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Intelligent Control System of a Real Industrial Process

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Abstract: Industrial systems are difficult to control and supervise efficiently because of the complexity of the production process. The aim is to automatically control in real-time as an alternative for operators as possible and highlight the importance of machine learning in the field of industry. Integrating SVM into the industrial supervision system in the cement factory (SCIMAT) permits the classification of different measurements coming from sensors to the Programmable Logic Controller (PLC) that indicates when the process is in good functioning or bad indicating that a default has occurred. These measurements are classified after training in three classes of level (low, medium, and high) that are classified in their turn into two classes (good and bad functioning). The three classes present the inputs of the fuzzy controllers. Based on this classification, the PLC makes orders for industrial equipment. Then a regression of variation of measurements in real-time is carried out to predict the good or the bad functioning of the production line. In conclusion, the proposed approach innovates the complex supervision system to learn how to control and preserve the habitual linguistic language used by operators, react in the right way, and prevent critical situations.

Keywords: Fuzzy control, machine learning, support vector machine, classification, regression

Introduction

In industry, intelligent automation must increase the productivity of the production system (cost reduction, reliability, availability, and quality); however, it increases the complexity of the development of the supervision systems too. The remarkable situation is that the data and knowledge are extracted from experts who usually rely on common sense when they solve problems. They use vague and ambiguous terms. A knowledge engineer would have difficulties providing a computer with the same level of understanding. This has led to the need for efficient technologies, such as Fuzzy Logic (Zadeh, 1965) and Machine Learning. This late contains several techniques including one of the most efficient, Support Vector Machine (SVM) (Awad M., 2015; Cristianini & Schölkopf, 2002).

SVM is developed to classify data according to their characteristics or make a regression for them. All this is to get the ability to predict the position that new data should be on. This work comes through this science, to drive it into the industry. The applications focus on meeting control challenges of pyro processes through best-applied technologies. The idea is to create an intelligent model that monitors the industrial supervision system instead of the operator and improves the existing system of supervision.

In this work, fuzzy logic and SVM technique using Python, and Simatic Step 7 code is implemented. The model treats the collected data from the real industrial system in real-time to get to the end of the Programmable Logic Controller (PLC) code. In the first section, machine learning and artificial intelligence are discussed. In the second part of this work, the big advantage is to integrate machine learning (ML) using SVM as a binary classification of different measurements coming from sensors to the PLC.

Materials

Clinker is an assembly of four artificial minerals that have hydraulic properties and harden when they are mixed with water. Fast cooling and freezing of these artificial minerals then happen in the clinker cooler, the third element of a cement kiln system. A crucial ingredient to make this mineral transformation happen is fuel. Historically oil and gas were used, then coal and petcock, but since the 1980s more and more alternative fuels are employed for heating.

In the present work, the dataset is collected from the cement factory of Ain Touta in the Est of Algeria (SCIMAT). The workshop of the raw mill is favored to be the case study. This workshop has a specific production line, within this line the product moves across a group of the electric, mechanic, automatic equipment, and many others, for processing this operation and keep it on functionality mode if the system needs. Classes of the dataset in our case are the presence or the absence of a default detected by an alarm. All the sensor settings are configured to be used in the training of the machine learning model.

Methods

Machine learning is briefly introduced in more detail concerning the manufacturing domain. It is based on knowledge extraction from data. It is a research field at the intersection of statistics, artificial intelligence, and computer science and is also known as predictive analytic or statistical learning. Fuzzy set theory was formalized by Lotfi Zadeh in 1965 (Zadeh, 1965, 1973). The generality and ambiguity are sufficient for human comprehension of complex systems. Fuzzy logic has rapidly become one of the most successful techniques for developing sophisticated control systems. It addresses such applications perfectly as it is like human decision-making with the ability to generate accurate solutions from uncertain or approximate information.

SVM is a supervised machine learning algorithm proposed by Vapnik (Corinna & Vapnik, 1995; Vapnik, 1998). SVM has been shown to provide higher performance than traditional learning machines and has been introduced as a powerful tool for solving classification problems. However, there are some limitations, including outlier handling, long learning times, and an increased number of support vectors (Lee et al., 2017). With the assistance of SVMs, one can perform both linear as well as non-linear classification (Goudjil et al., 2018; Liu et al., 2012). SVM has become very widespread in research and has been incorporated into several fields including medical (Bromová et al., 2014; Mark Chang, 2020), military (Mohril et al., 2020; Rozek et al., 2020), industry (Zermane & Kasmi, 2020), and so forth; and a variety of applications, including image classification (Elaziz et al., 2020), text mining (Chatterjee et al., 2021; Court & Cole, 2020), video recommendation (Bălan et al., 2020; Massiris Fernández et al., 2020), and multimedia concept retrieval (Aslam & Curry, 2021; Moreno-Schneider et al., 2017).

Proposed approach

The developed application consists of the classification of all features into specific ranges according to their setpoints interval, which are:

- High range: value greater than the setpoint.
- Medium range: value inside the interval of high and low setpoints.
- Low range: value less than the setpoint.

After calling the dataset, SVM takes its place to analyze these later using the two functions, classification, and regression. The most used of these two is coming separating, each one is for a different type of dataset according to the form that this data is shown. In this work, the two functions are aggregated.

SVM technique analyses the datasets by training each other together, testing this training motivation, then making validation. After training and testing the datasets, SVM classifies them according to our order and then gives us the ability to predict and put each new data into its special and fitted class.

The types of kernel functions include splines, polynomials, hyperbolic tangents, sigmoid functions, and radial basis functions (RBFs) (Hsu et al., 2010). In this study, we used an RBF kernel, which is generally known to have an excellent performance capability. SVM is a high-performance classification technology that has attracted much attention in various fields.

The developed code in Python is connected to the PLC code developed in Simatic Step 7. Thus, it allows us to import the data inside Python (v3.8) to predict and classify them from real data, or the industrial system, we work on. This is how we can make the program accessible to the system parameters, then it can control them automatically instead of the main control room operators. This operation has a special library known as Snap 7. The advantages of such architecture are its flexibility in control, and its ability to data process a lot of information to improve productivity and reduce maintenance costs. The architecture of the new contribution is illustrated in Figure 1.

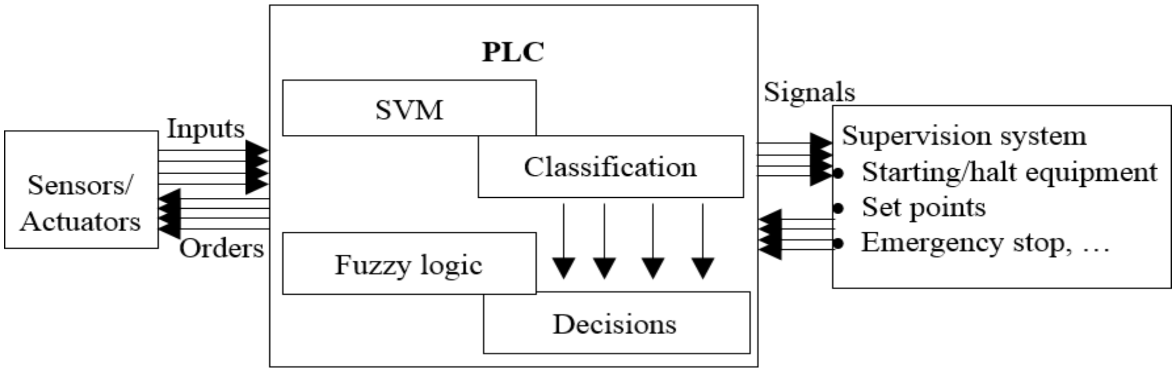

Figure 1. The proposed architecture

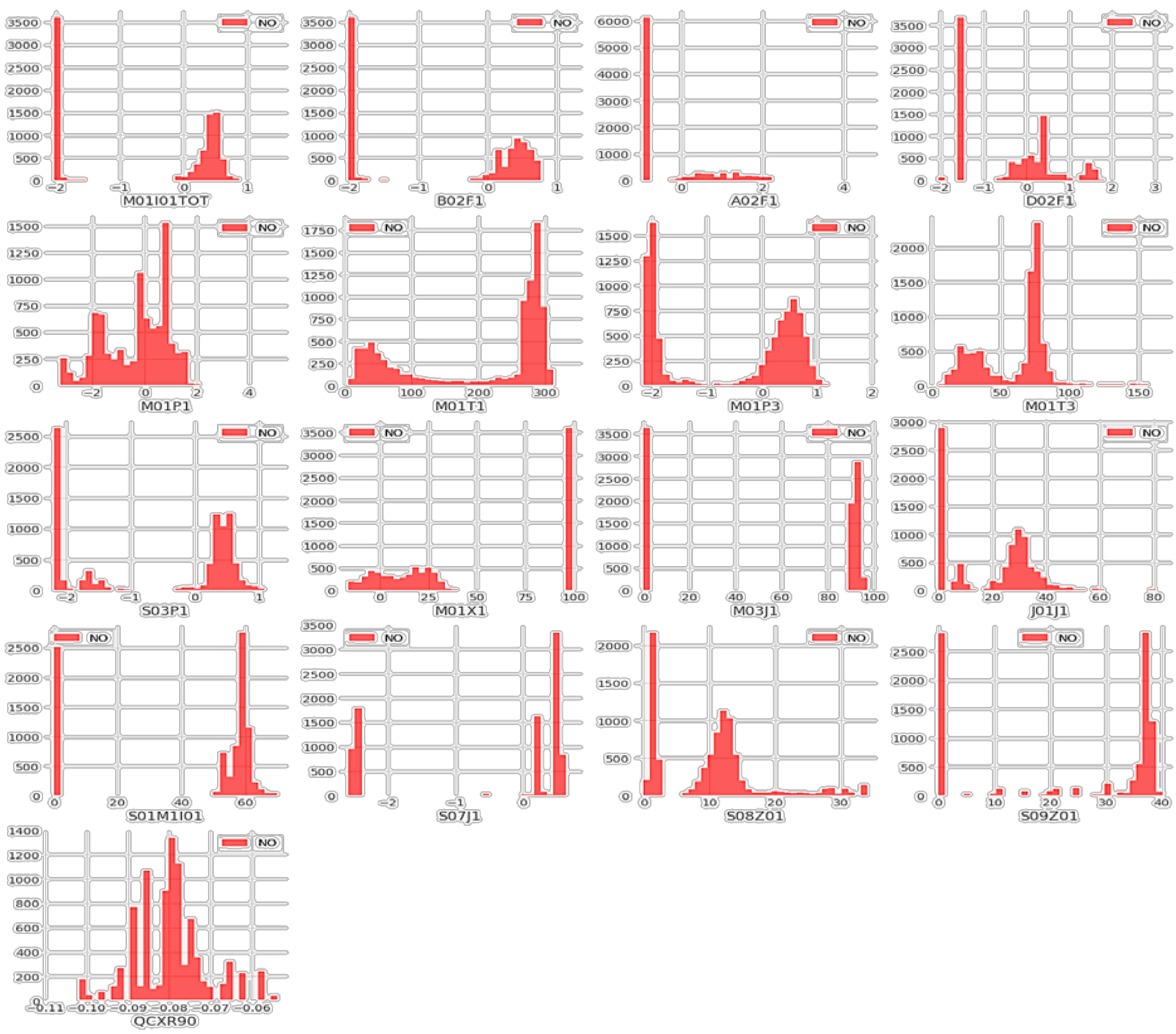

Figure 2. Distribution of features according to class 0 (bad functioning)

Results and Discussion

Creating such architecture needs in addition to the automation programming language Step 7, a programming language Python which is very helpful for the development of the predictive model. Characteristics/features given in the dataset are very less correlated with each other. This implies that all features are included in the study (Figure 2). Factors' indicators that affect negatively the state of the production line are the crusher acoustic equipment (M01X1) and the Operator sp03 (QCXH20). Several observations are noted. To evaluate the prediction model, several metrics are carried out (see Table 1).

Table 1. Model evaluation

Metrics	Value
Accuracy score	94.18039964970943
Training Accuracy	0.9887847535390769
Testing Accuracy	0.9418039964970942
Sensitivity	0.9245982694684796
Specificity	0.9459246102230117

Connecting python to Simatic Step 7 needs another tool which is NetToPlCSim and the Snap7 library. The running of this tool allows getting accessibility to run any automatic code after configuration of the network IP addresses including the computer, Simatic PlCSim, and Rack/Slot. In the case of the acquisition of new values in real-time, curves move and the classes change according to the amount of the values. This allows the operator knows that when the system is out of range, it means that there is one feature measure or more that are out of range.

The "Graphs" function in the menu allows operators to get access to SVM graphs for each one of the features. There are several measurements in the process control, the changes of the engine temperature input (M01T1) are selected as an example. M01T1 feature has a setpoint range of [220-400] C°. The SVM curve for this feature is illustrated in Figure 3.

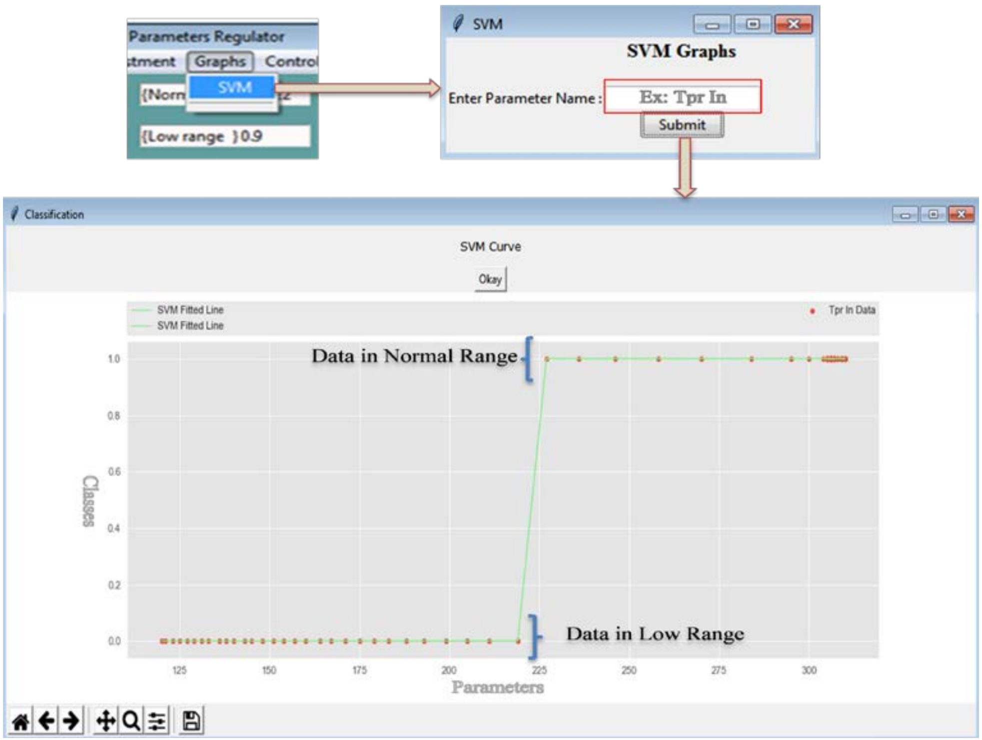

Figure 3. Classification of the system's state

The fuzzy controllers consist of establishing the fuzzy inference between inputs and outputs. The diagnosis tool is used to prevent, identify, and recover from abnormal operations or failures. Several controllers are developed to control the workshop. One of these fuzzy controllers is the controller that monitors the level of materials in the feeder and the elevator to commence the transportation of materials to the raw mill. The acoustic equipment indicates the level of materials inside the raw mill.

The fuzzy controller created to control and synchronize the control loop of the material's feeders and the other parameters in the cement mill workshop is displayed in Figure 4.

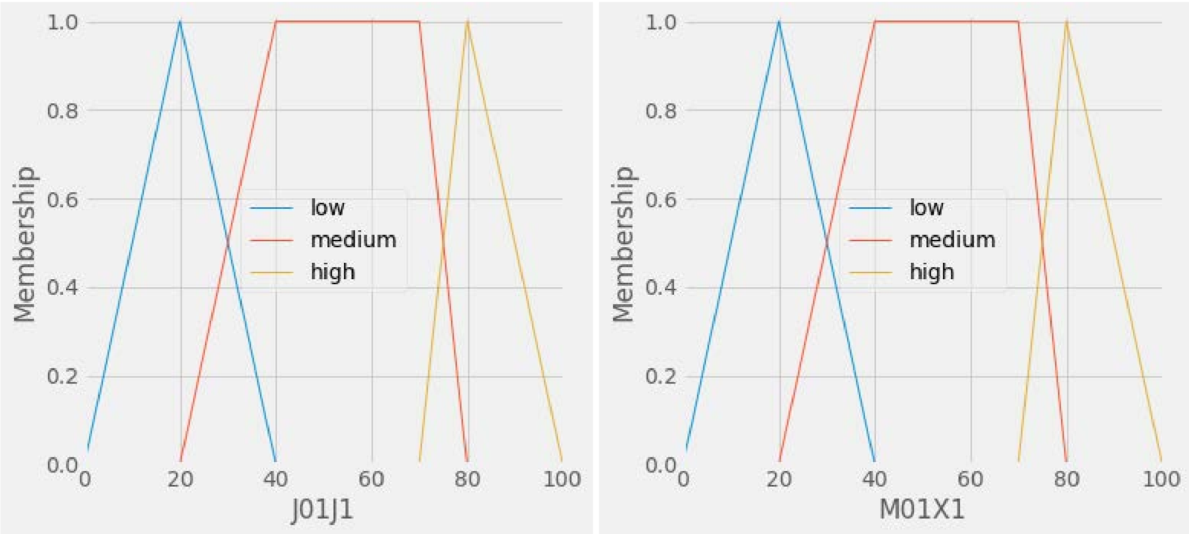

Figure 4. Inputs of the feeder's fuzzy controller

An example of the running of the fuzzy controller consists of two inputs and one output. The material level in the elevator, which is input J01J1 = 15%, and the acoustic equipment value, which is the input M01X1 = 25%. Consequently, the feeders' amount is M01I01 = 60%. Results are illustrated in Figure 5.

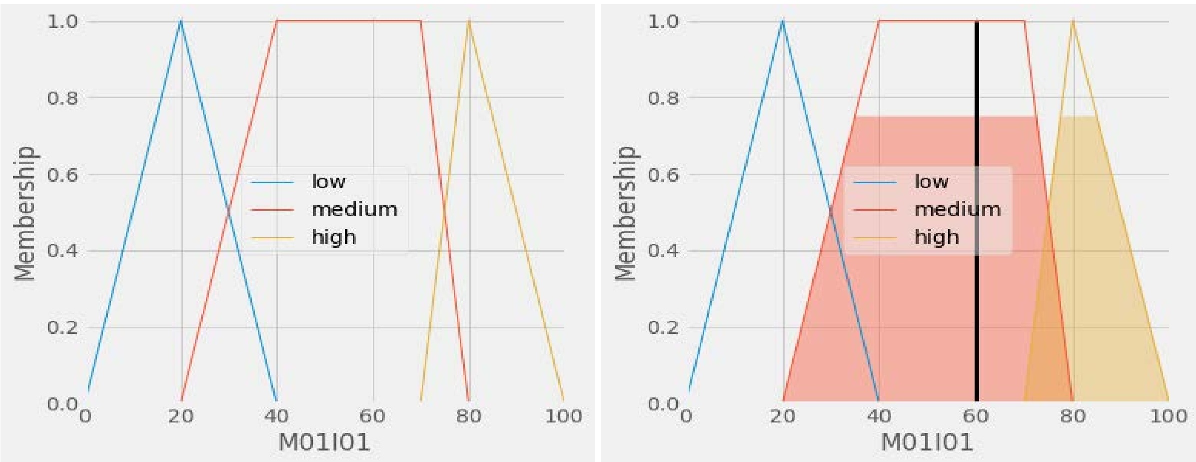

Figure 5. Output and result of the feeder's fuzzy controller

Conclusion

One of the most important points in this aim is the interactivity of the system interface. This can help the operator to get accessibility to control the system as much as he needs. Machine Learning can pass missing in industrial supervision systems and gets a better production system. This means we need to push up and insert machine learning inside the industry, where it can do better and drive the industry to the top, especially in our country where we miss this propriety very much. This proves that it can do more than just classify data and plot them, this technique can do very well in the industrial field too. It can be an alternative for human beings' missions in this issue. This gives us a chance to control the industrial system faster and more precisely, and get access to all system parameters without getting back to the human being handed. This can cost a lot of money and takes a long time as well as insufficient control, higher production, Consistent quality, more stable operation, lower fuel consumption, a lower standard deviation of free lime, and payback of investment in less than a year.

Scientific Ethics Declaration

The authors declare that they are responsible for the scientific, ethical, and legal aspects of the paper published in EPSTEM.

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References

Aslam, A., & Curry, E. (2021). A survey on object detection for the ınternet of multimedia things (IoMT) using deep learning and event-based middleware: approaches, challenges, and future directions. *Image and Vision Computing*, *106*, 104095.

Awad M., K. R. (2015). Support vector machines for classification. In: *Efficient Learning Machines.* Apress, Berkeley, CA. .

Bălan, O., Moise, G., Petrescu, L., Moldoveanu, A., Leordeanu, M., & Moldoveanu, F. (2020). Emotion classification based on biophysical signals and machine learning techniques. *Symmetry*, *12*(1), 1–22.

Bromová, P., Škoda, P., & Vážný, J. (2014). Classification of spectra of emission line stars using machine learning techniques. *International Journal of Automation and Computing*, *11*(3), 265–273.

Chatterjee, S., Goyal, D., Prakash, A., & Sharma, J. (2021). Exploring healthcare/health-product ecommerce satisfaction: A text mining and machine learning application. *Journal of Business Research*, *131*(October), 815–825.

Corinna, C., & Vapnik, V. (1995). Support-vector networks. *Machine Leaming*, *20*, 273–297.

Court, C. J., & Cole, J. M. (2020). Magnetic and superconducting phase diagrams and transition temperatures predicted using text mining and machine learning. *NPJ Computational Materials*, *6*(1), 1–9.

Cristianini, N., & Schölkopf, B. (2002). Support vector machines and kernel methods: The new generation of learning machines. *AI Magazine*, *23*(3), 31–41.

Elaziz, M. A., Hosny, K. M., Salah, A., Darwish, M. M., Lu, S., & Sahlol, A. T. (2020). New machine learning method for image-based diagnosis of COVID-19. *PLoS ONE*, *15*(6), 1–18.

Goudjil, M., Koudil, M., Bedda, M., & Ghoggali, N. (2018). A novel active learning method using SVM for Text classification. *International Journal of Automation and Computing*, *15*(3), 290–298.

Hsu, C.-W., Chang, C.-C., & Lin, C.-J. (2010). *A Practical Guide to Support Vector Classification*. Taipei: Department of Computer Science National Taiwan University.

Lee, S. Y., Urtnasan, E., & Lee, K. J. (2017). Design of a fast learning classifier for sleep apnea database based on fuzzy SVM. *International Journal of Fuzzy Logic and Intelligent Systems*, *17*(3), 187–193.

Liu, L., Yang, F., Zhang, P., Wu, J. Y., & Hu, L. (2012). SVM-based ontology matching approach. *International Journal of Automation and Computing*, *9*(3), 306–314.

Mark Chang. (2020). *Artificial ıntelligence for drug development, precision medicine, and healthcare* Biostatistics Series, Taylor & Francis Group, U.S.A.

Massiris Fernández, M., Fernández, J. Á., Bajo, J. M., & Delrieux, C. A. (2020). Ergonomic risk assessment based on computer vision and machine learning. *Computers and Industrial Engineering*, *149*(106816), 1–11.

Mohril, R. S., Solanki, B. S., Kulkarni, M. S., & Lad, B. K. (2020). Residual life prediction in the presence of human error using machine learning. *IFAC-PapersOnLine*, *53*(3), 119–124.

Moreno-Schneider, J., Martínez, P., & Martínez-Fernández, J. L. (2017). Combining heterogeneous sources in an interactive multimedia content retrieval model. *Expert Systems with Applications*, *69*, 201–213.

Rozek, D. C., Andres, W. C., Smith, N. B., Leifker, F. R., Arne, K., Jennings, G., Dartnell, N., Bryan, C. J., & Rudd, M. D. (2020). Using Machine learning to predict suicide attempts in military personnel. *Psychiatry Research*, *294*(October), 113–515.

Vapnik, V. N. (1998). *Pattern Recognition-Statistical Learning Theory*. Wiley.

Zadeh, L. A. (1965). Fuzzy sets. *Inf. Control*, *8*, 338–353.

Zadeh, L. A. (1973). Outline of a new approach to the analysis of complex systems and decision processes.

IEEE Transactions on Systems, Man and Cybernetics, *SMC-3*(1), 28–44.
Zermane, H., & Kasmi, R. (2020). Intelligent industrial process control based on fuzzy logic and machine learning. *International Journal of Fuzzy System Applications*, *9*(1), 92–111.

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