Observer-based control of uncertain systems for microforce generation and measurement in a traceable metrology context

General context of the PhD thesis

The measurement of small forces is needed in a large variety of applications such as atomic force microscopy (AFM), mechanical properties testing for micro/nano structures and surfaces, bio-components mechanical characterization at micro and nanoscale, etc. All these applications are currently suffering from the fact that the uncertainty of the forces measured is generally not known and that these forces are not traceable to the "système international d'unités" (SI), due to the lack of defined force standards below 500 mN. As a consequence, the reliability of small force measurements is questionable. The general objective of this PhD Thesis is to develop an observer-based control approach for uncertain systems in order to obtain a well-defined traceable metrology context to design traceable mechatronics systems involved in the generation or the measurement of forces below 1 mN.

Objectives and challenge

Small Forces are measured using transducers that convert forces into measurable physical effects. Therefore forces can be represented by unknown inputs of dynamic systems whose outputs are measured with some unknown errors (noise, drift). Force estimation necessitates dedicated Unknown Input Observers (UIO) that are well adapted to this context. The dynamic systems corresponding to the force transducers can be represented by uncertain systems because their temporal behaviors are modelled using approximate dynamic models. Moreover, parametric representations generally exhibit unknown time-varying drifts if environmental conditions change over time. Active force measurement systems necessitate to compensate the unknown input force using an additive opposite known force (controlled input) in order to control the system output towards a given reference.

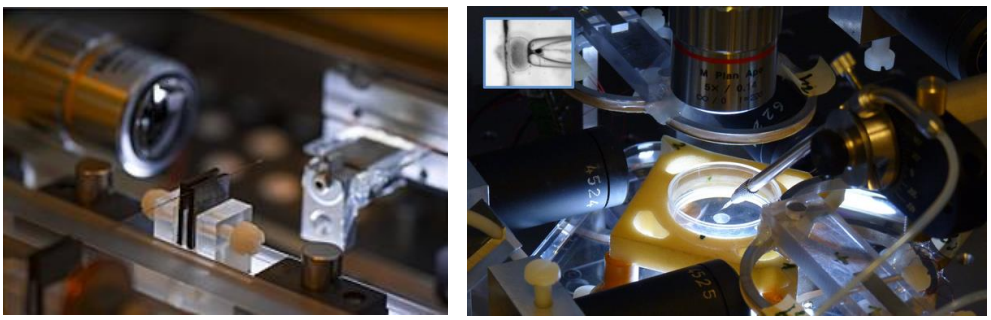

Fig. 1 – Examples of nanoforce sensors developed at FEMTO-ST using passive magnetic springs combined with macroscopic deadweight mass [1,3].

FEMTO-ST institute is the world leader in the design of micro and nanoforce sensors using passive magnetic springs combined with macroscopic deadweight mass of several milligrams [1,2,3,4]. Such technical principle makes possible to imagine a traceable metrology between mass standards and small force standards. Indeed, the deadweight involved in the force sensor can be known with a given uncertainty (mass traceability to the SI). The problem to address is to maintain

this traceability by determining the uncertainty in the UIO estimating the force despite all the external disturbances that affect the mass dynamic, despite the output measurement errors and despite the approximate dynamic model used to model the transducer. The fact that known force cannot be applied to the transducer in order to identify its dynamic has also to be taken into account in the UIO design. This UIO has to be implemented in active mechatronics systems using macroscopic deadweight mass that are currently developed at FEMTO-ST institute for both microforce generation and measurement. In these systems the deadweight mass acts as a vertical indenter and its apparent value has to be adjusted to control the associated vertical force that should be traceable. Thus, developing a traceable observer-based control approach is here necessary. A possible entry point that seems well-adapted for such development is the robust framework associated to Disturbance-Observer Based Control approaches [5,6].

Surrounding of the PhD. thesis

The PhD fellow will be part of the AS2M department[1] (Automatic Control and Micro-Mechatronic Systems) of the FEMTO-ST Institute. FEMTO-ST[2] is a joint research institute which is affiliated to four representative entities: CNRS, UFC, ENSMM and UTBM. FEMTO-ST hires more than 700 employees (among biggest French laboratories in engineering sciences) involved in different fields of engineering science, it is A+ ranked (best mark at the national level). It is organized according to 7 research departments and runs a microfabrication technology center, which is recognized nation-wide. Among them, the AS2M department is the largest French team involved in the fields of micromechatronics and micro-nano-robotics for microassembly tasks and for nanoscale perception. PhD. Students are immersed in a stimulating and fruitful working environment that enables them to get the best of their potential.

Technical and human means available for the thesis

Controlled environment, experimental nanoforce sensing platforms for research assessment, parallel scientific computing, scientific software (Matlab, Solidworks, Catia, Comsol Multiphysics), specialized engineering teams for extended supports on mechanics, electronics and microfabrication.

Requested skills

Profiles based on/or merging competencies of control theory, mechanics and instrumentation (mechatronics) with a high interest on experimentation will be considered with a great attention. A strong interest in control theory applied to control engineering is mandatory. Knowledge related to the micro and nanoscales are skills that will also pay attention but will be considered as optional. The proposed PhD thesis is for curious, inventive, dynamic applicants having a strong scientific background and a sense of communication in a collaborative and multidisciplinary environment.

Advisory team of the PhD

Emmanuel Piat - Associate professor HDR
SPECIMeN team[3] (leader) - emmanuel.piat@ens2m.fr
Joël Abadie - CNRS engineer
SPECIMeN team – joel.abadie@femto-st.fr

Contract

3 years' duration doctoral contract funded by the French government.
The PhD thesis may start in September or October 2017.
Doctoral school SPIM (Engineering Sciences and Microtechnologies) - http://ed-spim.univ-fcomte.fr/
Additional activities such as teaching will be possible (to be discussed).

[1] http://www.femto-st.fr/en/Research-departments/AS2M/Presentation/
[2] http://www.femto-st.fr/en/
[3] http://www.femto-st.fr/en/Research-departments/AS2M/Research-groups/SPECIMEN/

Application

Please send your application documents (all in one PDF file) by email to both members of the Advisory team (Emmanuel Piat and Joël Abadie) including a detailed CV, motivation letter dedicated to the proposed position, marks and ranks you obtained during your master degree or engineering school and at least one contact person (typically your supervisor for a training period, master thesis or responsible of your master diploma).

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