LogDynamics
International Graduate School

Autonomous Fault Detection and Isolation in Measurement Systems

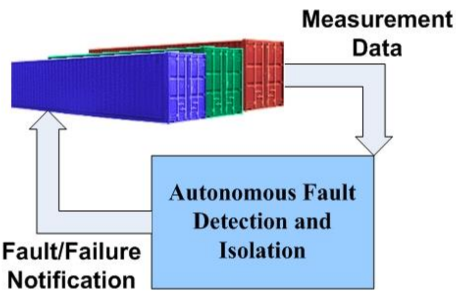
Reliable, Cost Efficient and Safe Food Transportation Systems

Motivation

Nowadays, application of autonomy is considered in industry, logistics and production processes. These processes can be monitored and controlled using suitable autonomy approaches which are implemented with autonomous measurement systems based on sensors and communication methods. Thus, autonomous methods play an important role in logistic applications such as tracking objects, reading data with or without line of sight, updating process databases instantaneously and providing high speed remote access to system components.

Transportation systems stand in need of autonomous features to increase reliability and security. By the introduction of autonomous processes some important tasks can be done locally based on pre-defined algorithms. First, it is necessary to define an area of autonomy; the subsequent selection of a suitable autonomy technique depends on the nature and complexity of the system which is to be made autonomous.

One important autonomy feature which could be applied to measurement systems is plausibility checking. Combining some tasks like plausibility check and self-configuration will assure improved performance, for being able to distinguish which measurement signals are valid and valuable. The most important objective of this project is the selection and application of autonomy features to achieve a more efficient and reliable transportation system. To be more precise, the selection of suitable plausibility checking mechanisms for "fault detection and isolation" of sensor networks for achieving reliable measurement is the major task of this project. It is important to have confident readings in measurement systems and the application of data verification and validation techniques will increase the reliability of such systems. Moreover, following fault detection in a sensor network the necessary considerations could be provided to recover the system from failure or fault conditions in optimized time and with lower risk; thus plausibility check algorithms will lead to cost efficiency, reliability and safety.



Research Question and Methodology

There are some useful methods for analyzing measurement data for the notification of sensor defect and failure. Innovation of new techniques for data classification in artificial neural networks (ANN) (like using probabilistic features) and fuzzy logic led to their application in plausibility checking. In this category, instead of modeling the whole process, the alternative of training the plausibility check mechanism with previous measurements should be considered. Application of artificial intelligence to measurement system will cause a nonlinear mapping between measurement results and judgment about reliability of measurements.

By adding ANN features, the measurement system will be intelligent because it will be possible to apply evolutionary computing, learning and adaptation features. Therefore, ANN architecture learns from previous measurement results and it could approximate new measurement results based on new conditions. Furthermore, it's possible to make assumptions about unknown events by using probabilistic neural networks, especially for classification purposes.

Neural network plausibility check is defined based on comparison of

Dr.-Ing. Amir Jabbari
M.Sc.
Faculty of Physics / Electrical Engineering

Tehran, Iran
Finished in August 2009

Universität Bremen

measured data with neural network prediction. To achieve this, suitable architectures for arranging the neural networks and required learning algorithm should be applied and previously measured data will provide the input patterns for ANN.

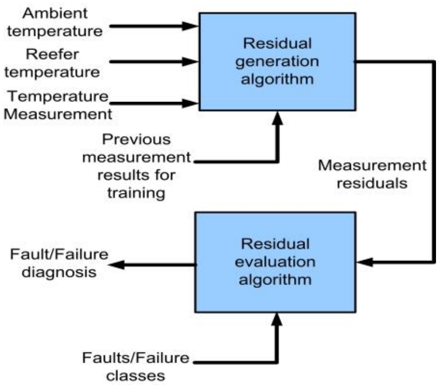
ANN algorithms are established for residual generation and residual verification phases, respectively. By comparison of measured data with network prediction, fault residuals are generated and then all residuals are evaluated and analyzed. For temperature readings, previously measured signals are defined and fed to the FDI mechanism with separate patterns. In each phase, the kernel-based learning method is applied with patterns which have been obtained from previous readings.

Applications

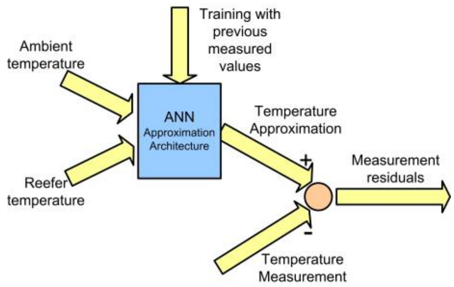
In food transportation systems it is necessary to supervise the quality of food by measuring environmental conditions, like temperature and humidity. Then the measured data should be processed based on an appropriate technique for extracting useful information about the quality of products. Thus, by tracking measurement results, all possible events in transportation system should be detected and classified according to pre-defined faults/failure classes by analyzing measurement results.

In this research the FDI algorithm is defined by two ANN architectures for residual generation and residual evaluation. Two-phase FDI architecture leads to better performance and higher flexibility in system design.

As a first step, ANN approximation architecture was applied to generate residuals by comparing current measurements with previously trained patterns. This architecture is a feed-forward neural network, which is generally used for function approximations in system modeling and prediction.



The approximation module copies the training patterns for mapping into related target patterns, which are then used for estimation of responses in comparison with new measurement inputs. The output is estimated using a weighted average of the outputs of the training patterns, where the weights are related to the distance of the point from the point being estimated.



For approximation of temperature measurement, reefer and ambient temperature are entered to the network as input patterns. Against input patterns, records of each data logger are considered as target patterns. In this way, each record for ambient temperature and reefer air are mapped to records of data loggers; therefore, after spreading the data to network, the approximation mechanism would be able to predict the next temperature values of data logger, based on new values of ambient and reefer temperature. Then, differences between temperature measurement and approximation are calculated and observed as residuals.

Residual evaluation techniques can be established by threshold decisions, statistical methods and classification mechanisms. Thus, residual evaluation for measurement system is established for classification of residuals, according to faults/failures classes and extra conditions for improving evaluation results.

The residual evaluation architecture can map input patterns to related classification targets; so the task of this network is estimation of the probability for classification purposes. Before applying the neural network for evaluation of these residuals, the network has to be trained based on the mentioned classes.

The goal of designing residual evaluation architecture is to describe fault/failure classes for pattern classification. In fact, in residual evaluation architecture, measurement results are classified in different fault/failure classes by using probabilistic features. Probabilistic features are used for decision making on measurement residuals, especially those located in borders of class boundaries. Also, some extra test routines, including threshold test and comparison of measured data with other data loggers, improved the performance of the pattern classification mechanism.

Therefore, the fault/failures classes are used in designing probabilistic neural network for decision making on measurement residuals. The distribution of fault/failure classes is very important and could have significant influences on fault diagnosis performance.

International Graduate School for Dynamics in Logistics
Contact: Dr.-Ing. Ingrid Rügge
Universität Bremen, c/o BIBA
Hochschulring 20, 28359 Bremen, Germany
www.logistics-gs.uni-bremen.de
info@IGS.Log*Dynamics*.de