Performance Comparison of Controllers with Fault-Dependent Control Allocation for UAVs
This paper combines fault-dependent control allocation with three different control schemes to obtain fault tolerance in the longitudinal control of unmanned aerial vehicles. The paper shows that fault-dependent control allocation is able to accommodate actuator faults that would otherwise be critical and it makes a performance assessment for the different control algorithms: an L1 adaptive backstepping controller; a robust sliding mode controller; and a standard PID controller. The actuator faults considered are the partial to total loss of the elevator, which is a critical component for the safe operation of unmanned aerial vehicles. During nominal operation, only the main actuator, namely the elevator, is active for pitch control. In the event of a partial or total loss of the elevator, fault-dependent control allocation is used to redistribute control to available healthy actuators. Using simulations of a Cessna 182 aircraft model, controller performance and robustness are evaluated by metrics that assess control accuracy and energy use. System uncertainties are investigated over an envelope of pertinent variation, showing that sliding mode and L1 adaptive backstepping provide robustness, where PID control falls short. Additionally, a key finding is that the fault-dependent control allocation is instrumental when handling actuator faults.
Diagnosis for Control and Decision Support for Autonomous Vehicles

Diagnosis and, when possible, prognosis of faults are essential for safe and reliable operation. The area of fault diagnosis has emerged over three decades. The majority of studies are related to linear systems but real-life systems are complex and nonlinear. The development of methodologies coping with complex and nonlinear systems have matured and even though there are many unsolved problems, methodology and associated tools have become available in the form of theory and software for design. Genuine industrial cases have also become available. Analysis of system topology, referred to as structural analysis, has proven to be unique and simple in use and a recent extension to active structural techniques have made fault isolation possible in a wide range of systems. Following residual generation using these topology-based methods, deterministic and statistical change detection has proven very useful for online prognosis and diagnosis. For complex systems, results from non-Gaussian detection theory have been employed with convincing results. The chapter presents the theoretical foundation for design methodologies that now appear as enabling technology for a new area of design of systems that are reliable in practise. Yet they are also affordable due to the use of fault-tolerant philosophies and tools that make engineering efforts minimal for their implementation. The chapter includes examples for an autonomous aircraft and a baling system for agriculture to illustrate the generic design procedures and real life results.
Experiences from developing a new course in mechatronics

Experiences from a new course in mechatronics at Technical University of Denmark are conveyed in this paper. The course is supposed to teach students enrolled in the bachelor degree in electrical engineering some fundamental knowledge about mechanics and to teach students enrolled in the bachelor degree in mechanical engineering fundamentals about electronics. Furthermore the course uses project work as a method to keep the students actively participating and in part have them teach each other the subjects. The general course plan is presented and the reasoning behind the course structure is discussed in the paper, together with a brief look at the student's reactions in form of data from the course evaluation.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Automation
Authors: Hansen, S. (Intern), Ravn, O. (Intern)
Pages: 135-138
Publication date: 2015

Host publication information
Title of host publication: Proceedings of 16th International Conference on research and Education in Mechatronics
Publisher: IEEE
ISBN (Print): 978-3-945728-01-7
Main Research Area: Technical/natural sciences
Conference: 16th International Conference on Research and Education in Mechatronics, Bochum, Germany, 18/11/2015 - 18/11/2015
Electronic versions:
rem2015.pdf
DOIs:
10.1109/REM.2015.7380383
Source: FindIt
Source-ID: 277178473
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

A Framework for Diagnosis of Critical Faults in Unmanned Aerial Vehicles

Unmanned Aerial Vehicles (UAVs) need a large degree of tolerance towards faults. If not diagnosed and handled in time, many types of faults can have catastrophic consequences if they occur during flight. Prognosis of faults is also valuable and so is the ability to distinguish the severity of the different faults in terms of both consequences and the frequency with which they appear. In this paper flight data from a fleet of UAVs is analysed with respect to certain faults and their frequency of appearance. Data is taken from a group of UAV's of the same type but with small differences in weight and handling due to different types of payloads and engines used. Categories of critical faults, that could and have caused UAV crashes are analysed and requirements to diagnosis are formulated. Faults in air system sensors and in control surfaces are given special attention. In a stochastic framework, and based on a large number of data logged during flights, diagnostic methods are employed to diagnose faults and the performance of these fault detectors are evaluated against light data. The paper demonstrates a significant potential for reducing the risk of unplanned loss of remotely piloted vehicles used by the Danish Navy for target practice.

General information
State: Published
Organisations: Department of Automation, Department of Electrical Engineering, Automation and Control
Authors: Hansen, S. (Intern), Blanke, M. (Intern), Adrian, J. (Ekstern)
Number of pages: 7
Publication date: 2014

Host publication information
Title of host publication: Proceedings of the 19th IFAC World Congress
Series: IFAC Workshop Series
Volume: 19
Number: 1
ISSN: 1474-6670
Main Research Area: Technical/natural sciences
Diagnosis of airspeed measurement faults for unmanned aerial vehicles

Airspeed sensor faults are common causes for incidents with unmanned aerial vehicles with pitot tube clogging or icing being the most common causes. Timely diagnosis of such faults or other artifacts in signals from airspeed sensing systems could potentially prevent crashes. This paper employs parameter adaptive estimators to provide analytical redundancies and a dedicated diagnosis scheme is designed. Robustness is investigated on sets of flight data to estimate distributions of test statistics. The result is robust diagnosis with adequate balance between false alarm rate and fault detectability.
Control Surface Fault Diagnosis with Specified Detection Probability - Real Event Experiences

Diagnosis of actuator faults is crucial for aircraft since loss of actuation can have catastrophic consequences. For autonomous aircraft the steps necessary to achieve fault tolerance is limited when only basic and non-redundant sensor and actuators suites are present. Through diagnosis that exploits analytical redundancies it is, nevertheless, possible to cheaply enhance the level of safety. This paper presents a method for diagnosing control surface faults by using basic sensors and hardware available on an autonomous aircraft. The capability of fault diagnosis is demonstrated obtaining desired levels of false alarms and detection probabilities. Self-tuning residual generators are employed for diagnosis and are combined with statistical change detection to form a setup for robust fault diagnosis. On-line estimation of test statistics is used to obtain a detection threshold and a desired false alarm probability. A data based method is used to determine the validity of the methods proposed. Verification is achieved using real data and shows that the presented diagnosis method is efficient and could have avoided incidents where faults led to loss of aircraft.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control
Authors: Hansen, S. (Intern), Blanke, M. (Intern)
Pages: 526-531
Publication date: 2013

Host publication information
Title of host publication: Proceedings of the 2013 International Conference on Unmanned Aircraft Systems
Publisher: IEEE
ISBN (Print): 978-1-4799-0815-8
Main Research Area: Technical/natural sciences
Conference: 2013 International Conference on Unmanned Aircraft Systems, Atlanta, Georgia, United States, 28/05/2013 - 28/05/2013
Electronic versions: icuas13-sh-mb.pdf
DOIs: 10.1109/ICUAS.2013.6564729
Source: dtu
Source-ID: u::7614
Publication: Research - peer-review › Article in proceedings – Annual report year: 2013

Towards self-tuning residual generators for UAV control surface fault diagnosis
Control surface fault diagnosis is essential for timely detection of manoeuvring and stability risks for an unmanned aircraft. Timely detection is crucial since control surface related faults impact stability of flight and safety. Reliable diagnosis require well fitting dynamical models but with the high cost of detailed modelling and wind tunnel testing, it would be highly desirable if good diagnosis could be obtained with very generic models that are adapted to individual conditions of aircraft and of its operation. This paper presents an approach where a basic generic model is applied and necessary parameters in residual generators are identified on the fly. Initial estimates of parameters are known from off-line analysis of previous flights. The paper analyses how such self-tuning residual generators are combined with change detection to obtain timely fault diagnosis. The paper investigates the parameter convergence and detection properties for the suggested combination of identification and change detection techniques and shows design aspects and trade-offs to be made to make this scheme an effective and robust system for diagnosis or even prognosis. Results are verified using a number of test flights with different members of a population of UAVs that have inherent model uncertainty from one member to another and from one flight to another. Events with actual faults on control surfaces demonstrates the efficacy of the
Contingency Estimation of States for Unmanned Aerial Vehicle using a Spherical Simplex Unscented Filter

Aiming at survival from contingency situations for unmanned aerial vehicles, a square root spherical simplex unscented Kalman filter is applied for state and parameter estimation and a rough model is used for state prediction when essential measurements are lost. Processing real flight data, received by telemetry at quite low sampling rate, the paper shows that filter performance of reasonable quality can be achieved despite the low sampling rate and the result is a low order model that can be useful during contingency operation. It is shown that the filter-estimator approach can cope with the low rate measurements requiring very little system knowledge and very limited tuning efforts. A generic aircraft model is utilised as process model where the non dimensional coefficients are identified online with joint estimation of states. Numerical stability is guaranteed by mathematically efficient square root implementation of the filter algorithm. A case of loss of GPS signal demonstrates the use of the state estimates to obtain return of the UAV to close to it’s home base where safe recovery is possible.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, University of Rostock
Authors: Hahn, T. (Ekstern), Hansen, S. (Intern), Blanke, M. (Intern)
Pages: 1797-1802
Publication date: 2012

Host publication information
Title of host publication: System Identification
Fault Diagnosis and Fault Handling for Autonomous Aircraft

Unmanned Aerial vehicles (UAVs) or drones are used increasingly for missions where piloted aircraft are unsuitable. The unmanned aircraft has a number of advantages with respect to size, weight and manoeuvrability that makes it possible for them to solve tasks that an aircraft previously has been unable to solve. The primary cause that UAVs has reached the current level of development is their military potential. Both for surveillance operations and direct strikes, UAVs has many benefits compared to manned aircraft, and the biggest of those are that no pilots are put in direct contact with enemy troops. Gradually UAV’s are also being introduced in civilian applications. In this setting they have reduced the difficulty of tasks such as photo inspections of large buildings and rescue missions at sea. All in all UAVs have shown their great potential within the recent years. The increasing use of UAVs causes them to coexist with manned aircraft and in areas where humans are present on ground. This of course carries demands to the safety and reliability of the aircraft. It is inevitable that components onboard a UAV will fail at some point in time. When this happens it is important that the fault is discovered in time such that appropriate actions can be taken. That could either be the aircraft controlling computer taking the fault into account or a human operator that intervenes. Detection of faults that occur during flight is exactly the subject of this thesis. Safety towards faults for manned aircraft is often achieved by making most of the systems onboard redundant. This is an easy way to obtain safety since no single system fault is catastrophic. The failed subsystem can be disconnected and the redundant systems can take over the tasks of the failed system. For smaller UAVs both price and weight of the aircraft is very important meaning that redundant hardware will not be an applicable safety solution. This is why focus of this thesis have been on methods where redundancies are obtained by models and knowledge about the aircraft behaviour. Based on telemetry data from a specific UAV, used by the Danish military, it is investigated how a number of critical faults can be detected and handled. One of the challenges using telemetry data for the fault diagnosis is the limited bandwidth in the radio link between the aircraft and the base-station on ground. This combined with noise on the signals makes it difficult to use precise models for the fault diagnosis. This is solved by using statistical distributions to describe the aircraft’s normal behaviour and deviations from this, indicating different faults. To increase the applicability of the models, used for fault diagnosis, these are adaptive to some extent. This makes small discrepancies between aircraft and wind conditions to have less influence on the performance of the fault diagnosis with respect to time to detect and false alarms. It also means that less adjustment is needed if the methods should be applied to another type of aircraft with different parameters. Amongst the main findings of this research project is a method to handle faults on the UAV’s pitot tube, which measures the aircraft speed. A set of software redundancies based on GPS velocity information and engine thrust are used to detect abnormal airspeed signals. Another contribution worth mentioning considers diagnosis of control surface faults. Here a set of low-complexity models between the aircraft’s turn rates and input deflections are used in the fault detection. Both methods has been verified against data from incidents where the respective faults occurs, and show good potential. The thesis consists of a summary of the different methods, investigations and results obtained during the project. Detailed descriptions are found in a number of papers submitted to research conferences and journals during the project. These have been enclosed in the last part of the thesis.
In-Flight Fault Diagnosis for Autonomous Aircraft Via Low-Rate Telemetry Channel

An in-flight diagnosis system that is able to detect faults on an unmanned aircraft using real-time telemetry data could provide operator assistance to warn about imminent risks due to faults. However, limited bandwidth of the air-ground radio-link makes diagnosis difficult. Loss of information about rapid dynamic changes and high parameter uncertainty are the main difficulties. This paper explores time-domain relations in received telemetry signals and uses knowledge of aircraft dynamics and the mechanics behind physical faults to obtain a set of greybox models for diagnosis. Relating actuator fin deflections with angular rates of the aircraft, low order models are derived and parameters are estimated using system identification techniques. Change detection methods are applied to the prediction error of angular rate estimates and properties of the test statistics are determined. Techniques to overcome correlations in data and cope with non-Gaussian distributions are employed and threshold selection is obtained for the particular distributions of test statistics. Verification using real data showed that the diagnosis method is efficient and could have avoided incidents where faults led to loss of aircraft.

Control Surface Fault Diagnosis for Small Autonomous Aircraft

Small unmanned aerial vehicles require a large degree of fault-tolerance in order to fulfil their duties in a satisfactory way, both with respect to economy and safety in operation. Small aerial vehicles are commonly constructed without much redundancy in hardware, primarily for reasons of cost but also weight. Single point of failure solutions are therefore commonly used and operation is typically allowed only in closed airspace. In order to enhance dependability, fault prognosis and diagnosis are needed. This paper explores principal redundancies at a very overall level, whether based on hardware or are analytical, and formulates residuals from which faults can be prognosed or diagnosed. An approach is suggested where detailed modelling is not needed but normal behaviour is learned from short segments of flight data using adaptive methods for learning. Statistical characterisation of distributions and change detection methods are employed to reach decisions about not-normal behaviour and it is shown how control surface faults can be diagnosed for a specific UAV without adding additional hardware to the platform. Only telemetry data from the aircraft is used together with a basic model of relations between signals within the aircraft. Frequency domain methods are shown to be robust in exploring relevant properties of the signals. The detection is shown to work on data from a real incident where an aileron gets stuck during launch of a UAV.
**Diagnosis for Control and Decision Support in Complex Systems**

Diagnosis and, when possible, prognosis of faults are essential for safe and reliable operation. The area of fault diagnosis has emerged over three decades. The majority of studies related to linear systems but real-life systems are complex and nonlinear. The development of methodologies coping with complex and nonlinear systems have matured and even though there are many un-solved problems, methodology and associated tools have become available in the form of theory and software for design. Genuine industrial cases have also become available. Analysis of system topology, referred to as structural analysis, has proven to be unique and simple in use and a recent extension to active structural techniques have made fault isolation possible in a wide range of systems. Following residual generation using these topology-based methods, deterministic and statistical change detection has proven very useful for on-line prognosis and diagnosis. For complex systems, results from non-Gaussian detection theory have been employed with convincing results. The paper presents the theoretical foundation for design methodologies that now appear as enabling technology for a new area of design of systems that are reliable in practise. Yet they are also affordable due to the use of fault-tolerant philosophies and tools that make engineering efforts minimal for their implementation. The paper includes examples for an autonomous aircraft and a baling system for agriculture.

**Orchard navigation using derivative free Kalman filtering**

This paper describes the use of derivative free filters for mobile robot localization and navigation in an orchard. The localization algorithm fuses odometry and gyro measurements with line features representing the surrounding fruit trees of the orchard. The line features are created on basis of 2D laser scanner data by a least square algorithm. The three derivative free filters are compared to an EKF based localization method on a typical run covering four rows in the orchard. The Matlab R toolbox Kalmtool is used for easy switching between different filter implementations without the need for changing the base structure of the system.
Derivative free filtering using Kalmtool

In this paper we present a toolbox enabling easy evaluation and comparison of different filtering algorithms. The toolbox is called Kalmtool 4 and is a set of MATLAB tools for state estimation of nonlinear systems. The toolbox contains functions for extended Kalman filtering as well as for DD1 filter and the DD2 filter. It also contains functions for Unscented Kalman filters as well as several versions of particle filters. The toolbox requires MATLAB version 7, but no additional toolboxes are required.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Authors: Bayramoglu, E. (Intern), Hansen, S. (Intern), Ravn, O. (Intern), Poulsen, N. K. (Intern)
Publication date: 2010

Host publication information
Title of host publication: Derivative free filtering using Kalmtool
ISBN (Print): 978-0-9824438-1-1
Main Research Area: Technical/natural sciences
Conference: 13th International Conference on Information Fusion, Edinburgh, United Kingdom, 26/07/2010 - 26/07/2010
Source: orbit
Source-ID: 265619
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

Derivative free Kalman filtering used for orchard navigation

In this paper the use of derivative free filters for mobile robot localisation is investigated. Three different filters are tested on real life data from an autonomous tractor running in an orchard environment. The localisation algorithm fuses odometry and gyro measurements with line features representing the surrounding fruit trees. The line features are created on basis of 2D laser scanner data by a least square algorithm. The Matlab (R) toolbox Kalmtool is used for easy switching between different filter implementations without the need for changing the base structure of the system.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Authors: Hansen, S. (Intern), Bayramoglu, E. (Intern), Andersen, J. C. (Intern), Ravn, O. (Intern), Andersen, N. A. (Intern), Poulsen, N. K. (Intern)
Publication date: 2010

Host publication information
Title of host publication: Derivative free Kalman filtering used for orchard navigation
ISBN (Print): 978-0-9824438-1-1
Main Research Area: Technical/natural sciences
Conference: 13th International Conference on Information Fusion, Edinburgh, United Kingdom, 26/07/2010 - 26/07/2010
Source: orbit
Source-ID: 265617
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

Diagnosis of UAV Pitot Tube Defects Using Statistical Change Detection

Unmanned Aerial Vehicles need a large degree of tolerance to faults. One of the most important steps towards this is the ability to detect and isolate faults in sensors and actuators in real time and make remedial actions to avoid that faults
develop to failure. This paper analyses the possibilities of detecting faults in the pitot tube of a small unmanned aerial vehicle, a fault that easily causes a crash if not diagnosed and handled in time. Using as redundant information the velocity measured from an onboard GPS receiver, the air-speed estimated from engine throttle and the pitot tube based airspeed, the paper analyses the properties of residuals. A dedicated change detector is suggested that works on pre-whitened residuals and a generalised likelihood ratio test is derived for a Cauchy probability density, which the residuals are observed to have. A detection scheme is obtained using a threshold that provides desired quantities of false alarm and detection probabilities. Fault detectors are build based on raw residual data and on a whitened edition of these. The two detectors are compared against recorded telemetry data of an actual event where a pitot tube defect occurred.

General information
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Naval Weapons School
Authors: Hansen, S. (Intern), Blanke, M. (Intern), Adrian, J. (Ekstern)
Publication date: 2010

Host publication information
Title of host publication: 7. Symposium on Intelligent Autonomous Vehicles
Main Research Area: Technical/natural sciences
Conference: 7th IFAC Symposium on Intelligent Autonomous Vehicles, Lecce, Italy, 06/09/2010 - 06/09/2010
Change detection, Pitot tube, Unmanned Aerial Vehicle, Fault detection
Electronic versions:
2010_sh_mb Ja.pdf
Source: orbit
Source-ID: 266678
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

Autonomous Tractor Navigation in Orchard - Diagnosis and Supervision for Enhanced Availability
Autonomous vehicles require a very high degree of availability and safety to become accepted by authorities and the public. Diagnosis and supervision are necessary means to achieve this. This paper investigates ways of using laser-scanner data to do localisation, and as a source of independent supervision, using expectation maximisation of laser-scanner output against uncertain map features. Analysis of system behaviours and their structure shows which redundant information is available to construct a supervisor. Tests on real life orchard data demonstrates the feasibility of the new approach.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control
Authors: Hansen, S. (Intern), Blanke, M. (Intern), Andersen, J. C. (Intern)
Pages: 360-365
Publication date: 2009

Host publication information
Title of host publication: Proceedings of 7. IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes
ISBN (Print): 978-3-902661-46-3
Main Research Area: Technical/natural sciences
Conference: 7th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes, Barcelona, Spain, 30/06/2009 - 30/06/2009
Autonomous vehicle, Structural analysis, Statistical methods
DOIs:
10.3182/20090630-4-ES-2003.00060
Source: orbit
Source-ID: 241844
Publication: Research - peer-review › Article in proceedings – Annual report year: 2009

Comparing mobile robot localisation algorithms using Kalmtool
In this paper we present an estimation platform with simulation capabilities to evaluate methods for localisation of a mobile robot using a feature map. The platform is based on the Kalmtool 4 toolbox which is a set of MATLAB tools for state estimation of nonlinear systems. The toolbox contains functions for extended Kalman filtering as well as for the DD1 filter and the DD2 filter. It also contains functions for Unscented Kalman filters as well as three versions of particle filters. The toolbox requires MATLAB version 7, but no additional toolboxes are required.

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Automation and Control, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Kalmtool used for laser scanner aided navigation in orchard

This paper concerns localisation of an autonomous tractor in an orchard environment, with the purpose of designing a localisation solution to be compared with GPS. The localisation is based on an estimate found by an extended Kalman filter, which fuses measurements from encoders and gyro with row measurements provided by a laser scanner. Kalmtool is used as a toolbox for developing the localisation algorithm. The result shows that the toolbox can be used successfully for dealing with localisation and sensor fusion.

Intelligent Quality Assessment of Railway Switches and Crossings

This project aims at significantly improving the safety, reliability and operational lifetime of the 3500 switches and crossings (S&Cs) in the Danish railway network. The project is a close cooperation between the Technical University of Denmark (DTU), the Danish rail infrastructure provider Rail Net Denmark and four affiliated European partners with significant expertise within this field. An inter-disciplinary scientific effort is employed to obtain enhanced rail transport reliability and regularity simultaneously with significant savings in S&Cs maintenance costs. The project results will make maintenance based on intelligent fault prediction tools, instead of the presently used regular planned inspections, and it will provide sophisticated tools to prevent hidden faults from developing to failure in the future. In a novel approach, the project will install state-of-the-art sensor technology in selected S&Cs and correlate dynamic parameters during train passage with static geometry data from conventional measurement vehicles. Monitoring of the dynamic responses will provide diagnosis of patterns that indicate when components or ballast begin to deviate from fully functional conditions. Modelling of dynamics will identify root causes to signs of degradation. Damage assessment of components identified by anomalous readings will be done by metallurgical examinations. Data and results will be processed by a holistic model that can produce Maintenance Performance Indicators (MPI) for the S&C condition. The correlation of sensor data to measuring vehicle data will allow existing data to be used reliably as input for the MPI model. It is expected that this project will enable optimisation of maintenance procedures, by which appropriate maintenance can be predicted in advance, thus avoiding unscheduled repairs and delays in the railway traffic.
Department of Mechanical Engineering
Solid Mechanics
Department of Applied Mathematics and Computer Science
Statistics and Data Analysis
Banedanmark
Period: 01/03/2015 → 28/02/2019
Number of participants: 9
Acronym: INTELLISWITCH
Project participant:
Galeazzi, Roberto (Intern)
Blanke, Mogens (Intern)
Hansen, Søren (Intern)
Santos, Ilmar (Intern)
Danielsen, Hilmar Kjartansson (Intern)
Tejada, Alejandro de Miguel (Intern)
Ersbøll, Bjarne Kjær (Intern)
Kulahci, Murat (Intern)
Project Manager, academic:
Juul Jensen, Dorte (Intern)

Financing sources
Source: Public research council
Name of research programme: Innovationsfonden
Web address: http://innovationsfonden.dk/da
Amount: 12,700,000.00 Danish Kroner
Year of approval: 2014

Fejldiagnose og fejlhåndtering til autonome fly
Department of Electrical Engineering
Period: 01/06/2009 → 21/02/2013
Number of participants: 6
Phd Student:
Hansen, Søren (Intern)
Supervisor:
Adrian, Jens (Ekstern)
Main Supervisor:
Blanke, Mogens (Intern)
Examiner:
Niemann, Hans Henrik (Intern)
Gustafsson, Fredrik (Ekstern)
Henry, David (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Ansat eksternt
Project: PhD

Strømningsmønstre i opsprækket moræneler
Department of Environmental Engineering
Period: 01/11/2000 → 23/12/2005
Number of participants: 8
Phd Student:
Rosenbom, Annette Elisabeth (Intern)
Supervisor:
Ernstsen, Vibeke (Ekstern)
Jensen, Karsten Høgh (Intern)
Refsgaard, Jens Christian (Ekstern)
Main Supervisor:
Larsen, Flemming (Intern)
Examiner:
Jakobsen, Rasmus (Intern)
Hansen, Søren (Intern)
Jarvis, Nicholas John (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Kandidatstipendiat
Project: PhD

Activities:

Control of Drones
Period: 11 Mar 2015
Søren Hansen (Lecturer)
Automation and Control
Department of Electrical Engineering
Description
Lecture for UNF
Related external organisation
Unknown external organisation
Activity: Talks and presentations › Conference presentations

Drones on Autopilot
Period: 14 Jan 2014
Søren Hansen (Lecturer)
Automation and Control
Department of Electrical Engineering
Description
Presentation and tour for E-gruppen, IDA.
Related external organisation
Unknown external organisation
Activity: Talks and presentations › Conference presentations