UPPSALA
UNIVERSITET

**Matematiska institutionen**
**Warwick Tucker**

Besöksadress:
Ångströmlaboratoriet
Lägerhyddvägen 1

Postadress:
Box 480
751 06 Uppsala

Telefon:
018–471 3318

Telefax:
018–471 32 01

Hemsida:
www.math.uu.se/~warwick

Epost:
warwick@math.uu.se

---

**Department of**
**Mathematics**
**Warwick Tucker**

Visiting address:
Ångströmlaboratoriet
Lägerhyddvägen 2

Postal address:
Box 480
SE-751 06 Uppsala
SWEDEN

Telephone:
+46 18–471 3318

Telefax:
+46 18–471 32 01

Web page:
www.math.uu.se/~warwick

Email:
warwick@math.uu.se

April 11, 2018

**Review of the PhD thesis of Mr Benoît Desrochers**

The thesis *SLAM in unstructured environments; a set-membership approach* develops and formalizes new methods, based on interval analysis, aimed at dealing with constraints that involve uncertain sets. The main motivation stems from applications in SLAM (Simultaneous Localization And Mapping). Special focus is given the unstructured environments, often appearing when working with AUVs (Autonomous Underwater Vehicles).

The thesis consists of two logical parts. The first one, from Chapters 2 to 4, is dedicated to the classical interval analysis used to solve problems involving variables that are vectors of $\mathbb{R}^n$. Here both inner and outer approximations can be computed using a combination of separators and pavers (a branch–and–bound method). This part ends with a chapter on the shape registration problem which asks for the smallest set of parameters of a transformation that links two sets. Here projections of separators are employed as a core primitive constraint.

The second part, composed of Chapters 5 and 6, focuses on constraints that involve shapes as variables. This second part is where the main novel work of the thesis lies. When such shapes are not exactly known, they are given a specific interpretation in the terms of *thick intervals* (thoroughly described in the appendix of the thesis). A new basic concept when working with thick sets is the notion of the penumbra. This is the set that carries the uncertainty of the shape. By developing new contractors (shape carvings), it is possible to compute inner and outer approximations of the penumbra, and thus avoid unnecessarily fine-grained computations on this region. This part ends with a chapter on applications: the bathymetric SLAM problem and the Dig-SLAM problem, respectively.

The ideas developed in the thesis have been implemented in a Python library called *pPyIbex*. This is of great value to the wider community, and should be recognized as a significant scientific contribution.

I find the dissertation very interesting, clearly written and on a very interesting topic. Mr Desrochers has proposed several original ideas and methods, and the obtained results are impressive. Amongst the main significant contributions of the thesis, I find the formalization of *interval shapes*, in part because such sets generalize intervals in an elegant manner, but also for their usefulness for a large set of applications. Also the accompanying machinery for set-inversion is elegant and formulated in a general manner. These contributions are very important for the successfully reaching the concrete goals targeted in this thesis, as well as for other future applications where this framework is appropriate.

The thesis work of Mr Desrochers has resulted in 10 publications and one source code package. This is, by any standards, very impressive.

In conclusion, my opinion is that the thesis proposed by Mr Desrochers is of high quality with several important contributions. It can therefore be defended without any change.

Sincerely,

Professor Warwick Tucker
Department of Mathematics
Uppsala University
SWEDEN