

Válaszok dr. Kenesei Tamás opponensi véleményére

Tarcsay Bálint Levente okleveles vegyészmérnök

*„System supervision and abnormality detection
through multivariate statistical methods”*

című doktori értekezéséről

Ezúton is szeretném megköszönni, hogy vállalta a dolgozatom bírálatát, a sok munkát és a részletes bírálatot. Szeretném megköszönni az elő bírálat során felsorolt hasznos tanácsait is, melyek hozzájárultak ahhoz, hogy a dolgozatomat még színvonalasabban elkészíthessem.

Question: Can you elaborate on the challenges you faced while integrating Bayesian Networks with FMEA for risk-based fault detection? How did you address these challenges?

Reply: *In general, the biggest issue during the development of a Bayesian network is determining of the network structure as it is an NP-hard problem with super exponential complexity. The use of expert knowledge obtained through FMEA as a basis for establishing the general network structure greatly facilitated this issue. Another challenge was the identification of the weights connecting the nodes of the network structure as sufficient synthetic data had to be generated and curated to properly identify the conditional probabilities linking symptoms and fault root causes in the network.*

Question: What were the main limitations you encountered during the validation of the compartment models using experimental data? How did you mitigate these limitations?

Reply: *The main challenges came from the setup of the physical system and the choice of proper measuring equipment as well as sensors to curate the proper amount and quality data for validation. As the goal was to acquire thorough knowledge about the spatio-temporal distribution of process variables to validate the compartment model it was imperative to find solutions to measure spatio-temporal tracer distributions within the system. To do this a colorful tracer (methylene blue) was used and the intensity of the blue color was measured using cameras to estimate tracer concentration within the tank. Setting up the cameras and selecting proper background lighting to mitigate the effect of noise (changes in ambient light intensity) was a challenging task and despite best efforts noise was still present in the experimental data (this resulted in non-monotonous residence time distribution functions). During the training phase of the model, it was imperative that the model should not fit to the results of that noise and to avoid overfitting. To ensure this the model was trained and its performance observed during cross-validation with different inlet velocity values.*

Question: Based on your findings, what are the potential areas for future research in fault detection and isolation using multivariate statistical methods?

Reply: *The main issue is the handling of strong nonlinearities coupled with dynamic system behavior. Methods such as kernel-based techniques have aimed to solve this problem of capturing nonlinear dynamics but suffer from being more complex and difficult to implement, which limits their applicability in industrial practice.*

Nevertheless, the focus should be on optimizing nonlinear methods to decrease their computational demand both in training and online application stages, in that regard the development of kernel PCA and kernel PLS seem the most promising for industrial application in my opinion.

Question: How do you envision the practical implementation of your proposed methods in real-world industrial settings? What are the key factors for successful deployment?

Reply: *As all the proposed methods rely on process data for their training the main key factor is the availability of a proper amount and quality of industrial process data. As such the key factors for successful deployment include the sensor coverage of the observed system and the presence of proper sensing accuracy.*

It is also crucial to create first principal models of systems to generate synthetic data in case real world data is lacking in quantity and to cover alternative fault scenarios and what-if case studies for the system to properly train the fault detection and isolation method for all possible manners of process abnormalities.

Question: How do your proposed methods compare with other state-of-the-art techniques in terms of computational efficiency and fault detection accuracy?

Reply: *The most impactful state-of-the-art methods in the fault detection and isolation framework include state estimation techniques, analytical redundancy methods and from a data-science perspective nonlinear classification schemes (neural networks, support vector machines, etc.) besides the multivariate statistical fault detection methods.*

It must be noted that while most of the developed methods are based on the linear technique of PCA it was found that by respecting the appropriate limits of the methods (fault detection near an operating point) the techniques could approximate the fault detection accuracy of nonlinear techniques in terms of false and missed alarm rates based on the results of the benchmark problems. In terms of computational efficiency, it can be said that the PCA derivative methods which are based on linear transformations require much less hyperparameter tuning and training than more complex solutions such as neural networks with a minuscule computational load for online system supervision.

Még egyszer köszönöm dr. Kenesei Tamás opponensi munkáját, és tisztelettel kérem válaszaim elfogadását.

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doktorjelölt