



RTC Experts d.o.o.

Buconjićeva 18, 10000 Zagreb, Croatia, MB 0627127, OIB: 52654759098

Tel: +385 1 3760 509, +385 98 391 623; E-mail: fjovic90@gmail.com

ALPHABET ENTROPY

The tool for essential information supply in the Industry 4.0

Introduction and issue statement

The fourth industrial revolution is about extensive application of information technology in industrial production. While the first industrial revolution was about extensive machine application in production, the second one was on extensive energy usage in production machines, the third one was about massive automation of production process, the fourth one extends from the production floor to the customer, to supply chain and to the customer service, combining the whole circle from the marketing idea to the product recycling. The essence of the production becomes quality, which can be traced from the product idea, design, manufacturing and usage.

Modern production automation can ensure massive amounts of products under competitive price by using large amount of energy on sophisticated machines. Any discrepancy in product quality thus tends to be highly sensitive to the adverse result: energy loss, product revocation and loss of buyer confidence. One should be always aware of the imminent possibility of the production chain to divert the prescribed product quality. There is the naïve assumption of the scholars and technicians that the nature of the quality loss is stochastic. The only argument in favor of this is the unexpectedness of the place and time of appearance of the product quality change.

The expectation that the worst enemy of the product owner and user is something purely stochastic is dangerous. The most naïve opinion of the production owner or user is that numerous sensors, automation and control appliances and procedures can ensure a spotless product. This belittlement of the 'enemy' hidden in the production cycle can only enforce the final end of particular industrial praxis as obsolete and downgrading. Careful owner and QC engineer needs the information 'on the hidden enemy'. This is the essence of the aim of the fourth industrial revolution.

Thus the term 'informon'¹ was forged a long time ago in the scholars' efforts to resolve the actual state of the process or organism adaptability, in all its parts and in the whole at the same time.

On informon in the batch production

Informon can be traced not from the large amount of neatly packed data but from the expansion of the most sensitive data – at its very production place. The reason is that there does not exist an attack model. Therefore, no one can guarantee the place and time of the error appearance. Thus the prime effort should be oriented toward detecting the place and time of the error. Our main tool in finding the proper place and time of the attack is data expansion, invented by Željko Jagnjić in 2009 and applied to electrochemical process. The method is direct and circumvents Shannon's theory and data mining, both being economically inconvenient for analysis of short data series. Exact measurement of the information content demands exact information measure that is the entropy content of the signal measurement.

Thus four successive measurements were taken from each quality control relevant measurement point. Data were expanded and encoded into a 27-letter alphabet with a unique entropy content. The alphabet entropy data were compared to the overall product/tile quality mark obtained from

¹A.M.Uttley, The informon: A network for adaptive pattern recognition, Journal of Theoretical Biology, Volume 27, Issue 1, April 1970, Pages 31-67

the final quality control. The results of comparison were marked as information identical (black), close (grey) and far (white) from the quality control data. On the time scale one gets the form named impactogram, Fig.1., presenting possible places and time intervals of quality decrease.

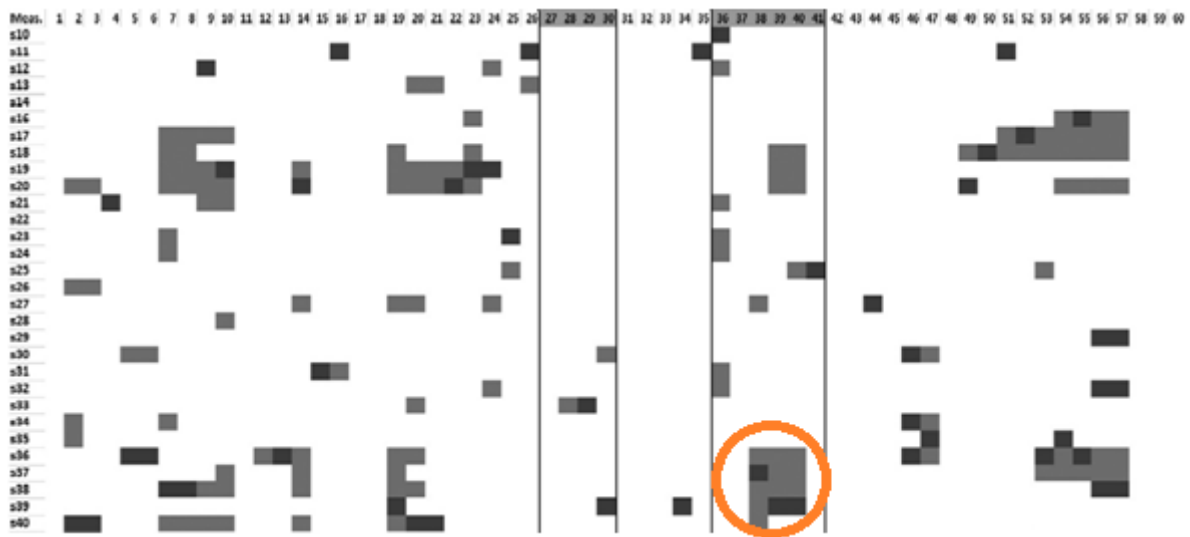


Fig.1. Impactogram of a tile press with 60 time intervals and 31 press quality control indications: black – information relevant, grey – information indicative and white – information irrelevant; framed data are indication of intervals with a quality decrease above 6% of reject; orange is indicating a suspicious place and time of reject increase.

Technical novelty and economic effects

The procedure of failure cause-and-effect determination is supported with the information content of the process signal at the failure event place and time. Dominant role hereby is on the side of quality control and on the production team of the fully automatic and robotized plant that uses the obtained information data for production correction. The framework of the reject signal can be changed to lower reject indication, thus enhancing possible economic effects in tile quality class and amount. The calculated benefits at the Orahovica ceramic tile factory (Croatia) was estimated at 1.5% of better yield above the 6% reject margin.

Conclusions

Alphabet entropy, a product from RTC-Experts d.o.o. firm is a simple, fast and low-demand computing method for measurable information inquiry in an automated batch production system. This data processing is based on the concept of one-dimensional expanded tessellation entropy, which takes a control signal as consecutive four point samples from the process and calculates its information content relevant to the QC demands of the production tuning. Finding out which signals caused the defect, and what were the effects in the automated production cycle, is an important step in production economy. Instant and preventive actions against such events are thus affordable. We have shown that the information sensitivity of our method has advantages over other approaches. Also, unlike control charts, our method is capable of discovering the cause of malfunction, particularly in situations where there is not much historical data for reliable statistical conclusions.

Finally, the presented procedure based on innate process information gives benefits to production owner, to production plant and equipment designer, and to control and QC engineers. It supplies the tool for the unique follow-up of automated and robotized industrial process by adaptable quality dynamics and in the cases where exception to the quality standard sporadically occurs. We have obtained a 1.5% economic benefit in the method application on site.

In Zagreb, January 28th 2019.