Kohonen Self-Organizing Maps for the detection of welds steel coils*

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Abstract

The aim of this work is to develop a new system to detect welds between steel coils. This detection is carried out by a Kohonen Self-Organizing Map (SOM).
In order to achieve good results, a set of experiments have been carried out. On the one hand, we pay special attention to the selection and preprocessing of the input data parameters, which are supplied by an artificial vision system currently working in a real steelmaking process. On the other hand, we take care of the training parameters, such as the evolution of the neighborhood radius and the learning rate, and of the criterio to assign each neuron to a particular cluster.
From these experiments we have performed a statistical analysis and found a specific Self Organizing Map, that reaches a sensitivity of 0,975 and a precision of 0,638. This means that our system keeps a similar value for sensitivity with respect to the currently running system (0,975 vs 0,998), and improves precision in a 22,4% (0,638 vs 0,414).
As a secondary result of our work, we have also developed an interface in order to organize the design and testing of the diferents experiments.

Problem

Steelmaking process in Acerinox - 3 phases

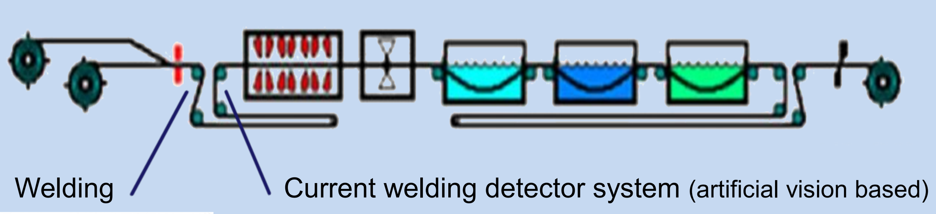
Melting Shop

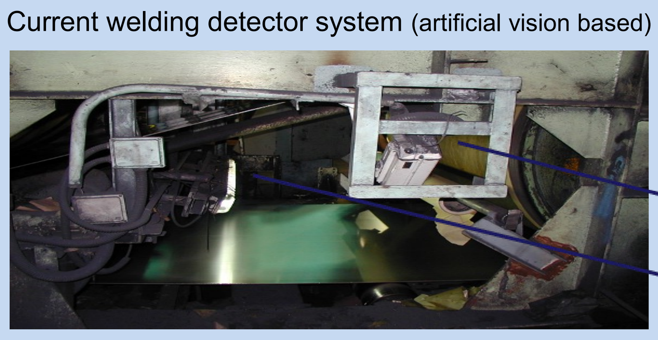
Hot Rolling Shop

Cold Rolling Shop

Cold Rolling Shop

Welding → Welding detector system → Thermal, mechanical and chemical treatment → Inspection





Cold rolling shop: coils are joined with a weld and they are subjected to a thermal, mechanical and chemical treatment.
Quality inspection needs to know the beginning and end of each coil and for this purpose a **welding detection system** is necessary.

Current welding detector system (artificial vision based)
Statistical Analysis of performance

January-March 2013, 10009 samples detections → True Positive 4113, False Negative 86, False Positive 5810 → Sensitivity 0,998, **Precision 0,414** → **The precision must be improved**

Solution

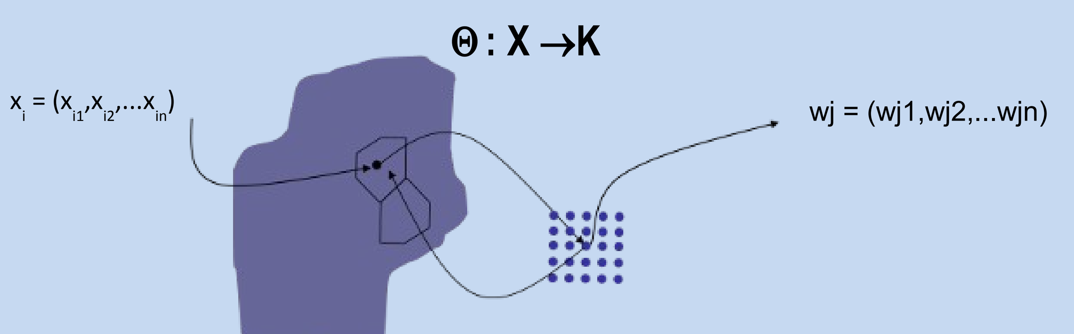
Our aim is to replace the current welds recognition system based on artificial vision, with a Kohonen Self-Organizing Map (SOM) that classifies accidents in WELDING / NO WELDING.

Self Organizing Maps of Kohonen (SOM) can be describe, at a higher level of abstraction,as a distribution between two spaces as follows:

Let X be a continuous high-dimensional space with a topology defined by a given metric relationship among elements.

Let K be a discrete space of smaller dimension (2 or 1) with a finite number of elements and a topology defined by the physical arrangement of the elements in a network.

The SOM's aim is to perform a distribution $\Theta : X \rightarrow K$ that maintains X topology.



Functionality of the SOM:
- SOM stores patterns, which are associated with prototypes
- SOM classifies patterns in regions unsupervised

Results

Planning of experiments

- Input samples: patterns of detections (P) (parameters supplied by the vision system: votes, threshold, borders, variance, contrast, gradient and vertical origin), or the first 3 components of a Principal Component Analysis on this pattern of deteccion (ACP3).
- Components of the input vector: in the case that the input samples are patterns of detections, components of the input vector can be 7 features (C_0) or 6, one can be removed(C_i /i = 1..7).
- Normalization applied to the input samples: without normalization (N_0), each one of the normalizations of the SOM library(N_j / j= 1..6), or the normalization unit norm (N_7).
- Initialization and training parameters of the map: One that is authomatically carried out by matlab (A), or another that is a particular selection designed by us (S).
- Netwoks regions: a neuron is adscribed to welding class when at least one (D_1) or two (D_2) welding patterns fall into it.

Statistical analysis

After analyzing the results of statistical calculation of 288 experiments, we identified two positive results because of their remarkable improvement in the precision maintaining the sensitivity. These results correspond to experiments with codes:

$P - C_2 - N_4 - S - D_2$ ("Experiment 1")

$P - C_0 - N_2 - S - D_2$ ("Experiment 2")

	Vision system	SOM Exp.1	SOM Exp.2
True Positive	4113	1020	1002
False Negative	86	8	26
False Positive	5810	646	569
Precision	**0,414**	**0,612**	**0,638**
Sensitivity	**0,998**	**0,992**	**0,975**

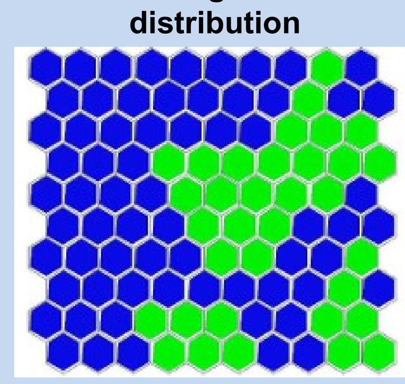
If we consider the inspection requirements, we understand that Experiment 2 is the most profitable because it has an improvement precision of 22,4% maintaining the sensitivity in 0,975.

In this practical case, the most important statistical characteristics are sensitivity and precision. On the one hand, sensitivity is meaningful because it reports the percentage of welds that have been recognized as such, and also reports the percentage of unrecognized welds. On the other hand, precision is key because it informs about false weld recognition.

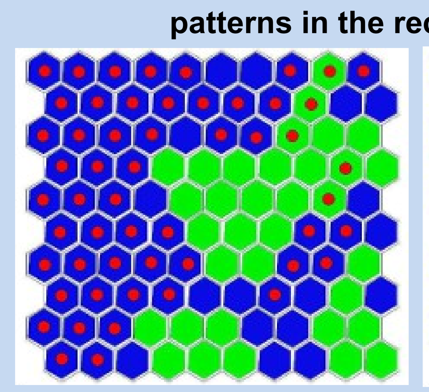
Experiment 2: SOM $P - C_0 - N_2 - S - D_2$

- Neurons attached to welding class in training phase
- Neurons att ached to accident class in training phase
- Neurons activated by welding class in recognition phase
- Neurons activated by accident class in recognition phase

Resulting cluster distribution



Distribution of welding and no welding patterns in the recognition fase



Conclusions and future work

We have evaluated the performance of welding detection system installed on Acerinox: sensitivity of 0,998 and precision of 0,414.

We have analized a set of differents SOM structures by changing the nature and the number of components of the input vector, the applied normalizations, the training parameters for learning and the way to attach neurons to clusters.

We have implemented a graphical user interface to facilitate the work.

We have found a particular model of SOM that improves precision a 22,4% and maintains sensitivity. This model achieves a precision of 0,638 and a sensitivity of 0,975.

Future work

Compare systems based on the cost savings provided by the improvement of the precision.
Explore new ways to attach neurons to clusters.

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