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SPITTING ALGORITHM TO IMPROVE DROP DETECTABILITY OF OPTICAL DROP DETECTOR SENSOR USED IN PRINT SYSTEMS

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Spitting algorithm to improve drop detectability of optical drop detector sensor used in print systems

1. Abstract

A solution is presented to improve drop detectability of optical drop detector sensors used in print systems. The disclosed approach uses the concept of intermediate, cleaning drops between microcirculation and drop detected sequences in order to prepare the nozzle to be able to produce a reliable and well-formed drop that will be detected by the sensor.

2. Problems solved

Companies use optical drop detector sensors to detect the nozzle health of the printheads. These systems allow the detection of the drop ejected by the nozzle in order to determine if the nozzle has really ejected the drop and also the quality of the drop. With that information the print engine can determine which nozzle use to fire ink, that is, nozzles that are now working can be replaced by others in order to avoid image quality problems.

Due to architectural limits in terms of space, ink waste capacity of the sensor, cost, etc. different configurations when it comes to sensor location, number of sensors, sensor capacity, etc. can be adopted. This makes that the implementation of algorithms to fire the drops and the processing of the sensor signal may differ to be suitable for each implementation.

The current problem that we address is that due to the architectural limits (described in detail in the next chapters) it is not possible to have good quality drop detector signal in order to differentiate what nozzles are ejecting good and what nozzles not. More specifically, the problem is that due to the significant number of particles in the ink we need to micro recirculate the ink thru the nozzles and eject a high number of drops to provide a good sensor signal. But the ink waste container is very limited due to space limitation (only 8g that need to cover all printer life) so we need to increase more and more the microrecirculation. This has a drawback, the microrecirculation create localized hotspots that in the end produce higher evaporation rates on non-firing nozzles just after the microrecirculation stops. This in the end produces that the first drops ejected in a previously-microrecirculation-nozzle are irregular and non-well formed.

The proposed solution addresses this problem by “cleaning” the nozzle after the microrecirculation and just before ejecting the train of drops that will be detected by the drop detector sensor. This way only well-formed drops will be detected, and sensor signal will be clean to be able to differentiate between good and bad nozzles.

3. Prior solutions

With the previous (currently on sale) ink generations, the low amount of non-ink particles allows the drops to be easily spit and detected using a standard sequence. This sequence usually consists of a previous servicing or spitting (also called “pre-spit”) and then to spit a small number of drops (between 6 and 12) while the sensor is measuring.

With the new ink generation, problems related to spit arose, and the routines needed for spitting a drop stream become more aggressive. However, in the MALT architecture this is not possible due to the limited capacity of the ink waste collector inside the drop detector.

Other products take a different approach and divide a printhead trench in multiple groups, each with its own preliminary servicing routine, but this has an impact on the detection time (thus affecting printer productivity) and increases the ink waste.

4. Description

4.1. Optical measurement principle

The detection of the printhead ejected drops is done using a combination of LED and photodiode. The printhead, by means of moving the carriage where it sits, and the drop detector sensor will move to the location where the firing of drops will cross the light beam of the optical sensor. Then will fire a train of drops that will be detected.

Figure 1 show the diagram of the optical photobarrier and an example of signal outputs from the sensor when a train of drops is detected and when there is no train of drops.

From that signal of each nozzle and the population of signals of all the nozzles in a trench those are the main metrics to evaluate performance: from that signal of each nozzle and the population of signals of all the nozzles in a trench those are the main metrics to evaluate performance:

- Peak to peak signal (P2P) is the strength of the signal quantified as the difference valley to peak. This is often used to determine the presence or absence of the drop. P2P average is the average of all the signals of the trench. P2P stdev is the standard deviation.
- Drop velocity (dvel) is the average of drop velocity of the nozzles

Having a lot of signals (1568 in our case per trench) in a graph makes it difficult to visualize and extract conclusions. That's why a drop detector specific graph chart is normally plotted to better interpret the results (see figure 7).

4.2. Architecture

Cost and scope had defined requirements and limitations in this project that prevented the possibility to reuse a drop detection system from another project: a very restricted space to locate the drop detector asset, a big projection surface to cover due to the amount of print heads and their distribution in X and Y axes, and also a reduced budget for this subsystem.

To cover all requirements, a drop detector sensor assembly has been reused from other projects. This assembly is made by the sensor and its cover. The shape of this drop detector is aligned with the restricted space in X axis of this project. It has a reading window long enough to cover a print head length. Despite this fact, the current print heads layout needs a bigger range to cover them.

Left image from figure 2 shows the layout and how the drop detector needs to move in order to be able to cover each one of the printheads. As the drop detector moves along Y axis, carriage moves along X axis. The right image is a render of this layout.

Using this design to perform the drop detection for all print heads means the optical sensor detects anything through its window. A single nozzle can be fired each time because of that. So, there is no possibility to fire other nozzles while performing the drop detection, otherwise the reading would be a mixed of more than one nozzle. This is an important factor, because it means there is no possibility to fire a nozzle in order to keep it alive while performing the drop detection for another specific nozzle.

4.3. Firmware implementation for this solution:

4.3.1. Basics: image-based DD

When detecting micro-recirculation printheads, the adjacent micro-recirculation nozzles are energized prior to the spitting nozzles, resulting this sequence: 0. Micro-Recirculation, 1. Drop Firing, 2. Flying time wait, 3. Measurement

Steps 0 and 1 can be achieved by printing an image (with rows and columns) statically, which is processed as a normal image by the printer. The only difference is that the spitting times are marked by an internal timer instead of the Carriage encoder (during DD, the carriage is stopped over the detector).

The use of an image allows to overlap the spitting phases of different nozzles. The micro-recirculation pumps don't spit any ink outside the trench. The figure 3 (left) shows several consecutive nozzles sequences overlapped. This provides a significant time saving. Given that the number of pumps is bigger than the number of drops, a real DD image turns to have many micro-recirculation rows overlapped, as in figure 3 (right).

Fly time wait is performed by a timer or an active delay. After flying time, measurement is done by asking multiple times to the sensor for the signal value when the drops are crossing the barrier. Sampling period is fixed and depends on the communication protocol settings between the main board and the drop detector.

4.3.2. Image DD + interspits

Since the current Drop Detector architecture is composed of a unique barrier, every drop spit will be detected by the sensor. With the proposed solution, interspit (a.k.a. intermediate spits or intermediate drops) drops don't inform about nozzle health. They are only intended to improve the consistency of the next drops, which are the ones used for the detection. Interspit drops signal from the DD must be discarded. See figure 4 for schematic view.

To find a way to distinguish between what has to be measured and what must be discarded, the image is fictitiously divided into column groups, each of the same size. This way, the printer can count and know which drop streams should be ignored. For each real nozzle, the printer triggers two spitting streams. The first one goes for inter-spits and the second one spits the drops to be detected. See figure 5 for more details.

5. Results

In Polestar project where the described algorithms are implemented the following results prove the effectiveness of the proposed solution. In our case we tested the following drop fire settings:

Condition	Micro pulses and F	Interspits	DD drops
Default	1232@36Khz	0	8@18Khz
Condition 1 (proposed solution)	1232@36Khz	1	8@18Khz
Condition 2 (proposed solution)	1232@36Khz	4@36Khz	8@18Khz
Condition 3 (proposed solution)	1232@36Khz	8@36Khz	8@18Khz

Note that the proposed solution allows us to set different frequency in the interspits and drop detected drops, this is particularly useful to increase the "cleaning" performance of the interspit.

Figure 6 shows the signals of a determined nozzle in different conditions and the metrics described in paragraph 4.1.

Note that many trenches are graphed to demonstrate that the proposed solution works for all different ink colors in the printer. As we increase the number of interspits the peak to peak signal becomes stronger hence improving the drop detectability signal to noise ratio. The dispersion of them is tighter hence we have a more robust collection of signals.

In figures 8 to 11 you will find graphed signals for colorant M1 (magenta) where a big improvement can be seen with the proposed solution vs default configuration.

6. Advantages

The disclosure presented proposes a solution that provides drop detection effectiveness in architectural implementations where the following aspects are important:

- Cost of sensor: allows the use of small sensors with limited ink waste capacity
- Customer cost of ownership thru reduction of waste as lower number of drops need to be fired
- Throughput of the drop detection compared to prior solutions where grouping of nozzles and pre-spitting was contemplated
    - Less risks hw redesign, mfg, etc.
- Scalability as can be adopted for other projects with different architectures
- Allows the use of inks with a significative amount of particles with higher color gamuts and durability

Disclosed by Pol Vinardell, Guillermo Alejandre and Josep Maria Cuner, HP Inc.

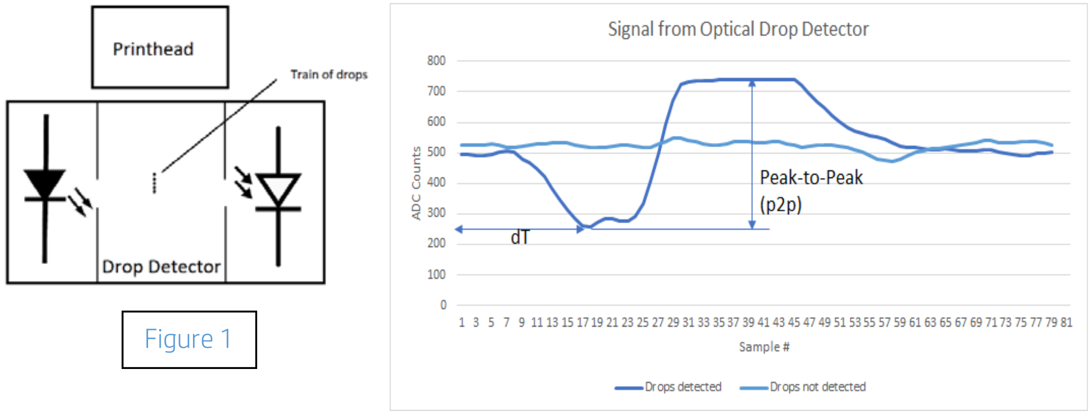

Figure 1

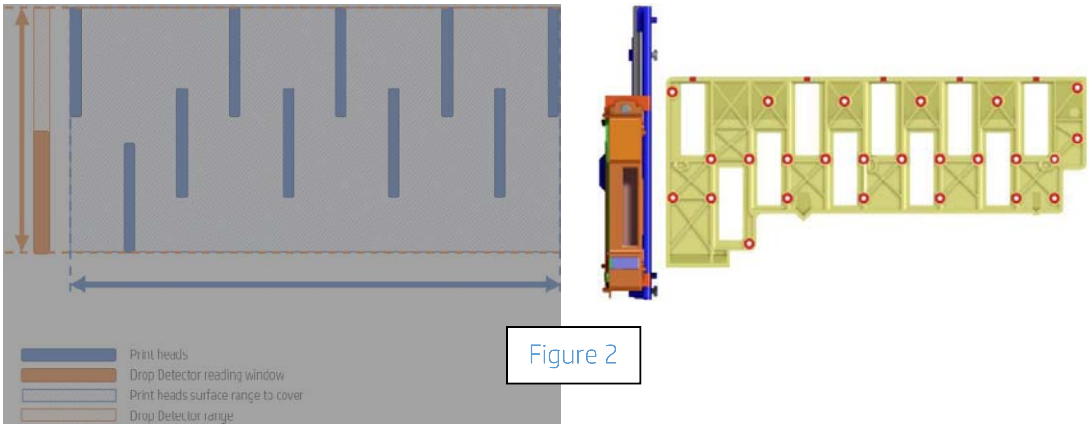

Figure 2

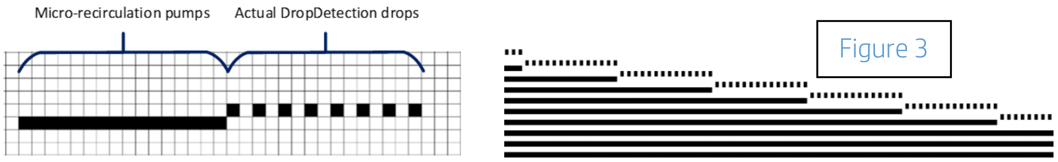

Figure 3

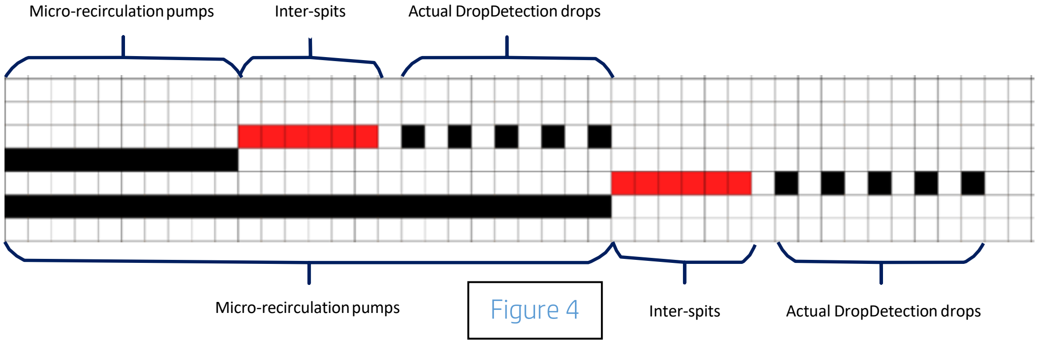

Figure 4

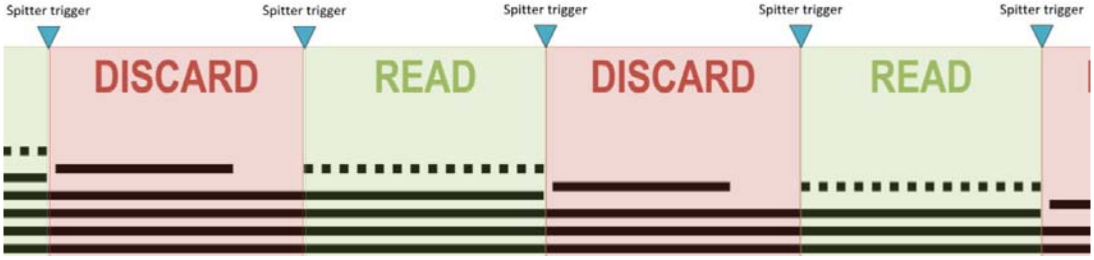

Figure 5

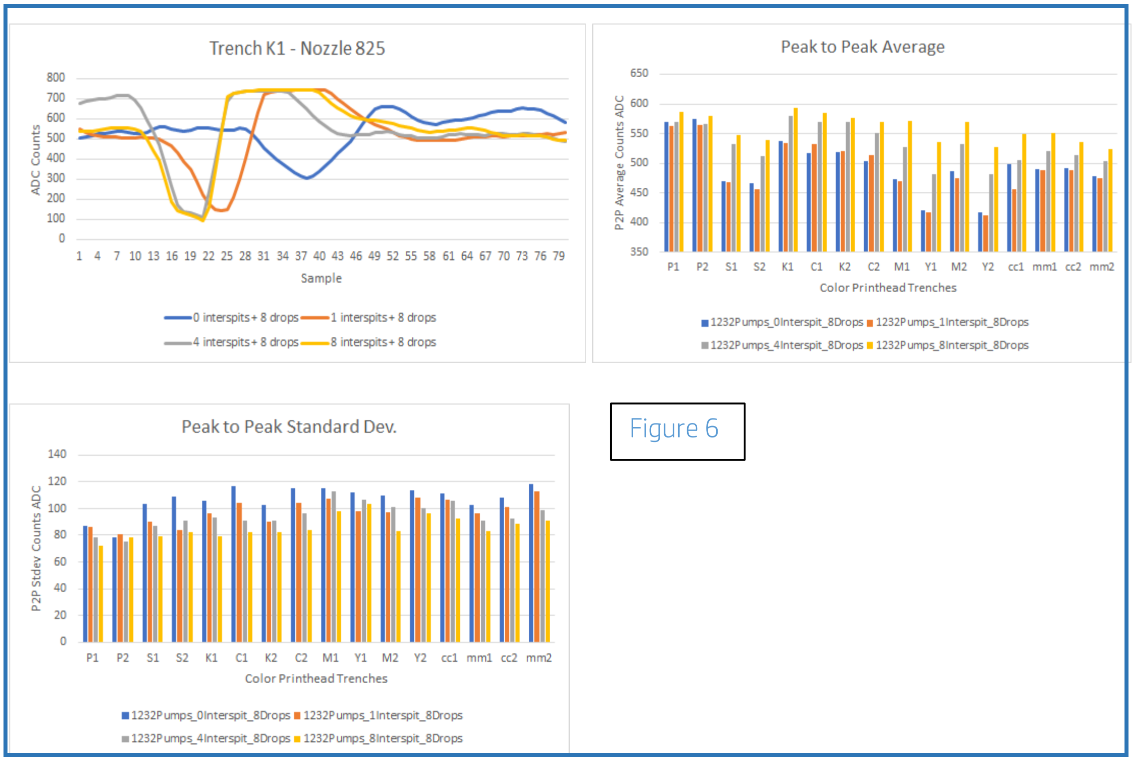

Figure 6

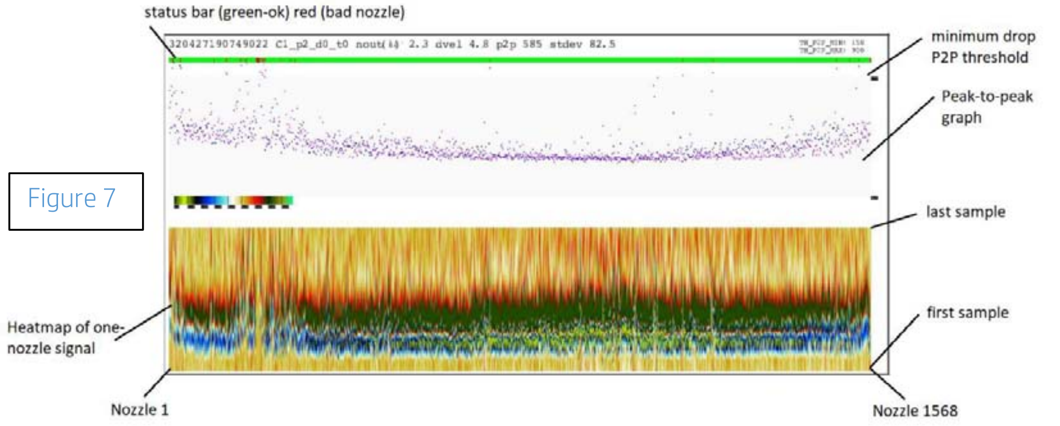

Figure 7

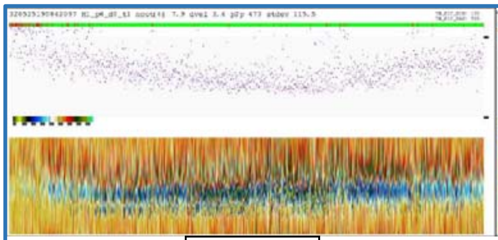

Figure 8

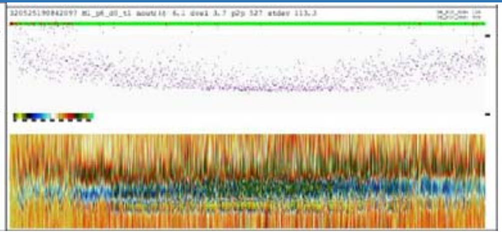

Figure 10

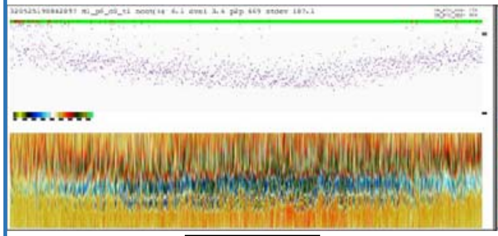

Figure 9

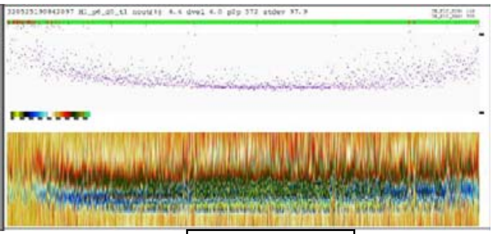

Figure 11