitfalls of an analysis which is not correctly performed.

Some of the on-going work for this system is the following:

- Qualification of new systems (print-head/ink)
- Validation of good printing heads.

The future work will concentrate on drop impact and ink/media interactions where a lot remains to be done.

References

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Biography

Patrice Giraud graduated from l'Institut National Polytechnique de Grenoble (INPG) with a degree in electronics and data processing. He is now Marketing Manager of ARDEJE, a company highly specialized in the development of electronic architectures, software and customized apparatuses for use in large width ink-jet printing.