SOFT SKILLS

Seeking improved printing stability, Dr. Daniel Hall discusses the results of an experiment to determine the benefits of density compensation software

Software density compensation for increasing uniformity is gaining acceptance as a solution to eliminate banding artefacts in inkjet digital printing. Compared with tuning physical parameters, software compensation can be more efficient and produce a more uniform result.

In a recent experiment we've discovered an additional significant benefit: using software density compensation can free up physical parameters to be optimised for stability i.e. stable jetting, fewer dropped nozzles, and lower printhead variability over time.

THE PROBLEM OF STABILITY

The fundamental challenge for inkjet is the physics of the micron-scale domain in which picolitre drops operate, which can be referred to as the mesoscopic physical domain. At this size, nanoscale molecular interactions, such as dynamic viscosity and surface tension, become increasingly important. However, the macro scale forces of bulk mass and thermal inertia are still strong. Therefore, picolitre scale drops are subject to a complex dynamic equilibrium between many strong forces with very different scaling parameters. So, for example, as drops get smaller the relative strength of surface tension increases greatly while the effects of mass inertia diminish, significantly altering the way in which drops evolve over time. Just as a mouse does not behave like an elephant, the behaviour of drops changes with size, e.g. modes of coalescence and transport change greatly with physical and chemical parameters. The effects of heat, chemistry, humidity, air flow, electric fields, particulates, bubbles are all felt strongly at the mesoscopic scale in which inkjet operates.

Bringing these physical parameters into perfect dynamic equilibrium to achieve consistent printing density on a printed page is not easy. Engineers working at large scales on machinery or on small scales like electronics may not fully appreciate the challenges of working with effects from both bulk and molecular scale forces at the same time. It is these inherent scale-dependent challenges that underly the engineering requirement for software density compensation for micron-scale digital printing systems.

Software density compensation like PrintFlat is a good solution to the density instability engineering challenge. In many ways this is analogous to the use of fly-by-wire in military jets: fly-by-wire allows the aerodynamics of an aircraft to be dynamically unstable to provide enhanced performance. Like jet aircraft, high performance inkjet will always push the engineering envelope of fluid dynamic instability.

TUNING FOR STABILITY

A nice thing about using software density compensation is that it frees up whatever physical parameters were used previously for density compensation. These parameters, e.g. driver voltages, can now be deployed to other tasks such as increasing printing stability or printhead lifetime.

One approach is to set driver voltages to manufacturer-recommended values. This ought to produce optimal performance; however, in reality printheads often vary in situ – either intrinsically or because of small differences in their immediate physical environment.

This suggests a new opportunity. Rather

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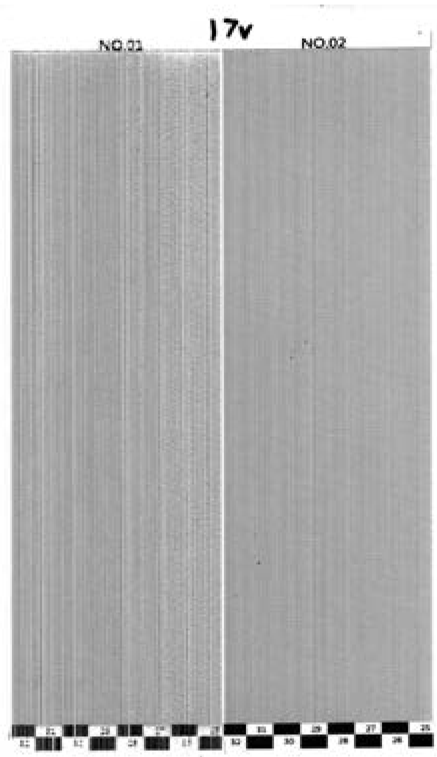

Figure 1: sample print at 17V, PH1 (left) and PH2 (right)

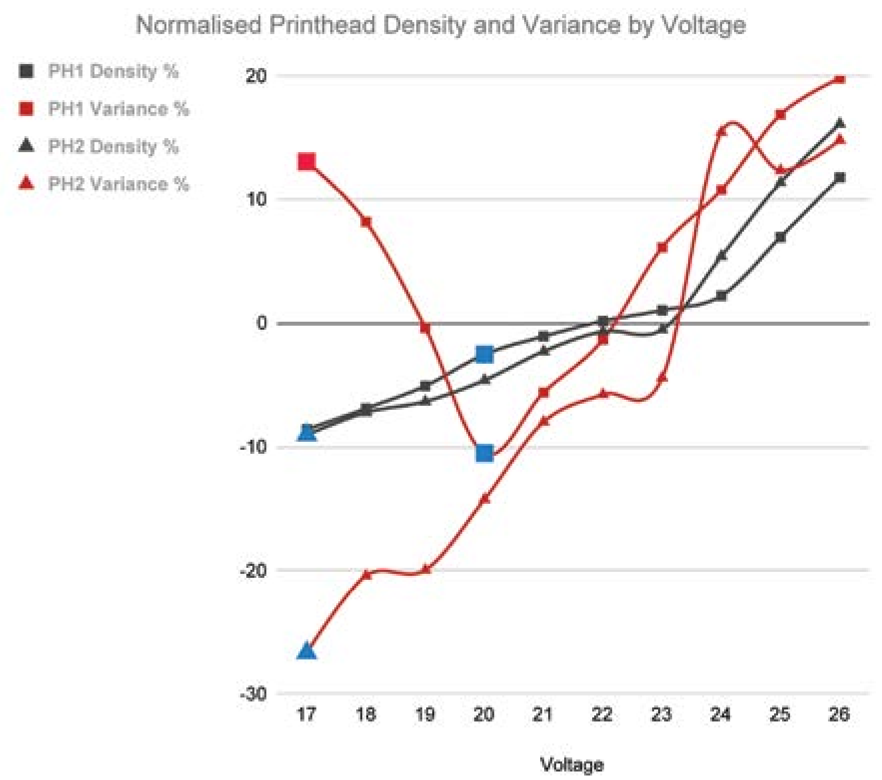

Figure 2: diagram showing the relationship between print density and variance for the two printheads over the experimental driver voltage range

Printhead 1	Drive Voltage	Relative Density	Relative Variance
	17.0	-8.6%	13.1%
	18.0	-6.9%	8.2%
	19.0	-5.1%	-0.4%
	20.0	-2.5%	-10.5%
	21.0	-1.1%	-5.6%
	22.0	0.2%	-1.3%
	23.0	1.0%	6.1%
	24.0	2.2%	10.8%
	25.0	6.9%	16.9%
	26.0	11.8%	19.8%
Printhead 2	Drive Voltage	Relative Density	Relative Variance
	17.0	-9.0%	-26.7%
	18.0	-7.2%	-20.4%
	19.0	-6.3%	-19.9%
	20.0	-4.6%	-14.2%
	21.0	-2.3%	-8.0%
	22.0	-0.7%	-5.8%
	23.0	-0.5%	-4.4%
	24.0	5.4%	15.4%
	25.0	11.4%	12.4%
	26.0	16.1%	14.8%

Figure 3: results table

than tune for density we wondered if it might be possible to detect and tune printheads for 'sweet spots' in their jetting stability?

To explore this possibility, we set up a test rig with two, notionally identical, printheads and measured the density variance from each printhead at different driver voltages. I'd like to thank Meteor Inkjet Ltd for making this experiment possible, especially Kevin Yu for managing the test rig.

Results (see **Figure 1**): The older printhead on the left shows more directional variance than the newer printhead on the right.

Figure 2 shows the following data collected from the experiment: The Relative Density is given as +/- percentage relative to the average density of both heads. The

'At this voltage PH2 is starting to climb dramatically'

Relative Variance is the +/- percentage relative to the average variance of both heads. Presenting the data in this format allows the data to be mapped meaningfully onto the same range. Each result shown was averaged from two separate print measurements. Printhead 1 and Printhead 2 printed simultaneously onto the same substrate for each print.

In the data we can clearly see that the newer Printhead 2 exhibits substantially lower minimum variance to -26.7% @17V (compared to the average of all measurements) while the older Printhead 1 has a 'sweet spot' minimum relative variance around 20V.

ANALYSIS

Figure 3 shows the relationship between print density and variance for the two printheads over the experimental driver voltage range. Points to note include:

- The generally lower variance of the newer Printhead 2
- The monotonically increasing density of both printheads with driver voltage
- The clear variance minima characteristic of the older printhead (PH1)

Various voltage driver policies could potentially be enacted:

1. Set the voltages to the same recommended default values, i.e. 22V. In this example this policy would work quite well as far as density is concerned with the new printhead (PH2) coming out just a few % lower density than the older one (PH1). However, this voltage is clearly sub-optimal from a variance point of view for both printheads.

2. Set the new printhead to mimic the density of the older printhead. This policy would be typical if a new printhead is installed in an existing digital press. In this case if PH1 was already at 22.0V, PH2 would intersect this density value at about 23.2V. However, at this voltage PH2 is starting to climb dramatically in intra-head density variance, indicating that printhead stability would be significantly worse.

3. Set each printhead to its intra-printhead variance minimising value (blue square and blue triangle on red curves). These voltages have the prospect of much lower intra-head variance and therefore likely printhead stability. These voltages (PH1 20.0V, PH2 17.0V) would generate significantly different densities from the two printheads (-8% and -3% compared to average density, an approximately 5% difference in absolute density). This is still well within the range where software compensation, e.g. PrintFlat, can eliminate banding. And as the underlying intra-printhead variances are much lower the net quality and stability is likely to be significantly improved.

CONCLUSION

Clearly the experiment demonstrates that the opportunity exists for these printheads to reduce the baseline intra-head variance by setting variance-minimising voltages. In this experiment for both PH1 and PH2 this reduction in variance would be significant (10-20% of total variance). However, setting these voltages would yield an average density difference between the printheads of about 5% which without software mitigation would result in printhead density bands in the output.

The general significance of these results still needs to be replicated and the wider scope determined.

Even in this quick investigation clearly the opportunity exists to improve printing stability by tuning physical parameters for stability, while using software compensation to deal with the resulting increase in baseline printhead to printhead density variation.

The length of our initial project did not allow for follow up investigations. However, anecdotally we believe that lower intra-head variance will also be correlated with printhead stability over time. It is known that there is often a correspondence between driver voltage and missing and deflected nozzles. This needs more careful investigation but promises to usefully address one of the most challenging issues in digital printing quality and stability.

Paradoxically, by loosening control of printhead average density, we may achieve greater printer stability over time.

We would welcome collaborations to explore these issues and to develop the potential of this technique for improving press stability. ■

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