OSE4

4th European Optimisation in Space Engineering Workshop

March 27th - 30th 2017

Universität Bremen

Zentrum für Technomathematik

OSE

OPTIMISATION IN SPACE ENGINEERING

Moin![1]

The 4th workshop on Optimisation in Space Engineering (OSE) is organised by the European Space Agency and the University of Bremen. The goal of the OSE initiative is to provide a forum for space companies, universities, research institutes and organisations to discuss recent advances in space technology and further research in the area of optimisation in space engineering.

Scientific Program

The OSE4 consists of:

- On Monday, March 27th, **tutorials** will be given for the ESA NLP solver WORHP and the optimal control library TransWORHP. This day addresses especially to PhD students and active researchers. However, anyone is invited to participate.
- From Tuesday to Thursday, March 28th to March 30th, the workshop including **presentations** of the participants and round table discussion take place. Each presentation takes 30 minutes, including discussion.

Venue

The venue for the OSE4 is the building MZH on the campus of the University of Bremen.

- Registration is in MZH 1450 (first floor)
- The tutorials on Monday as well as the workshop from Tuesday to Thursday will be held in the lecture room MZH 1470.
- Coffee will be served directly in front of these rooms.
- Lunch can be taken at the Mensa of the university, or in some nearby restaurants.
- Free WiFi is available at the university for eduroam users. We organize WiFi access also for non university participants.

Social Events

- The **mathematical city tour** starts on Monday at 17:30 on the Marktplatz (market square) in the city center near the statue of Roland in front of the Rathaus (town hall). You can accompany us to the meeting point after the Monday tutorial finishes.
- The **wine reception** will be in room MZH 7260 (seventh floor) on Tuesday evening.
- The **guided tour through Technologiepark** on Wednesday afternoon starts at 13:30 in front of the building of the DLR.
- The **conference dinner** will be at the traditional restaurant Bremer Ratskeller in the city center. The conference fee includes the menu and two beverages.

[1] Local form of greeting

Monday, March 27

10:00–10:30	Registration, Coffee
10:30–12:30	Tutorial: Optimisation with WORHP Lab *Matthias Knauer, Universität Bremen*
12:30–13:30	Lunch
13:30–15:00	Tutorial: Optimal Control with WORHP Lab *Matthias Knauer, Universität Bremen*
15:00–15:30	Coffee break
15:30–17:00	Tutorial: Realtime Optimisation with WORHP Lab *Matthias Knauer, Universität Bremen*
17:30–19:00	Mathematical city tour. Meeting point: Roland statue

Tuesday, March 28

09:00–09:45	Registration, Coffee
09:45–10:00	Welcome
10:00–10:30	Optimization for Space Applications at ESA *Celia Yabar Valles, ESA*
10:30–11:00	Parameter Analysis of a Concurrent Engineering Satellite Study *Dominik Quantius, DLR*
11:00–11:30	Coffee break
11:30–12:00	Nonlinear regression analysis in space engineering: a global optimization approach *Maria Chiara Vola, Altran Italy*
12:00–12:30	Spacecraft control dispatch: an advanced optimization approach *Fasano Giorgio, Thales Alenia Space*
12:30–14:00	Lunch
14:00–14:30	Uncertainty based Multidisciplinary Design Optimisation *Annalisa Riccardi, University of Strathclyde*
14:30–15:00	Minimization of the ground casualty risk due to re-entering spacecraft *Bent Fritsche, Hyperschall Technologie Göttingen*
15:00–15:30	Coffee break
15:30–16:00	Autonomous Subsurface Exploration of the Icy Moon Enceladus *Joachim Clemens, Universität Bremen*
16:00–17:00	Round Table
17:00–19:00	Wine Reception at MZH 7260

Wednesday, March 29

09:30–10:00	ATOSS: Automated Trajectory Optimiser for Solar Sailing *Alessandro Peloni, University of Glasgow*
10:00–10:30	On the use of Indirect Methods for the optimisation of GTO to GEO chemical propulsion transfers *Juan Carlos Bastante, OHB System*
10:30–11:00	Motion Planning with Structure-Exploiting Motion Primitives *Kathrin Flaßkamp, Universität Bremen*
11:00–11:30	Coffee break
11:30–12:00	Entropy Driven Swarm Exploration with several Quadrocopters *Christoph Manß, DLR*
12:00–12:30	Global Optimization of Continuous-Thrust Trajectories Using Evolutionary Neurocontrol *Bernd Dachwald, FH Aachen*
12:30–13:30	Lunch
13:30–17:00	Guided tours through Technologiepark 13:30 DLR, 14:45 ZARM, 16:00 DFKI
19:00–	Conference Dinner at Bremer Ratskeller

Thursday, March 30

09:30–10:00	Multi-objective Optimisation and Multi-objective Optimal Control of Space Systems *Lorenzo Ricciardi, University of Strathclyde*
10:00–10:30	On proper efficiency in multiobjective semi-infinite optimization *Jan-J. Rückmann, University of Bergen*
10:30–11:00	The upcoming multi-objective interface for WORHP *Sören Geffken, Arne Berger, Universität Bremen*
11:00–11:30	Coffee break
11:30–12:00	Stochastic filter methods for global optimization *Christopher John Price, University of Canterbury*
12:00–12:30	Trajectory Optimization for Autonomous Deep Space Asteroid Missions within the project KaNaRiA *Anne Schattel, Universität Bremen*
12:30–12:45	Closing remarks

Tuesday, March 28

Optimisation for space applications at ESA

Celia Yabar Valles
ESA

Optimisation is indispensable for many different aspects of any space mission such as mission analysis, trajectory planning, system design and payload performace. Moreover, space missions are continuosly becoming more complex, requiring the solution of increasingly hard optimisation problems.

The aim of this talk is to show that the collaboration between ESA, industry and academia is essential to continue innovating, regarding both theoretical advances and ready-to-use tools for actual space applications. First, a brief introduction of ESA and the GNC section will be presented, followed by the optimisation challenges in current and future ESA space missions. Afterwards, some optimisation techniques developed and used by the GNC section will be shown. Finally, a summary on the ESA industrial policy and possible technology research and development collaboration programs will be explained.

Parameter Analysis of a Concurrent Engineering Satellite Study

Dominik Quantius
DLR, Institute of Space Systems

Aim of this talk is the analysis of the design parameter space, i.e. the amount of used parameters and their interdependencies observed during the SolmeX Concurrent Engineering (CE) study, a Sun observation satellite mission, which was conducted by the DLR Institute of Space Systems in Bremen. In total a number of 406 parameters have been detected including 9531 interconnections. By the help of the graph theory the structure of those parameters is elaborated counting their vertices and nodes. It builds the basis for the development of a generic design analysis and optimization tool for the CE data model.

Nonlinear regression analysis in space engineering: a global optimization approach

Vola Maria Chiara
Altran Italy, Aerospace, defense and railways

Model fitting to observational data plays an important role in space engineering. Traditionally, local optimization techniques have been applied to solve nonlinear calibration problems. The limitations of such approaches are, nonetheless, well known. Global optimization strategies can be used, as a profitable alternative. This work discusses the case of a scientific instrument, installed on board the International Space Station and aimed at studying the Sun's effect on the Earth's atmosphere. The mathematical model is illustrated with the computational results, obtained with the LGO solver. This study shows the robust and efficient performance of the global scope model calibration approach.

Spacecraft control dispatch: an advanced optimization approach

Giorgio Fasano
Thales Alenia Space, Exploration and Science

Spacecraft attitude control is notoriously a major issue, entailing the conception of a dedicated on-board system. An appropriate strategy, expressed in terms of total force and torque demand, occurring, step by step, during the whole time span relevant to a baseline mission, represents the operational framework. The control distribution among the available actuators has to be optimized, in order to minimize the overall fuel consumption. A very hard (non-convex) optimization scenario arises, concerning the thruster layout and utilization. This presentation focuses on the topical mathematical modeling and algorithmic aspects, pointing out a global optimization and mathematical programming perspective.

Uncertainty based Multidisciplinary Design Optimisation

Annalisa Riccardi
University of Strathclyde

The design of complex systems is inherently multidisciplinary, as several disciplines must be taken into account. What has changed during the last decades is the level of interaction among the disciplines, which is exploited to obtain a faster design process and an optimal configuration, having optimal performance in real operational conditions. Multidisciplinary Design Optimisation (MDO) emerged as a new approach providing a set of methods and tools to help engineers in the design of system for which the whole is greater than the sum of the parts. In the common formulation MDO does not necessarily mean that uncertainties are considered during the design process. When this happens we refer to it as Uncertainty-based Multidisciplinary Design Optimization (UMDO).

This presentation addresses the integrated design of system and mission/pro-cess control under uncertainty developed and currently used that Dept. of Mechanical & Aerospace Engineering of the University of Strathclyde. The main aspects of the approach are detailed and some test cases are shown.

Minimization of the ground casualty risk due to re-entering spacecraft

Bent Fritsche
Hyperschall Technologie Göttingen

Large spacecraft re-entering the Earth atmosphere pose a risk to the population on ground since they do not burn up completely during re-entry. At present many investigations are performed to minimize this risk for future launches by design, either by choosing suitable initial re-entry state vectors, or by selecting less temperature-resistant materials, or by arranging the components within or attached to the spacecraft in an appropriate way. In the presentation examples will be shown for the results of a coupling of a re-entry risk prediction tool with an optimizer to find minimum risk conditions.

Autonomous Subsurface Exploration of the Icy Moon Enceladus

Joachim Clemens
University of Bremen, Cognitive Neuroinformatics

Recent evaluations of the data of the Cassini spacecraft provide strong evidence for the existence of liquid water under the ice-covered surface of the Saturnian moon Enceladus. The aim of this talk is to present new technologies for navigating maneuverable melting probes through deep ice in order to collect clean samples from such subglacial water reservoirs and search for extraterrestrial live. The main focus is on four topics: (a) in-ice localization, which is formulated in terms of a graph optimization problem, (b) parameter identification, (c) optimal trajectory planning, and (d) model-predictive control. We give an overview of our work and present preliminary results.

Wednesday, March 29

ATOSS: Automated Trajectory Optimiser for Solar Sailing

Alessandro Peloni
University of Glasgow

This talk presents an automated toolbox for multi-leg solar-sail trajectories. ATOSS uses a pseudospectral method together with a shape-based approach. Two continuations are implemented to help the convergence of the optimiser: one on the dynamics and a second one on the flight time. Each optimisation problem is solved by means of GPOPS-II, which is interfaced with IPOPT, SNOPT and WORHP. A study on single and multiple NEA rendezvous missions proved the robustness of ATOSS. Moreover, ATOSS requires minimum external input and, therefore, it is suitable for preliminary mission design involving a large number of mission options.

On the use of Indirect Methods for the optimisation of GTO to GEO chemical propulsion transfers

Juan Carlos Bastante
OHB System

The first North-South Station Keeping manoeuvre of a GEO satellite, after injection in its operational orbit, can be delayed up to several months if carefully selecting the initial inclination vector. Since such initialisation of the GEO orbit can imply some propellant cost (depending on the launch date & time, it might be necessary to command big RAAN changes), adopting this strategy would result in global (transfer + operational) delta-v savings when the first manoeuvre is delayed a long enough period of time, i.e., for a big enough control box.

The talk will present the application of an Indirect Method to solve for the execution of the 4 to 6 burns of a chemical propulsion engine from GTO to GEO, illustrating the links to the operational context and quantifying the potential savings in real scenarios.

Motion Planning with Structure-Exploiting Motion Primitives

Kathrin Flaßkamp
Universität Bremen, Zentrum für Technomathematik

Optimal control methods for nonlinear systems strongly depend on good initial guesses in order to find locally optimal solutions which are globally efficient. This talk introduces motion planning with motion primitives as an approach to derive admissible solutions to control problems which then serve as sophisticated initial guesses for optimization. Motion primitives are pieces of trajectories that exploit inherent system structures, i.e. symmetry (invariances) and invariant (un)stable manifolds. Motion planning with primitives provide a suitable framework for efficiently designing optimal trajectories during operation of a system, also for multiple optimization criteria.

Entropy Driven Swarm Exploration with several Quadrocopters

Christoph Manß
Deutsches Zentrum für Luft- und Raumfahrt, Kommunikation und Navigation

Efficient data processing algorithms for information gathering with multi-agent systems are of paramount importance for future robotic space missions, especially where a high level of autonomy and robustness is expected. This work shows an experiment, where a decentralized learning of a stationary spatial process using a swarm of intelligent agents, has been done last summer.

The spatial process is represented as a linear combination of radial basis functions, called features, such that a splitting-over-features distributed learning with a sparse Bayesian learning technique can be applied to estimate the weights of individual features and identify relevant model features using sparsity techniques.

Global Optimization of Continuous-Thrust Trajectories Using Evolutionary Neurocontrol

Bernd Dachwald
FH Aachen University of Applied Sciences, Faculty of Aerospace Engineering

Fusing artificial neural networks and evolutionary algorithms, evolutionary neurocontrol tackles continuous-thrust trajectory optimization problems not from the perspective of optimal control theory but from that of artificial intelligence and machine learning. Continuous-thrust trajectories can be optimized without an initial guess and without supervision by an expert in astrodynamics and optimal control. For several existing low-thrust problems, it was demonstrated that this method can be used to find near-globally optimal solutions, even for very complex trajectories with many revolutions. Its field of application may be extended to a variety of optimal control problems.

Thursday, March 30

Multi-objective Optimisation and Multi-objective Optimal Control of Space Systems

Lorenzo Ricciardi
University of Strathclyde, Aerospace Centre of Excellence

This talk will introduce multi-objective optimisation and multi-objective optimal control, and why they are important in space applications. The Multi Agent Collaborative Search algorithm (MACS), a memetic algorithm to solve global multi-objective optimisation problems, will be illustrated and the solutions it provides to some space related problems will be presented.

Then it will be shown that combining MACS with DFET, a direct transcription method for the solution of optimal control problems, it is possible to tackle multi-objective optimal control problems both locally and globally. Examples coming from space related problems will be shown also in this case.

On proper efficiency in multiobjective semi-infinite optimization

Jan-J. Rückmann
University of Bergen

We consider multiobjective semi-infinite optimization problems which are defined by finitely many objective functions and infinitely many inequality constraints in a finite-dimensional space. We discuss constraint qualifications as well as necessary and sufficient conditions for locally weakly efficient solutions. Furthermore, we generalize two concepts of properly efficient solutions to the semi-infinite setting and present corresponding optimality conditions.

The upcoming multi-objective interface for WORHP

Sören Geffken, Arne Berger
Universität Bremen

This talk focusses on the Multi-Objective Interface for WORHP. Using the WORHP Multi-Core Interface parallelism can straightforwardly be exploited and the scalarised problems are thus solved efficiently. Technical details as well as preliminary results are presented.

Stochastic filter methods for global optimization

Christopher John Price
Mathematics and Statistics, University of Canterbury

This talk looks at variants of Accelerated Random Search (ARS) for black box global optimization of non-smooth functions subject to finite simple bounds on all variables. A variation (OSCARS) is presented which outperforms ARS and a similar deterministic algorithm. OSCARS can also be adapted to generally constrained global problems via a filter approach. This approach is shown to be effective in practice on Michalewicz' test set. The filter approach is easily adapted to many underlying global optimization methods other than OSCARS.

Trajectory Optimization for Autonomous Deep Space Asteroid Missions within the project KaNaRiA

Anne Schattel
Universität Bremen

This talk focuses on trajectory optimization for autonomous deep space small celestial body missions, including cruise flight, proximity operations, and landing. The transcription of respective optimal control problems into nonlinear optimization problems is introduced and different solutions are presented. Additionally, the use of parametric sensitivity analysis for stability and perturbation analysis of optimal solutions is explained.

Campus of Universität Bremen

City center of Bremen