Modeling correction factor for metal sheet rolling via polynomial fuzzy system

1st Adam Peichl
Department of Instrumentation and Control Engineering
Faculty of Mechanical Engineering
Czech Technical University in Prague
Prague, Czech Republic
adam.peichl@fs.cvut.cz

***Abstract*—This paper proposes a fuzzy based polynomial model for prediction of force correction factors for metal sheet rolling. The goal of this work is to design, test and implement set of robust algorithms in C++.**

***Index Terms*—mathematical modeling, metal sheets rolling, fuzzy, polynomial, machine learning**

I. Introduction

Correct design of metal sheet rolling production process needs to determine forces and moments with adequate precision. Unfortunately the process is so complicated that need for some kind of numerical adaptive model emerges.

In [1] we designed model based on *polynomial neural units* (HONUs). This model proved to be robust, simple and reliable enough to be deployed and successfully tested in real conditions.

Unfortunately production line for metal sheet rolling usually needs to process different kinds of metals and model proposed in [1] assumed that for every single metal there will be dedicated polynomial unit, which proved to be a little bit unpractical at best.

Therefore we propose usage of *polynomial fuzzy system* which preserves desirable properties of original model to some degree but also removes the need for multiple separately trained and stored polynomial units.

II. Methodology

The methods and approaches used to accomplish the goal of this project are described in this section.

A. Preprocessing

Since our model works with various different inputs and those inputs also have huge scale differences[1] it is important to put all our inputs into similar scale. Therefore we use (same as in [1]) *z-scoring* which is defined as follows:

$$x_z = \frac{x - \overline{x}}{\sigma_x} \tag{1}$$

Where x is original input, $\overline{x}$ is mean of original input, σ_x is standart deviation of original input and x_z is z-scored input.

From now on, if there is input somewhere (in text, equation etc), we think of that as it is already z-scored.

B. Polynomial Fuzzy System

Proposed fuzzy system is basically the same as the one proposed by Kim and Vachtsevanos in [2].

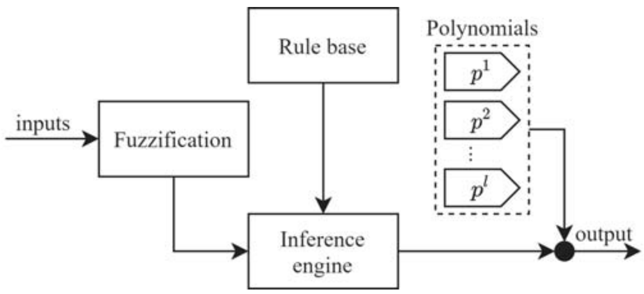

Fig. 1. Scheme of a polynomial fuzzy system

Fuzzy IF-THEN rules are defined as follows:

$$IF \bigwedge_{x_i \in \mathbf{x}} (x_i \ is \ A_i^l) \ THEN \ y \ is \ p^l(\mathbf{x}) \tag{2}$$

The fuzzy system can be described via following equation:

$$f(\mathbf{x}) = \frac{\sum_{l=1}^{M} p^l(\mathbf{x}) \prod_{i=1}^{n} \mu_{A_i^l}(x_i)}{\sum_{l=1}^{M} \prod_{i=1}^{n} \mu_{A_i^l}(x_i)} \tag{3}$$

Where $p^l(\mathbf{x})$ is a polynomial connected to fuzzy IF-THEN rule l and $\mu_{A_i^l}(x_i)$ is a membership function of a fuzzy set A_i^l defined as follows:

$$\mu_{A_i^l}(x_i) = \exp\left(- \left(\frac{x_i - c_{A_i^l}}{\sigma_{A_i^l}} \right)^2 \right) \tag{4}$$

Where $c_{A_i^l}$ is center and $\sigma_{A_i^l}$ is a parameter affecting the width of gaussian membership function.

C. Training Algorithm

In [2] they actually trained their model via complicated *genetic algorithm*. Since our system is much smaller and

This work was supported by grant SGS18/177/OHK2/3T/12. Algorithms were developed in collaboration with PT Solutions Worldwide s.r.o.

[1] For instance *temperature* of metal sheet is in hundreds of °C and *aspect ratio* is usually somewhere between 0.8 and 2.0.

simpler, we will use *stochastic gradient descent* as described in [3]:

$$\theta_{k+1} = \theta_k - \alpha \nabla_\theta Q(\mathbf{x_r}, y_r; \theta_k) \tag{5}$$

Where θ is a vector of *trainable parameters*[2], α is *learning rate* and $Q(\mathbf{x_r}, y_r; \theta_k)$ is standard SE criterion, defined as follows:

$$Q(\mathbf{x_r}, y_r); \theta_k = \left(f(\mathbf{x_r}; \theta) - y_r\right)^2 \tag{6}$$

Where input-oputput pair $\mathbf{x_r}, y_r$ is randomly selected from our training set.

III. Model validation and testing

Model was validated on small number of input-output pairs not used for training process.

As you can see on figures 2 and 3, there is significant improvement in absolute force and torque correction factor errors.

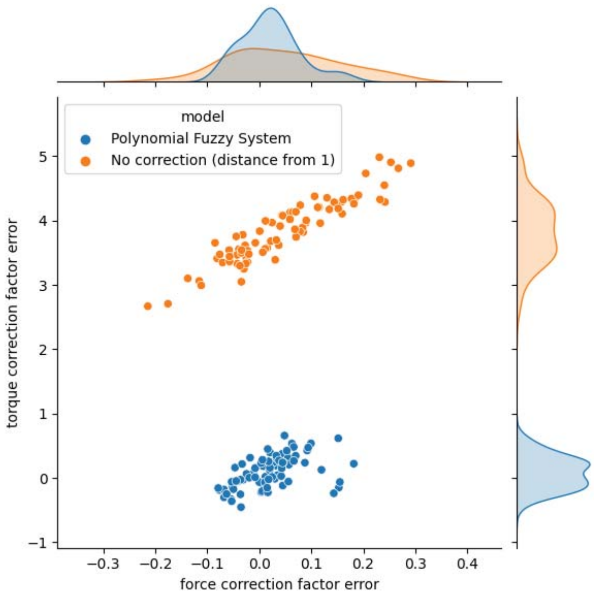

Fig. 2. Scatter plot of errors for roller FM2 for 80 input-output pairs left for validation (not used for training)

Model will be tested on another huge set of measured data in 2021.

IV. Implementation

The whole set of classes and functions was implemented in C++. The result of this project is C++ header library.

V. Conclusion

The proposed model solves problem with multiple separated polynomial units.

Model was validated on small set of real measured data and results shown are very promising.

[2]So in our case all centers and sigmas of gaussian membership functions and coefficients of polynomials

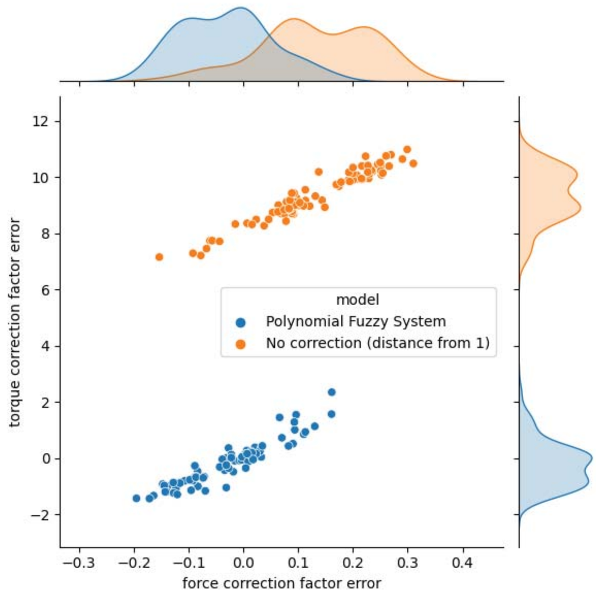

Fig. 3. Scatter plot of errors for roller FM1 for 80 input-output pairs left for validation (not used for training), you can see, that results for this roller are not that great (but still good in comparison to no correction) as in figure 2

Model was not yet fully tested in real application. On the other hand, when properly trained, it should not be worse then single polynomial unit.

Acknowledgment

Special thanks to PT Solutions Worldwide s.r.o., all algorithms were developed in collaboration with them. Also, this work was supported by grant SGS18/177/OHK2/3T/12.

References

[1] Peichl, Adam, Oswald, Cyril, Predikce silových a momentových korekčních faktorů pro válcování kovů pomocí AI, Studentská tvůrčí činnost 2019. Praha: České vysoké učení technické v Praze, Fakulta strojní, 2019. ISBN 978-80-01-06564-8.

[2] Kim, Sungshin and Vachtsevanos, George J, A polynomial fuzzy neural network for identification and control, Proceedings of North American Fuzzy Information Processing, 1996

[3] Bottou, Léon. Large-scale machine learning with stochastic gradient descent. In: Proceedings of COMPSTAT'2010. Physica-Verlag HD, 2010

Selected article from

Tento dokument byl publikován ve sborníku

Nové metody a postupy v oblasti přístrojové techniky, automatického řízení a informatiky 2020

New Methods and Practices in the Instrumentation, Automatic Control and Informatics 2020

14. 9. – 16. 9. 2020, Zámek Lobeč

ISBN 978-80-01-06776-5

Web page of the original document:
http://iat.fs.cvut.cz/nmp/2020.pdf

Obsah čísla/individual articles:
http://iat.fs.cvut.cz/nmp/2020/

Ústav přístrojové a řídicí techniky, FS ČVUT v Praze, Technická 4, Praha 6