Enabling better decisions in the paper mill control room with advanced harmony modeling

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INTRODUCTION:

Catching the first signs of emerging disturbances in the variable and dynamic papermaking process is a challenging task, even for the most experienced operators and engineers. This article explores how advanced monitoring and the innovative approach of harmony modeling support process stability in paper and board mills. This unique visibility into the entire papermaking process empowers process experts to identify, mitigate, and prevent production issues before they impact runnability, quality, and overall production efficiency.

When production problems arise at a paper or board machine and impact the runnability of the process, the papermaking process might have already deviated from its intended course for hours or even days, all going unnoticed. At other times, production problems emerge rapidly, leaving minimal opportunity for preventive actions in the control room.

The papermaking process is an intricate and complex system characterized by an almost limitless number of combinations of constantly changing variables. These variables significantly affect the runnability of the paper machine, the quality of the final product, and the overall efficiency and sustainability of production. Accurately predicting the future trajectory of the operations or correctly identifying the root cause of a production issue is a challenge, as even the most experienced operators and engineers cannot grasp all the interdependencies within the multifaceted process.

In the midst of this complexity, the papermaking process also generates an enormous amount of data. The pressing question in the industry today is how to utilize the extensive amount of data effectively to enhance operations. There are many analytical tools and data visualizations at hand in the control rooms. Still, it is impossible for any human to follow all the developments and changes in the process. Since process experts' time is limited, it would be essential that their focus is directed toward solving the most pressing issues at any given moment to maintain a stable production process and achieve higher machine efficiency. After all, the consequences – breaks, defects, spots, holes, quality issues – of delayed or incorrect decisions can accumulate rapidly in this long, continuous process, where different process phases interplay and affect each other.

Transparency from headbox to rollers

The answer to the challenge can be found in the synergistic combination of human expertise, process data, advanced monitoring and analytics, and automated machine learning. Kemira KemConnect™ Harmonizer, a state-of-the-art digital service developed in collaboration by Kemira and SimAnalytics, is specifically designed for the operators and engineers in the pulp and paper mills; to help them improve the efficiency of the process they oversee and are responsible for.

The traditional analytical tools and methods, which rely, e.g., on predetermined patterns to recognize disturbances, often fall short of sufficiently reflecting the dynamic nature of the papermaking process. These specialist tools tend to focus on a specific interaction inside the paper mill, providing only a narrow view of the process and, thus, often failing to ensure stable production.

KemConnect Harmonizer utilizes automated machine learning and unique harmony models to accommodate the ever-evolving process and its complex logic and correlations. Moreover, Harmonizer monitors the papermaking process as one system, one logical entity from headbox to rollers. It combines real-time operation and performance data from diverse aspects of the process, including both the mechanical and chemical parameters. It can also enrich the view with data from downstream or upstream subprocesses.

This approach covering the entire papermaking process provides unique transparency and predictability, enabling the detection of hidden phenomena that, if unnoticed, could impede smooth operations. By providing actionable insights, Harmonizer empowers operators and engineers on-site to make informed and timely decisions. These insights help mitigate and reduce process disruptions and runnability issues, which could otherwise impact and impair productivity, product quality, or resource efficiency.

Detecting deviations in process harmony

At the core of this novel way to optimize the papermaking process is the concept of process harmony. In practice, Harmonizer monitors multiple key parameters and variables in the process to ensure that the process is stable – in other words, in harmony. Deviations in process harmony indicate that there are emerging issues in the process and that the risk for production disturbances is increasing. Early detection enables fast reaction and corrective measures.

The unique view into the papermaking process is made possible with harmony modeling. A harmony model estimates if a particular process parameter, a tag, is in harmony with other tags at the plant. In harmony modeling, the value of a dependent variable is estimated based on explanatory variables. Here's a simple example: a harmony model monitoring the outflow of a filter. In this case, the explanatory variables for the outflow measure would be the inflow, pressure measurements, and other data tags that are closely related; these connections have been automatically found by the machine learning model, without human interaction. If the filter started to clog for any reason, harmony would decrease as the outflow would no longer match the other variables. The harmony deviation highlights that there is something wrong with the filter and allows operators to investigate the issue in time, even if it does not pinpoint the exact issue.

There are thousands of tags at a single mill site. To have enough coverage to monitor the papermaking process, the model building is highly automated. Also, the retraining of the harmony models is automated.

Automated modeling ensures that the harmony analysis is easy to deploy at a mill site and that the models are always up to date. Users don't need to spend time building or training the model, but they can focus on utilizing the provided information and insights for continuous development in their operations.

From a data perspective, all the interconnected variables in a paper machine could look like this [Figure 1]. The lines represent how different tags are connected to each other, and the size of the dots represents how strongly the specific tags relate to each other. The colors are based on different clusters of tags. The picture illustrates the power of algorithms in finding meaningful connections and correlations in the data. As an example: the blue dots represent the heating system. Different tags related directly to the heating system are naturally tightly connected to each other, but as heat is a central part of a paper mill, the blue tags correlate with multiple other tags in the picture as well.

Harmony modeling can be described as advanced monitoring. Many automated models explain the current harmony in the papermaking system by estimating each tag value based on other tags. As a result, the harmony level is not a fixed statistical minimum or maximum value of a variable but a dynamic calculation of its optimum level derived from other measurements.

All disharmonies are not equally critical to process stability and runnability, but it is critically important to understand which are. Harmonizer helps operators and engineers at the mill effectively manage the process's findings by drawing their attention to the most important issues for process stability and supporting the efficient implementation of needed process changes.

Chemistry either makes it or breaks it

A stable papermaking system cannot be built by understanding only the mechanical part of the process or focusing on paper physics through optimized refining. Chemistry plays a crucial role in the papermaking system, both for production efficiency and end-product quality. The ability to better manage and optimize, e.g. wet end chemistry performance, provides vast opportunities, e.g., through reduced machine downtime and rejected reels, decreased water consumption, energy, raw material, or optimized chemical usage.

End-product quality

Chemistry greatly impacts the quality parameters of the final paper or board: strength, hydrophobicity, formation, smoothness, bulk, ash content...

Energy consumption

Chemical stability influences retention and dewatering performance, directly impacting sheet moisture after the press section. Focusing on wet end applications helps create conditions for optimum dewatering and thus reduces energy consumption in the dryer section.

Deposition

Chemical stability also plays a role in the physicochemical colloidal state of the process through,

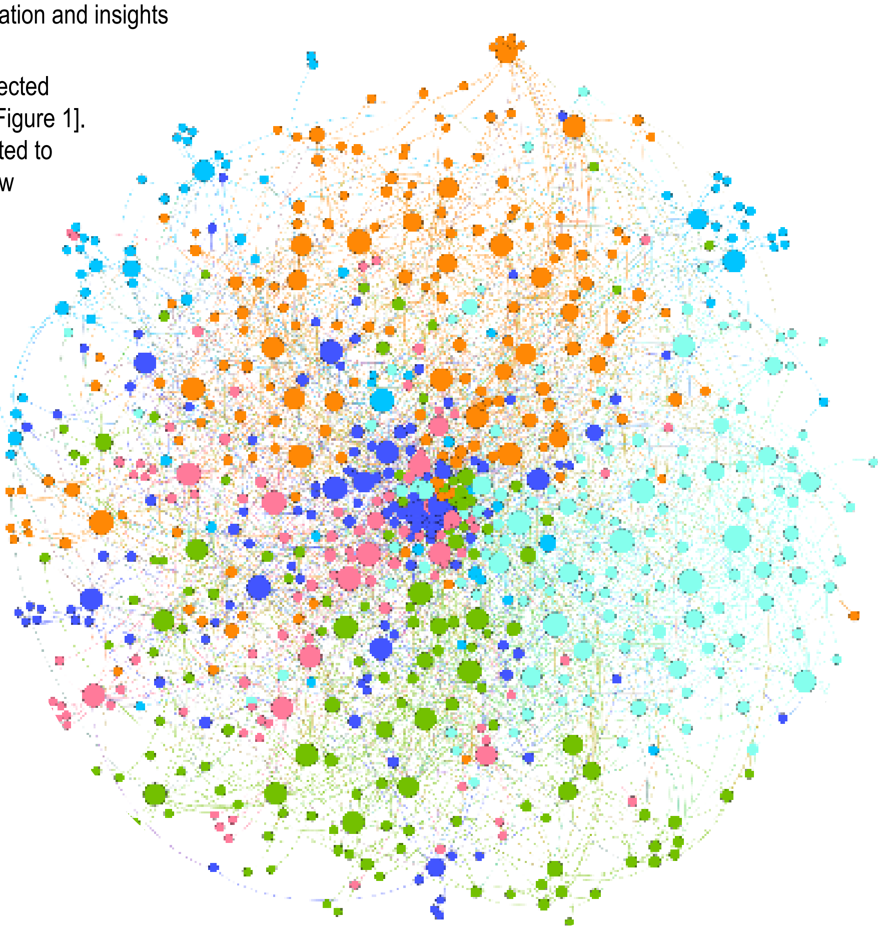


Figure 1: A paper machine as seen by algorithms.

e.g., pH levels, electrochemical charges, steric stability, and conductivity. Unfavorable process conditions significantly increase the risk for deposition, slime, and scaling and lead to increased deposit build-up, resulting in defects, spots, holes, and hole breaks.

These were some examples of how, in papermaking, everything impacts everything. Harmonizer can encompass comprehensive chemistry application status and performance data, e.g., using Kemira's patented technologies for real-time measuring and monitoring in the papermaking process.

In addition, soft sensors can be used to enrich the data with measurements that are not possible to measure directly online. For example, many critical quality measurements are done in the laboratory and the data is available infrequently and with a delay, such as strength properties of board, ash content or paper caliper, bulk or opacity. Modern computational technologies can calculate the missing metrics from online data tags in real time. These so-called soft sensors make the predicted quality values available immediately, constantly, and accurately, providing even more insights for the mill's experts to make decisions. Harmonizer provides a platform to efficiently utilize data sources to automate the construction of soft sensors in a novel manner, which saves time and helps deliver superior performance.

Generating value for paper and board production

Better visibility into the harmony of the papermaking process can support the ongoing operative production optimization in multiple ways. The use cases can vary from physical issues to different running conditions. Harmonizer can also help to ensure process stability in situations where disharmony can quickly appear, e.g. after grade changes or shutdowns.

In addition, the service enables knowledge sharing and aids the operators in gaining a better understanding of the overall process and how the different variables and dependencies in the papermaking system impact production. Over time, the visualization of the process harmony and analysis of the root causes can reveal previously unknown cause-and-effect relationships behind process disturbances. With these insights, Harmonizer can also help create a uniform way of running the papermaking process at the mill, leveling out differences between operator shifts and supporting the implementation of best practices from different operator shifts.

The service can be built and tested offline before building online connectivity. This allows end users at the mill site to evaluate the tools with their historical process data before online deployment.

Case study 1. Revealing previously unknown cause-and-effect relationships behind process disturbances

Sometimes, deviations in the papermaking process escalate into severe production and quality disturbances in minutes. Harmonizer can shed light onto the quickly emerging process disruptions.

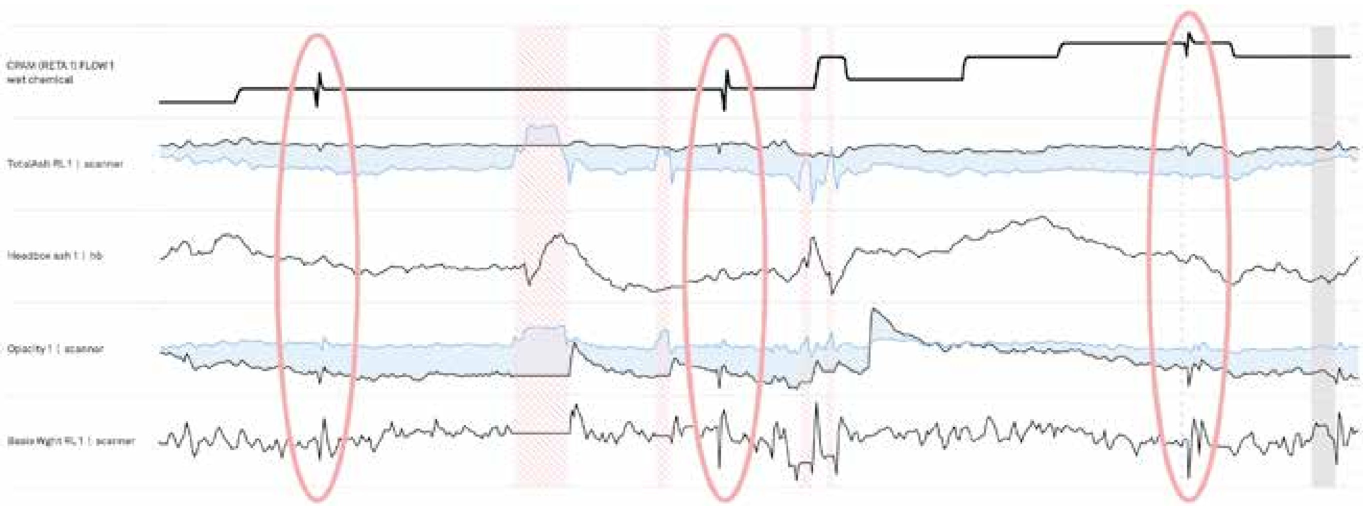
It can reveal previously unknown cause-and-effect relationships behind these types of disturbances by making visible how different process parameters are influenced by each other and how changing conditions and the identified disharmony in one area impact other areas. Process experts are, of course, familiar with many of these impacts, but especially with unexpected process disturbances, the comprehensive harmony model can provide novel insights and allow users to understand the phenomena in more depth.

In this case, Harmonizer revealed how a sudden drop in the retention polymer dosage immediately impacted the production of a board machine (highlighted in Figure 2). The harmony model shows that the dosing deviations quickly impacted the ash content, the basis weight, and the opacity of the final paper, leading to issues with quality. The problems start to accumulate even after a short drop in the polymer dosing.

As the disturbances only last for less than 10 minutes at a time, the board machine operators were simply unaware of many of the incidents earlier, and especially of their full impact on the production process. Harmonizer brought these sudden changes in the process behavior to the operators' attention for corrective measures and, at the same time, increased understanding of which process parameters are directly impacted by the sudden changes in the process conditions.

The model also revealed how such deviations contributed to the risk for breaks (shown with red diagonal lines in Figure 2), further supporting the work of the operators.

Figure 2: The impact of a sudden drop in retention polymer dosing.



Case study 2. Identifying energy-and cost-efficient operation practices

Often, there might be differences in operational routines and ways of running the paper machine between operator shifts, developed over time. With the help of Harmonizer, these differences can be revealed and the most efficient operational practices, e.g. by experienced operators, can be identified and implemented for broader use.

In this case, the harmony models made visible the varying ways of utilizing additional heat unit that was used to secure adequate water removal at a board machine. With measurements from water removal and heat utilization, the tool revealed an occasional disharmony that happened immediately after grade changes [figure 3]. The findings indicated that the operational guidelines were not optimal for each produced grade at the mill.

Before the grade change, the measured (black line) and harmony levels (blue line) were at the same level, indicating that water removal, heat unit, and other related process parameters were in balance. After the grade change, the measurement drops and deviates significantly from the harmony level, revealing that the water removal is no longer sufficient. After a few control adjustments by the operators (showing as level changes in the black line), the harmony is restored. On other occasions, the insights from the model indicated the opposite: that the additional heat was not needed after the grade change to reach the desired water removal.

Process engineers made a deeper analysis of the phenomena and discovered that these types of deviations repeated, especially with lighter grammages. They also recognized that the reduced temperature in the heat unit – as regularly applied by a particular operator – did not negatively impact product quality. With this new data and evidence, they could make new grade-specific guidelines on the use of the additional heat unit, optimizing energy consumption and leading to significant energy savings.

Case Study 3. Investigating simultaneous issues in the process

Harmony models can extract simultaneous changes in the process parameters and highlight them for the operators and engineers at the mill. This helps make interdependencies in the process visible and visualizes how deviations escalate in production.

In this case, Harmonizer revealed several simultaneous problems that started to develop in the papermaking system following a production break (figure 4). First, the pH in the machine chest and fresh water increased, causing a harmony deviation. When the fresh water pH was then reduced, it immediately impacted the whole system, including the vacuums in the forming section. This example shows well how the harmony model can combine different tags from different parts of the process, revealing previously unknown interdependencies.

With this insight into the simultaneous problems in different machine positions, operators and engineers can take more informed corrective and preventive measures. The benefit of the holistic view is that the user does not just see one measurement that is off from its intended value but can also investigate its impact in the process.

Empowering operators

The essence of the papermaking process is in constant change. The fluctuating quality of the main raw materials – wood-based fibers and water – also impacts how the paper machine runs. The countless interdependencies, delays, and spillover effects in the long, continuous process all cause unpredictability.

Process harmony is the key to unlocking the next level of production efficiency. With automated machine learning and harmony modeling, KemConnect Harmonizer creates unique transparency in the multifaceted papermaking environment. It provides a comprehensive view of the stability of the papermaking system as a whole. These insights and visibility are a powerful tool that enables the process experts, the operators and engineers at

Figure 3: Disharmony revealed by the harmony models in the utilization of additional heat after a grade change.

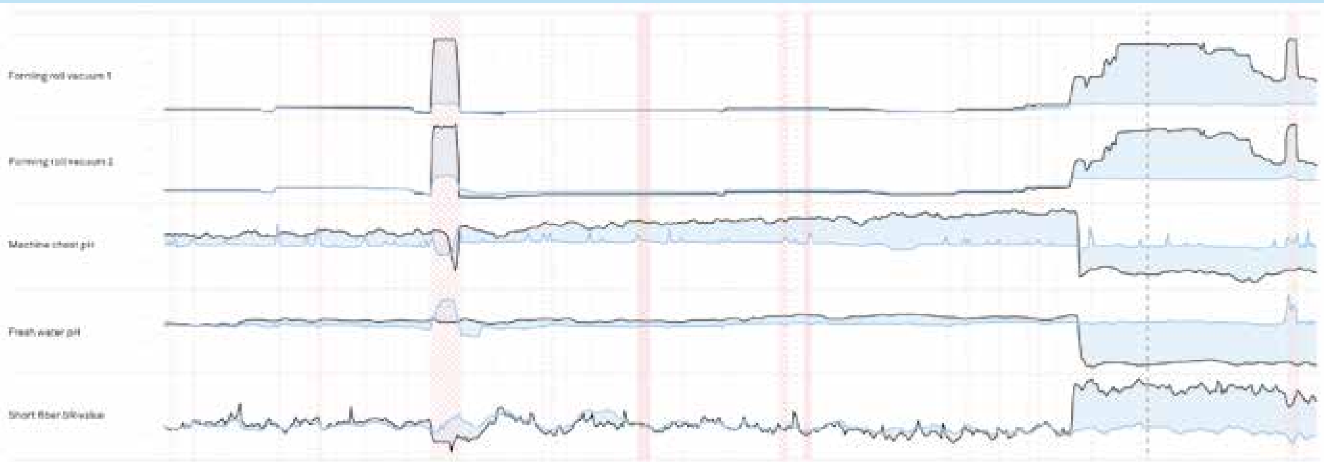


Figure 4: The harmony model revealed multiple simultaneous issues in the papermaking systems following an issue with fresh water pH.

the mill, to discover deviations in the process – alerting them to emerging issues early on and enabling fact-based decisions and fast reactions. The goal is to make the best experts even better and start a positive trend in the mill's production overall equipment effectiveness.

But it is equally important to understand the reasons for the periods when the papermaking process is running smoothly and without problems. Process efficiency goes hand in hand with resource efficiency and more sustainable operations. A stable and predictable papermaking process allows the mills to focus more on projects that target reducing energy, water, and fiber consumption. The transparency created by modern digital technologies helps mills work toward their sustainability goals without jeopardizing their competitiveness and daily operations.

Images 1: (Title page) 2, (Above) and 3, (Below) - Unique harmony modeling creates transparency and predictability in the paper. and board marking process.