Are Low Cost Consumer and Industrial Grade Electronics with Ready-Made Image Processing Software the Next Generation of Web Monitoring and Web Inspection Systems?

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ABSTRACT

Cameras have a long history in the pulp and paper industry. The first analog cameras were developed in the 1950's and this technology provided the foundation for web monitoring until mid-2000 while digital cameras have been used for web inspection since the mid-nineties. These solutions have always used a combination of consumer and industrial grade components in the key building blocks which include cameras, lights and computers. Many of the key features that justified the return on investment for these installations 10 to 20 years ago can now be done by consumer grade electronics, low cost industrial smart cameras and ready-made vision libraries. These are also the same technologies that drive the majority of advancements in video capture, transmission, storage, display and processing.

The cost difference between these components and highly custom web monitoring and web inspection systems can be significant. Mills continue to be under extreme pressure to increase machine OEE (Overall Equipment Effectiveness) and the use of web monitoring and inspection cameras is a vital tool to achieve these results. The decision of what single technology or a combination of several can be difficult for a mill given these substantial cost differences, increased functionality of non-custom solutions and the absolute uptime these systems require.

This paper reviews current trends that non-custom solutions provide and discusses how these are similar or different to the requirements for the demanding and vital tools papermakers depend on for web monitoring and web inspection.

INTRODUCTION

The power of computers to handle massive amounts of computations (process algorithms), the cameras that capture motion and the software that instructs these computers have seen tremendous growth in the past 20 years. Moore's Law suggests that this growth will continue by leaps and bounds in the immediate future. For the pulp and paper industry, camera technology remains to be driven by a combination of off-the-shelf and proprietary hardware with highly custom made software. While most of the paper machines in the globalized world have some type of event capture system many of them lack camera based quality control (web inspection). Additionally, subsequent value add processes have limited event capture and camera based quality control. There are many barriers that create this result but two dominate the rest – cost and complexity.

One product that best illustrates the power of the confluence of processing power, cameras and software is the cell phone. There are now projects at NASA to use cell phones to replace multi-million dollar guidance and stabilization systems. Why not? The cell phone is low cost, highly reliable, low power, shock and temperature tolerant and has the ability to deal with complex algorithms. The next pulp and paper camera system may not be an Apple 5s in a metal tube running a $2.99 app but the future for some of the needs for pulp and paper may not be far from this.

The 'Pareto Principle' will be used to analyze the critical functions and market segment for this product within the pulp and paper industry. A selection of consumer grade, industrial grade and ready-made vision libraries will be reviewed. The next generation of successful camera solutions for pulp and paper will differ from past trends as these solutions will have broader applications at lower costs and provide more total process quality control.

THE PARETO PRINCIPLE

The Pareto Principle is also known as the 80/20 rule. In the context of this paper it has two results. 20% of the features of a camera system provide 80% of the value and this feature set has an outstanding value proposition to 80% of the paper machines and subsequent value add processes.

The 80/20 Rule As Applied to Event Capture

Event capture is essentially the discipline of buffering video. It is a reactive tool (vs a pro-active tool, i.e. web inspection). As used in a manufacturing environment single or multiple cameras are constantly recording video so when a randomly occurring problem happens – a user can 'rewind' the video to look at the condition of the process before the fault occurred. This trouble shooting tool has been used in pulp and paper for as long as VCR's have been commercially available (1980's). This is an analog technology and this functional requirement has been replaced by digital means with some increase in performance. But the essential requirements are the same – buffer video for later review. New digital camera technologies and better hardware (camera enclosures and lighting) provide for better video quality in harsh environments but the fundamental requirements have remained the same.

Modern event capture systems can also do image processing. This is a program that contains a set of algorithms that attempt to determine a change in process condition. Image processing provides a set of 'pro-active' tools to the operator. The use of this for actual quality control is limited and the quality of this information will depend on the algorithms used to process the frames. Event capture in pulp and paper is by nature done in a hostile environment and the presence of 'noise' can create more false readings than convey usable information.

The application of process monitoring (event capture) for pulp and paper is not new and the familiarity with the capabilities and what the vendors can offer is well understood by the industry. Vendors will always strive to differentiate themselves from the competition but it is common that the comparison of the most critical requirements becomes a 'me too' game and price is a prevailing consideration. The value of vendor service has come to supersede functional product capability as the product is used in extremely harsh environments. Mills continue to reduce staff and may not have internal resources to maintain system uptime. But this aspect of product offering is dependent on the vendor and less so on the technical merits of the solution.

A list of capabilities and software features could easily populate several pages on an Excel Spreadsheet. Certainly a daunting task for a thorough Kempner Trego analysis. Applying the 80/20 rule would create the below list of four items. The last item gets further off the mark it is the last in the critical chain. You cannot have success in advanced features if there are too many false positives, the operator cannot use it, the image quality is poor and finally the cameras and/or lights are not working.

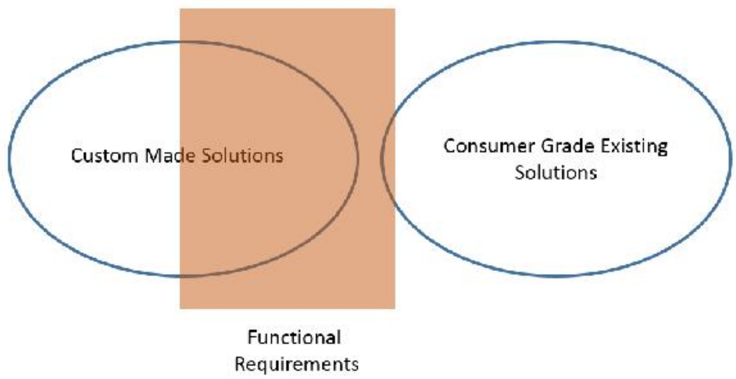
1. Uptime
    a. The complete system has to be working to provide trouble shooting and QC data
2. Quality of image
    a. If the captured data has poor resolution little to no actionable data can be extracted
        i. Machine hardware (cameras, lighting systems and enclosures)
3. Ease of use by the operators
    a. A known set of user functions is intuitive and consistently engaged by all users
    b. Actionable data is distributed throughout the manufacturing environment
4. Advanced features
    a. Additional tools beyond high quality buffered video that provide pro-active tools

The 80/20 Rule as Applied to the Pulp and Paper Market

The 80/20 rule can also be used to determine the best candidates for these three functional requirements in the pulp and paper industry. A portion of the industry will need to utilize traditional large camera systems that require the combination of machine direction process monitoring (event capture) and extensive single or multiple beam web inspection systems and these solutions can be expensive and complex. These candidates are the minority when compared to the rest of the pulp and paper industry especially when combined with the value add processes outside of the parent paper machine. So as a whole when the 80/20 rule is applied to create the most essential function list as well as the best candidates that will use this feature set – a system that can perform in these four critical areas will provide a substantial value proposition to the market.

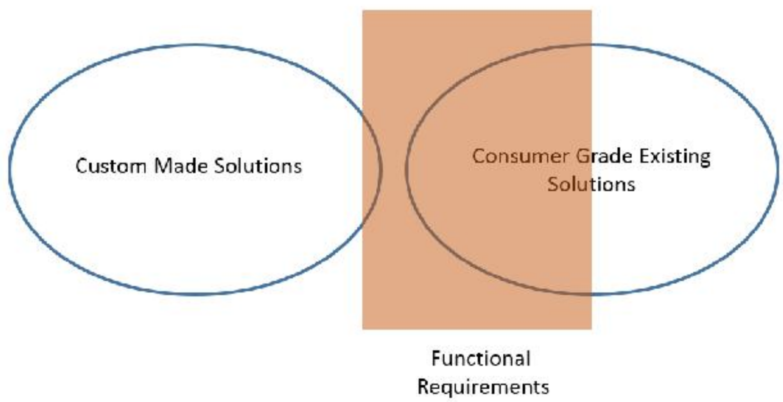
Can these four requirements be satisfied by low cost high performing consumer and industrial grade products with minimal changes as shown in Figure 2? This proposition may or may not be true now – but it is only a matter of time. Event capture and web inspection uses a combination of some of the most heavily invested and sophisticated technologies in play today (1) computers (2) cameras and (3) image processing software. Four promising consumer and low cost industrial grade technologies will be briefly reviewed below.

1. Drift Ghost
2. Cell phones with specialized apps
3. GPU processing with vison libraries
4. Small form factor heterogeneous solutions



Current Makeup of Event Capture and Web Inspection Systems

Figure 1



Future Makeup of Event Capture and Web Inspection Systems

Figure 2

CONSUMER GRADE OPTIONS

1. Drift Ghost (AKA GoPro)

This is a competitor to the better known product called GoPro which was just evaluated at a market capitalization of 6.36 billion. The concept is to buffer video for later use. Pulp and paper calls this capturing pre-event video from a trigger; Drift calls it 'tagging'. Additional functionality includes:

- Frame rates from 25 to 240
- Resolution from 1080P to WVGA
- Multiple cameras can be wirelessly linked together
- Time synchronization with master clock (cloning)
- High shutter or 'sports mode'
- IP 67 rating
- Shock resistant
- Local wireless review and control
- Imbedded monitor

Proposed minimal functional add-ons for use in the paper industry

- Wired connectivity between devices
- Master playback screen for shared live video and review
- Optional GPU parallel path for image processing
- Higher Frame Rate

Cost $399 per camera

2. Cell Phone App's

2a. O Snap for Apple Supported Devices

- 200 frames per second
- 720/1080 pixel per frame resolution
- Frame by frame playback (adjustable while playing video)
- Wireless
- Archive videos
- Overlay options

Cost $2.99 (not including camera)

2b. FLIR ONE

- Add thermal imaging to an I5 or I5s
- Provides both image and video capability
- Spot Meter
    - Emissivity (Temperature value)
- FLIR ONE Time-lapse
    - Turns a series of thermal images into a seamless time-lapse video and can reveal temperature changes over time

Retail cost $350 (not including phone)

3. GPU processing

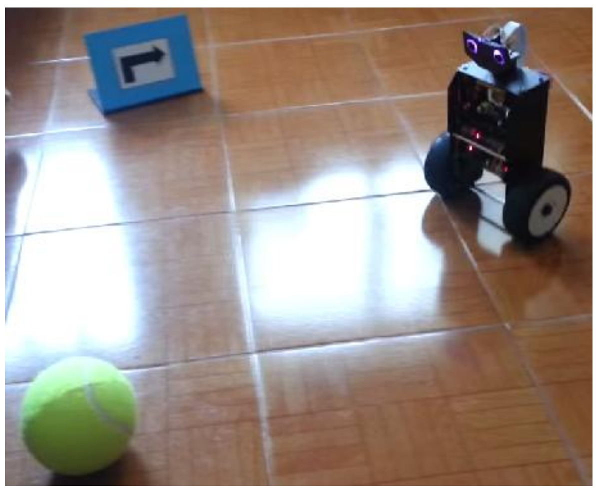
GPU stands for graphics processing unit. It is a specialized chip designed for image processing. Its parallel structure makes them more effective than CPU's for algorithms required in image processing. These specialized chips can be combined on boards with standard CPU's to create powerful low cost solutions for any type of camera acquisition and processing solution.

Many of the standard tools required for event capture and image processing have already been developed in what is called vision libraries. In addition – there are many vision library tools that have been developed that have not been considered for web based and discrete manufacturing fault analysis. Near all of the available event capture and web inspection solutions may be using off the shelf components – but they are not using 'off the shelf' software. There will always be a need for the GUI (front end) to have some level of customization for the markets served – but the engine that drives the solution may not have to be single purpose driven.

4. Heterogeneous Computing Example

Small commercially available boards that combines both GPU and CPU processors have been available for years. These boards are low cost low power units with several input and output options. Existing vision libraries via the Linux OS would handle the bulk of image acquisition and image processing. These small platforms, low power and low heat offer fanless and dustless solutions for many of the value-add paper and packaging converting lines that current traditional Microsoft OS based systems cannot offer. An example is shown below.

A self-balancing two wheeled robot is built with a $45 dollar Raspberry board (a lower powered predecessor to more current offerings). This unit is capable of understanding instructions from visual commands (arrow – forward, left, right, turn around, etc.). Additionally it can change modes to seek a tennis ball and follow the ball as it's moved around the room. The mode change applies when the device sees the visual command shown in Figure 4.



https://www.youtube.com/watch?v=O6XkH84J 1

Figure 3

Ball command for Self Balancing Raspberry

Figure 4

WEB INSPECTION

Web inspection is not the same as event capture with image processing. Web inspection is used for quality control and as such the data it provides must be actionable and free of false positives. Process decisions on how to run a multi-million dollar operation and products that will be sold, downgraded, re-processed or thrown-out are made from the information derived from web inspection systems. The systems must also have absolute uptime. The information provided is automatic and usually no or little human interaction (once the system is setup) is required. It is a pro-active solution vs. the reactive nature of event capture. With event capture – a human is responsible to take action based on the information provided.

General market research indicates that a small portion of the web based manufacturing processes in the worldwide market use any type of web inspection quality control. Why is this so low? Barriers to entry include cost and complexity. New off the shelf products at lower price points will change that paradigm. One example is shown below. In this case the camera and the onboard processors contain an embedded 'Inspect Express Software'. This application provides the core set of processing tools that include identification, measurement and flaw detection. This setup wizard is accessible through a web browser and is termed as 'intuitive one-click navigation' by the manufacturer.

Off the Shelf Industrial Grade Option with Ready-Made Vision Libraries

A fine paper machine in NA is using an off the shelf industrial product. It is an 'all in one' solution comprising of a camera and processing logic in the camera body to make quality control decisions. The rate and resolution depend on model but range from 640 x 480 at 60 frames per second to 1600 x 1200 at 15 frames per second. An optional switch can be used to combine several cameras into one cross directional system.

Dalsa BOA Smart Camera

Figure 5

This system was able to detect and classify a range of defects on the wet end of the paper machine by using four cameras in the cross direction. Retail cost per cameras range from $1,800 to $2,700.

There are many requirements of web inspection systems that this camera is not currently able to accommodate. But the point is that in time – the inspection requirements of a large portion of pulp and paper as well as other non-web based processes will intersect with the capabilities of off the shelf hardware and software at a cost far below what is available today.

CONCLUSIONS

Today the pulp and paper event capture and web inspection solutions are driven by a combination of off the shelf and proprietary hardware but the software engine and GUI are done from highly custom software programs. The power of the market drivers behind computers, cameras and image processing software dictates that when the 80/20 rule is applied to both the critical features and the market segment – the solutions of event capture and a portion of web inspection can be done today and more so in the future by both off the shelf hardware and ready-made image processing tools. Additionally, there are still many applications within the paper industry that lack event capture and quality control automation. These needs as well as the upgrade of many of the existing systems will be meet by this same solution.

If current suppliers can take advantage of these advancements in the acquisition and processing of camera data it would allow for more concentration on new product deliverables dedicated on how the information is processed, transferred and used to ultimately increase the total process OEE. This means product quality and defect data is not only applied to the parent asset but tracked through the entire manufacturing process to the final value add step. And the ultimate challenge is to make these solutions free of the barriers to entry that current quality control systems have – cost and complexity.