LogDynamics
International Graduate School

Analysis and Prediction of Sensor and Quality Data in Food Transport Supervision

Perishable goods are at risk of suffering quality degradation during transportation, nowadays, it is assumed that older goods perish first, for such reason FIFO prioritization is made for their delivery. However, cold-chain logistic planning is more complicated; the speed of perishing varies between containers of same characteristics and also from position to position inside the same container.

The “Intelligent container” project intends to make a change of paradigm: First-Expires, First-Out (FEFO) through an efficient remote monitoring of environmental variables during transportation, such as temperature and humidity, by deploying a wireless sensor network (WSN) in the in-terior of the cargo which can communicate with the exter-nal world through a gateway as can be seen in figure 1.

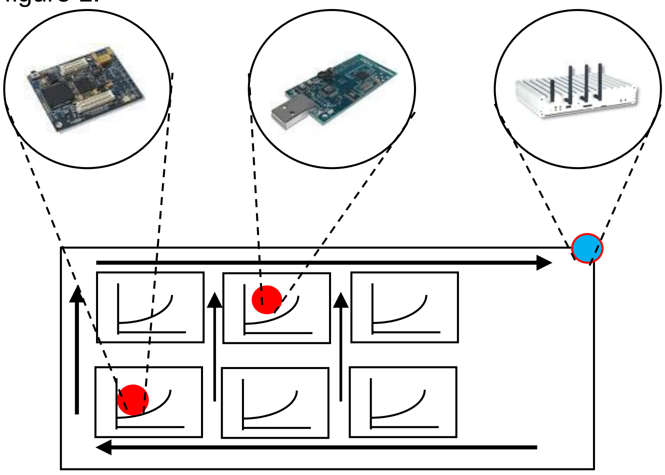

Figure 1: WSN in the intelligent container

Research Questions

In order to perform an efficient monitoring of the cargo by using the mentioned hardware, the following research questions have to be answered:

- How can an accurate monitoring with a limited number of sensors be performed?
- Are the hardware platforms able to perform the required computations?

Additionally, an intelligent container should also have the following features:

- Be robust enough to cope with unexpected behaviors.
- Interpret the acquired environmental data.

Kriging Interpolation

Kriging Interpolation will help to reduce the number of temperature sensors. Temperatures in desired points are estimated by summing up the product of weights and available source values. The weights are calculated by solving a linear system.

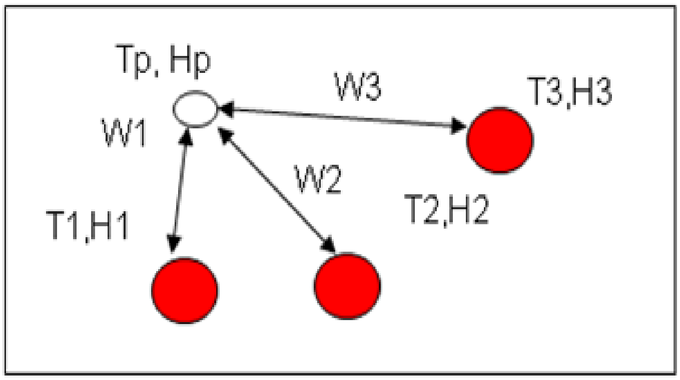

Figure 2: Spatial Interpolation.

Kriging Interpolation is more accurate than other interpolation methods, such as the Inverse Distance Weighting Method; however it is also more complicated. The optimal weights are data-driven, they are calculated from the spatial covariance values which are calculated from a proposed theoretical variogram which has to be fitted to an experimental variogram. As a second step a linear system of equations needs to be solved to get the weights.

Universität Bremen*

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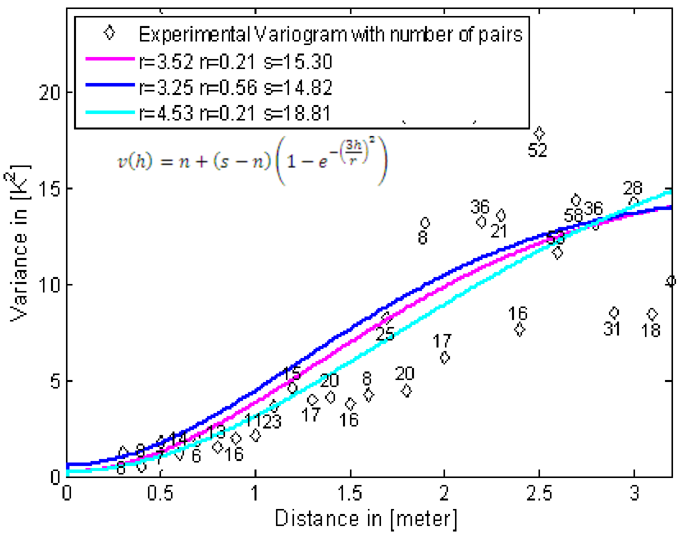

Figure 3: Variogram fitting

The steps required for Kriging Interpolation may be very complex or energy-consuming in the context of WSN. Variogram fitting algorithms and matrix inversions matrices required to solve the linear system may take much time and energy and require software libraries which cannot be run on embedded systems because of the memory requirements. The research will focus on the accuracy and energy consumption of the required algorithms.

Co-Kriging Interpolation

Temperature and humidity inside the refrigerated container are correlated variables; if a good cross-correlation model is found Co-Kriging will allow reducing the required number of humidity sensors. Two sets of weights are found, one for the under-sampled variable of interest and one for the full-samples second variable.

Despite its advantages, the method has also disadvantages, It requires two variograms, and one cross-variogram; each of them having to be fitted to its experimental data. The size of the linear equation system is increased by the square of the number of variables involved, making it computationally challenging in the context of WSNs. Research will focus on distributed solutions of the linear system.

Task Allocation

Every system is error-prone, in the intelligent container the sensor nodes the battery levels may run-out of energy, read false temperature values, etc. Despite all the possible failures, the system should perform the required tasks. The nodes and the gateway have to assign them according to the remaining energy, complexity, required accuracy, etc. Research will be done regarding dynamic task allocation for environmental monitoring in WSNs.

Machine Learning

Acquisition and interpolation of environmental variables is not enough to estimate the expiring date of the cargo. An intelligent container is able to interpret the historical records of transports and learn from them. If the patterns between environmental variables and quality defects are found, supervised machine learning algorithms may be trained to classify the data. Research will be done in machine learning techniques for environmental data in WSNs.

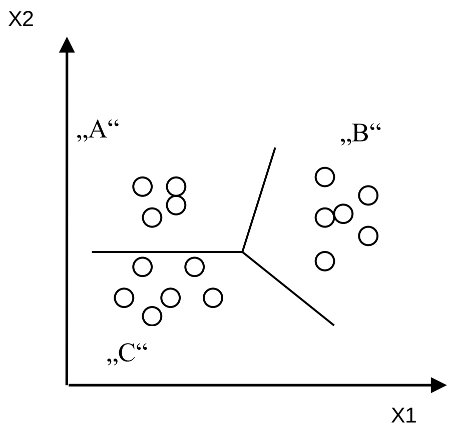

Figure 4: Supervised learning

Expected Contributions

The research results will contribute to the fields of modeling of dynamic environmental data, distributed optimization problems, efficient and robust monitoring networks, as well as machine learning techniques in monitoring networks. The benefits are for the academic community, as well as for companies involved in Automation, Remote Monitoring and Logistics.

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