Masterthesis

at Schneider Electric in Marktheidfeld, Germany

General information

Today's packaging machines cover a wide range of products in pharmaceutical, cosmetic, home care, food, beverage, dairy, tissue and paper etc. Their main task is to automate steps that happen over an over again in the packaging process in a fast and reliable way. Using state of the art technology, for example 1000 dish washer detergents can be wrapped in only one minute. This figure could move up to 2000 wrapped candies per minute, which means that the paper travels at a speed of 3 m/s.

To accomplish these goals a packaging machine distributes the control task across several components. The servomotors house the motor feedback controller along with sensors and their signal processing. The motion/logic control generates the reference values for the motor controllers; this functionality can range from pure feedforward and logics to a complex MIMO structure involving feedback from other sensors and coupling of different axis.

Schneider Electric supplies these components to machine makers, including hardware, platform and application software. While machine makers cannot change that much within the servomotors' controller, they usually programme the motion controller using an application software with given technology functions.

Master's theses usually touch at least one of the following areas:

- Modelling,
- Identification, parameter estimation and validation,
- Fault detection,
- Controller design, both linear and nonlinear.

Models are based on data that are collected in the laboratory or a complete machine (often both). Following the same philosophy, controllers are designed based on the developed models or on already existing ones. Followed by a validation process based on simulation, controllers will be tested in the machine or a lab setup directly.

Students of electrical engineering or computer science programmes, as well as students of mechatronics or applied mathematics programmes are mostly welcome to work on a thesis at Schneider Electric in Marktheidenfeld.

In order to complete these works successfully, a strong background in control engineering is required: this includes a basic course in control (covering modelling and control of linear systems), possibly courses on control theory, some lab-experience using Matlab/Simulink and related tools and basic programming skills in C++ or IEC 61131 type of languages (the latter is not necessary to know in advance, since this can be learned). Depending on the problem in particular, some familiarity with commissioning issues and electronics (basic wiring, taking measurements) is useful. However, there is an opportunity to learn these technicalities "on the job".

The development department in Marktheidenfeld consists of some 100 engineers dealing with machine functionality development, software, hardware, robotics, functional safety and testing.

Applications shall include a cover letter with statement of interests and name of a reference person at the university, copy of university courses and apprenticeships done so far, including credit points, marks etc.

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Masterthesis

Fault detection schemes for a servo motor

Students of Electrical Engineering, Mechatronics, Computer Science or Mathematics

What finally will create movement in a machine, is a drive and motor. The drive houses feedback control algorithms and sensors to measure e.g. motor’s position and currents and will control the motor using a power stage. The drive will receive reference inputs from the controller, which in turn will co-ordinate all drives in the machine.

Obviously, motor and drive play a very central role from the pure functional point of view: when motor or control algorithm work incorrectly, the machine will respond with a poor tracking behaviour. Reasons for an incorrectly working control algorithm may be wrong input signals, such as the current motor angle, provided by the respective sensor. Therefore this position signal has to be continuosly monitored.

The generic scheme used for this monitoring is shown in Fig.1.

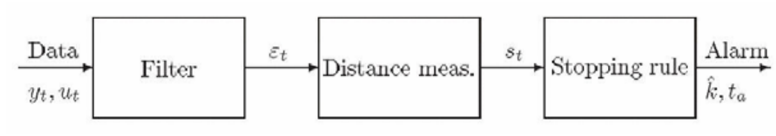

Fig.1: generic change detection scheme using filtering, distance measure and stopping rule, copy of [1, Fig.1.11].

In most cases, the filter, or model based monitoring function estimates the signal *y(t)* in question from independent signals and compares to the sensed one. For example, the measured position of the motor in the system is compared to an estimated one, computed with an observer using the motor’s currents and voltages. The output is the the difference between sensed an estimated signal, the residuum *ε(t)*. The question now is to how to deal with the size of the residuum. Is it really big enough to alert a malfunction, or has it been big enough for a sufficient time? These are the jobs of the stopping rule and the distance measure respectively [1]. So far, some investigations and benchmarks have been done, both in simulation and on the testbench [2]. We would like to continue them in the following directions:

- Inestigate a wider range of motors, driver, encoder and combinations thereof.
- Investigate adaptive thresholding and multi-model approaches: in case of monitoring a sensor signal, a second source of information could be taken into account. This could be viewed as a multimodel approach to change detection and the interplay between these two information shall be investigated. Of particular interest would be strategies when one of the models is not valid.
- Explicite failure modelling [5].
- In some cases, the filter is designed as a (extended) Kalman filter, that could be integrated within the distance measure and stopping rule [1, chap 8.10)]. The existing filters have to be reviewed with respect to fault models before that.

Although the approach will follow [3-5] quite closely, it should be noted that the results there have been derived in a different context, which is

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automotive. Aspects, that will make the carry-over quite challenging incluse, but are not limited to: approach must work with a wide variations of motors, sensors, drives (while automotive has a fixed equipment). External load is generally not know, as well as environmental conditions (e.g. ranging from cold & dry when cutting cheese over clean in pharmaceutical to warm and dry in tabacco packaging).

The work will obviously need a lot of data collection both on the test bench and possibly in real machines. After having built the algorithms it is necessary to validate the structure, the parameters and the associated uncertainies by measurement data.

Area/Background Modeling, Parameter estimation/Identification, Fault detection, Programming (Matlab, Simulink), Experiments at testbench.

Interested? Then we are looking forward to receiving your application:

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References

[1] Gustafsson, F.: Adaptive filtering and change detection. John Wiley & Sons Ltd, 2000.

[2] Usman, Z: Motor Modeling And Sensor Monitoring For Safety Applications. Master's thesis, Dept of EE, Paderborn University, Germany, December 2014

[3] Malinen, S. AFS change detection using signal estimation. Master's thesis, Dept of Electrical Engineering, Linköping University, Linköping, Sweden, Apr. 2005.

[4] Malinen, S., C. Lundquist and W. Reinelt. Fault detection of a steering wheel angle sensor in an active steering system. In Preprints of the IFAC Symposium SAFEPROCESS, pp. 547–552. Beijing, China, Aug. 2006.

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Masterthesis

Designated safety functions for Machinery or robotics

Students of Electrical Engineering, Mechatronics, Computer Science or Mathematics

What finally will create movement in a machine, is a drive and a motor. The drive houses feedback control algorithms and sensors to measure e.g. motor's position and currents and will control the motor using a power stage. The drive will receive reference inputs from the controller, which in turn will co-ordinate all drives in the machine. Obviously, motor and drive play a very central role from the pure functional point of view: when motor or control algorithm work incorrectly, the machine will respond with a poor tracking behaviour. Reasons for an incorrectly working control algorithm may be wrong input signals, such as the motor position, provided by the sensor.

When it comes to safety related applications, a motion profile that is deemed to be safe is run by the system just sketched. This is monitored by a separate safety system, which would shut down the motion system in case of unintended behaviour.

This "monitoring" is called a "designated safety function" in international safety standards [1]. For example functions like "safety limited speed" are defined. This function basically compares the present speed of the drive and to a given threshold. Once exceeding this threshold, it calles a fall-back state, which is very often to switch off the system. Although very simple conceptually, quite a few challenges can be observed, especially in the context of robustness: not to raise false alarms when being "a little bit" above threshold and/or only for short time; accuracy of signal vs. accuracy of threshold; transient behaviour between detection and switch off; quality of diagnostics at low speeds.

The task would be to model and implement a selection of the designated functions as listed in [1], followed by assessment of accuracy and robustness on a testbench.

The work will obviously need a lot of data collection both on the test bench and possibly in real machines. After having built the algorithms it is necessary to validate the structure, the parameters and the associated uncertainies by measurement data.

Area/Background Modeling, Parameter estimation/Identification, Fault detection, Programming (Matlab, Simulink), Experiments at testbench.

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References

[1] IEC 61800-5-2. Adjustable speed electrical power drive systems – Part 5-2: Safety requirements –Functional. First edition 2007-07.

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Masterthesis

Simulation of hoisting applications

Students of Mechatronics, Mechanical Engineering, Electrical Engineering, Computer Science or Mathematics

Background. Modelling, Simulation, hoisting appliciations.

Application area. Various variants of hoists exist to lift or lower loads. In this work we focus on indoor hoists for lifting and moving loads in industrial environments, more specifically overhead travelling cranes. These cranes are specified to move up some 100 tons some 50 meters in industrial construction sites. The crane is operated via remote control by an operator in order to move heavy goods from or onto e.g. trucks. While in early industry times, function and precision was mainly a task of the operator, today's cranes host a variety of sophisticated functions such as anti-sway, collision avoidance, overload control and so on. All these functions need to be designed, implemented, parametrised and validated. To do this on the real application can be a cumberstone and lenghtly excersise.

Goal. A simulation model shall be developed based on first order principles in order to simulate the apparatus prior to implementation. Parameters used shall be physical parameters and ideally those used by the automation equipment (controller, drive, software). The interface of the operator should also be part of the model. Once the model is derived, opportunity will be given to validate this on a real crane. These areas are of particular interest:

- Performance of the crane (speed, reaction time)
- Energy efficiency
- Reaction in case of failures (to implement the adequate stopping distance for example)

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Master's thesis / Apprentice

Markov chains in reliability or safety engineering

Students of Mathematics or Engineering

Area/Background. RAMS – reliability, availability, mainatainabilty, safety; statistics, random failures, programming (Matlab, octave, …), theory, no work in laboratory, no prior knowledge about industrial automation, literature search and survey.

Reliability engineering is, among other things, about having a quantified idea about occurance of failures in products, based on random failures in their components (could be electrics, electronics, mechanics etc). For example, a change in value of a resistor might imply that the green button of your cell phone does not work any more any you cannot accept any incoming calls. The failure (or change of property) of the resistor cannot be avoided, it occurs randomly[1].

A very simple and widely used method in industrial automation is to calculate the reliability of an item by making a list of all (electronic) components inside, consult a reliabilty standard for all failure rates, and just sum them up. Shortcomings of this approach include, but are not limited to:

1. Failure rates are not constant (over life time). In electronics, they follow a so-called bathtube curve, being constant in the "middle" implies that life time needs to taken into account.
2. Summing up all figures leads to conservative results.
3. Analysis of effects is often simplified to easy calculation.
4. Accuracy of data. Base failure rates are measured and hence a mean value from a data collection, accompanied by standard deviation etc, which of very often neglected.

A more sophisticated method to address this area are Markov chains (coming from Russian, one might find them also as Markoff or Markow). They are intended to at least counter the first shortcoming listed. After having gained an overview of the concept and available tools, the goal of this work is to apply this methodology to safety componets such as safety controllers, drives and so on. To foster understanding, basic concepts should be implemented self rather than using software packages. Finally, results should be compared to existing analyis to investigate the shortcomings listed above. By nature, this work is also well suited for shorter durations such as apprenticeships.

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[1] Note, that the blue screen on your laptop is most likely caused by a systematic failure (e.g. a software bug) that could be avoided when the software would have been done perfectly.

Masterthesis

Security for safety in industrial control systems

Students of Electrical Engineering, Mechatronics, Computer Science or Mathematics

Background While safety is an established and mature discipline, secury emerged over that past years, especially with recent incidents in industrial control systems and other IT based sytems. Loosely speaking, safety is about protecting the environment from the system, while security seeks to protect the system from its environment. Obviously, security issues can quickly transform into safety issues, once we are looking at security of a safety related system. Despite of this, both disciplines did not really converge in the past years. Reasons for this include, but are not limited to the following aspects:

- Risk analysis in safety is static (as long as you don't change the enviroment/application, it will be correct, hence your safety concept will be fine). Threat analysis in security is not static at all. Attack schemes might change because technology changes around you. Probability might increase because you are more interesting now. So your defense strategy might not be appropriate any more
- Incident reporting: in security, you would not go public unless you have a solution in place. In safety, you are legally obliged to do so.
- Updates: safety people don't like daily patches so much, security people have to.

Goals & approach

Based on a recent work, an example should be developed to simulate an industrial system which is safety related and possibly subject to cyber attacks. The system should have the usual fault detection schemes on board in order to detect random failures in hardware/mechanics etc. Fitness for purpose of these measures shall be proven by fault injection tests. Having laid this basis it can be investigated how these measures would react to the various cyber attacks (both in theory and practice).

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References

[1] Mahmood, A. Security for safety in machinery. MSc Thesis. Dept of Engineering, FH Köln, Köln, Germany. September 2016.

[2] Van Long DO, Lionel FILLATRE, Igor NIKIFOROV. Sequential monitoring of SCADA systems against cyber/physical attacks? Pages 746-753. Preprints, 9th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes. September 2-4, 2015, Paris, France

[3] Benjamin D. Rodes, John C. Knight, Anh Nguyen-Tuong, Jason D. Hiser, Michele Co, and Jack W. Davidson. A Case Study of Security Case Development. Proceedings of the 23rd Safety-Critical Systems Symposium, February 2015. Bristol, UK.

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