NEXT4MEMS Project
PhD Thesis on
Joint identification and control of MEMS sensors

Laboratory: Ampère, UMR CNRS 5005, Ecole Centrale de Lyon, Ecully, France
Main scientific field: Systems and Control
Secondary scientific field: Microelectronics
Keywords: System identification, Identification for control, MEMS sensors, LPV systems

Supervising committee
PhD thesis Director: BOMBOIS Xavier xavier.bombois@ec-lyon.fr DR CNRS
Other supervisors: KORNIIENKO Anton anton.korniienko@ec-lyon.fr MCF ECL

Xavier BOMBOIS is a CNRS Research Director whose expertise lies in data-based modeling (system identification), optimal experiment design and the interaction between data-based-modeling and robust control (see http://www.ampere-lyon.fr/spip.php?article815).

Anton KORNIIENKO is an Assistant Professor at Ecole Centrale de Lyon. He coordinates the Ampère efforts in the NEXT4MEMS project. His expertise lies in the development of robust control methodologies for the design of electronic systems and in the development of robustness analysis methods for large-scale systems (see http://www.ampere-lab.fr/spip.php?article552).

Laboratory department: MIS
Associated priority: M1
External partner(s): Asygn

Funding: BPI France through the funding instrument Projets de Recherche et Développement Structurants pour la Compétitivité (PSPC).

Employer: Ecole Centrale de Lyon (for a period of three years)

Scientific background
This PhD project will be performed within the scope of the project NEXT4MEMS. The objective of this large-scale project is the development of a new generation of MEMS inertial sensors with higher performance (as e.g. required by the aerospace industry). To cover the multiple facets of this ambitious project, the project consortium consists of the French leaders in the inertial sensor industry and two academic laboratories that will be in charge of the related fundamental research challenges: Ampère for the control engineering aspects and ONERA for the aerospace aspects.

Objectives of the PhD project and expected scientific contributions
MEMS inertial sensors are generally operated in a feedback loop in order to obtain an acceptable level of performance. To attain the level of sensor accuracy required in NEXT4MEMS, this feedback loop will have to be finely optimized and integrated in the electronic instrumentation (developed by our industrial partner Asygn). This fine optimization of the feedback loop will require both the determination of an accurate model of the dynamics of the MEMS sensor and the determination, based on this dynamics, of an appropriate control law using modern model-based control techniques (e.g. H∞ control).
Based on a thorough literature study, we will first develop a model of the MEMS sensor based on first principles. Even though a first-principle model is useful to obtain a first idea of the dynamics of the system, such a model generally suffers from a series of shortcomings. First, it can be difficult to model complex dynamics (e.g. the electronic instrumentation in the case of a MEMS sensor) using first principles and neglecting those particular dynamics can be highly detrimental for the control performance. Second, a first-principle model is generally far too complex for the design of a control law. Indeed, modern model-based techniques (such as H∞ control) requires models with low complexity. Consequently, first-principle modeling will not lead to a model which is appropriate for control and system identification (i.e. data-based modelling) will therefore be used instead to obtain this model.

System identification is indeed an efficient technique to obtain mathematical models that are both simple and accurate [Lju:99,Pin:04]. An identification procedure is made up of different steps. First, an identification experiment is performed on the to-be-identified system by applying, at its input, an excitation signal and by measuring the corresponding output signal. The input-output data collected in this way are subsequently used to determine the mathematical (black-box) model that is best able to reproduce these data. By delivering a mathematical model that reproduces the input-output data, system identification allows to model all the important dynamics with a complexity that is generally much lower than a first-principle model. This is the major advantage of system identification. See [Kha:12] for an example of successful application of system identification for the control of a MEMS system (an inkjet printhead).

Since the model in system identification is based on input-output data, the quality of these data is crucial for the quality of the model. In particular, the collected data must be sufficiently informative on those dynamics that are important for control. Indeed, the model uncertainty (i.e. the modelling error) highly depends on the richness of the collected data and robust control learns us that, to guarantee a certain level of control performance, the uncertainty pertaining to the relevant system characteristics must remain smaller than a certain limit [Gev:93,Bom:06,Hja:09]. These considerations will be essential in the NEXT4MEMS project due to the extremely high performance requirements (i.e. the uncertainty for the relevant system characteristics will have to be particularly small).

In the recent years, we have developed methodologies [Bom:06,Bar:08,Bom:10,For:15a] to appropriately design the identification experiment in order to obtain models that are appropriate for control. We have applied this philosophy for various domains of applications, e.g. for the design of feedback controllers for industrial processes (EU-FP7 project Autoprofit) [Lar:15,For15b], for the monitoring of electrical transmission networks (collaboration with the SmartTS Lab, KTH Stockholm) [Per:16a,Per:16b] and for the design of feedforward actuation for mechatronics systems (Octopus project in collaboration with Océ Technologies) [Kha:12].

Based on this past experience, this PhD thesis aims at developing generic methodologies for the identification of a sufficiently accurate model for a MEMS inertial sensor and for the subsequent design of a satisfactory model-based feedback law for this particular system.

In the first phase, we will restrict attention to linear time-invariant models. In some of their applications, though, the MEMS sensors will be subject to relatively fast variations in temperature and it is likely that their dynamics will be different in different temperature ranges. To model these variations of dynamics in an efficient way, an elegant framework is the Linear Parameter Varying (LPV) framework [Tot:10] where the parameter of the model depends on an external variable (the temperature, in our case) and for which identification and control methodologies have been developed. Consequently, we will also develop methodologies to identify an LPV model of the MEMS sensor and propose a corresponding LPV control law. This objective will require the extension of the identification for control tools developed for LTI systems towards LPV systems. Preliminary works on the subject are available in [Kha:09,Dan:11,For:14]. Note also that the research on this aspect will benefit from the PhD work of D. Ghosh on “Identification for control of time-varying systems” (started at Ampère in October 2015).
Like all systems, the dynamics of the MEMS sensor will evolve with time. To guarantee the desired performance over a longer timeframe, it will be therefore necessary to monitor the performance of the feedback loop over the time in order to detect any performance drop and to subsequently restore this performance via the identification of a new model and the redesign of the feedback loop. A last objective of the PhD thesis will be to develop algorithms in order to optimize and automate this procedure. This research component can build on the related results obtained during the Autoprofit project [Mes:15]

Research plan

The first work package will be a thorough literature study on the modeling and control of MEMS inertial sensors. This will allow the development of a first-principle model of a MEMS sensor that can be used for simulation and analysis purposes. The second work package will the development of methodologies leading to an LTI model of a MEMS sensor that is sufficiently accurate for the design of a feedback loop achieving the desired performance. The methodologies will be first tested on the simulation model and then validated on a real setup in the premises of our industrial partner Asygn. The third work package pertains to the extension of the methodologies towards LPV modeling and control and the fourth work package will be the developments of algorithms for monitoring, diagnosis and performance restoration. This PhD thesis will be realized in close collaboration with the engineers of Asygn and the other Ampère researchers in this project.

Requirements

We are looking for candidates who have:

- a MSc degree in Systems and Control, in Electrical or Mechanical Engineering or in Applied Mathematics
- a strong interest in control engineering
- the ability of integrating a team in an multidisciplinary project environment
- strong analytical, communication and writing skills
- a very good command of the English language. The command on the French language is an asset

Appointment and employment perspectives

We offer a challenging job in a multidisciplinary project environment including several industrial and academic partners through a fixed-term appointment for a period of three years.

Since this challenging project involves both fundamental and applied research components, such a position offers an ideal stepping stone towards either an academic career or a career in the industry.

Information and Application

For further information on this PhD thesis, please contact X. Bombois (xavier.bombois@ec-lyon.fr) and A. Korniienko (anton.korniienko@ec-lyon.fr). Applications must also be sent to these email addresses and must include a cover letter, a detailed curriculum vitae, electronic copies of the BSc and MSc grades and a recommendation letter (if available). Applications must be submitted before 1 May 2017. The PhD project is expected to start on 01/10/17.

References


