ERCIM "ALAIN BENSOUSSAN" FELLOWSHIP PROGRAMME

ERCIM
European Research Consortium for Informatics and Mathematics

Scientific Report

First name / Family name	James / Potter
Nationality	USA
Name of the *Host Organisation*	VTT
First Name / family name of the *Scientific Coordinator*	Kari / Tammi
Period of the fellowship	01/09/2014 to 30/04/2015 01/09/2015 to 30/11/2015

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During this fellowship, I used systems modeling and optimization tools for two main application areas: manual tracking, and ship energy flow simulation.

Manual Tracking
My fellowship proposal involved modeling human control behavior in mechanical systems with a human "in-the-loop." In systems such as vehicles, construction equipment, and industrial processes, a human must manually control part of the system to make it track a desired trajectory. In essence, the human acts as a feedback controller. This human controller must be represented in order to simulate the entire system. I created a library of human-like controller models from the literature that allows designers to add human control elements to their simulation models.

I used literature reviews from my PhD work to find appropriate controller models, and programmed them in the Modelica modeling language. I also used the Python programming language to create tools that allow a user to participate, in real time, in the block diagram created in Modelica. The tools can also tune parameter values in the manual controller models to either maximize tracking performance, or to match recorded control input from a user experiment. This library (and a supporting paper) was presented at the 2015 International Modelica Conference in Versailles, France. The library can be downloaded here: http://jjpotterkowski.github.io/

Ship Energy Flow Simulation
To gain even more experience with simulation and systems modeling tools, I also contributed to one of Kari Tammi's projects at VTT. In the Ship Energy Efficiency Technologies (SET) project, the MathWorks Simulink and Simscape modeling tools are used to simulate the main energy flows in a cruise ship. Knowledge gained from simulating the ship under different conditions is used to optimize the control of subsystems for maximum energy efficiency.

My work focused on the steam system of this ship energy flow simulator. To improve fidelity of the drum boiler system, I took a steam drum model from the literature, and created a component in MathWorks Simscape. This component was validated against a Modelica version of the same model. Another project examined the potential energy savings achieved by changing the number, and type, of circulator pumps used to harvest heat from the engine exhaust gas. This study was documented in a conference paper, and presented at the 2015 Energy Efficiency in Motor Driven Systems (EEMODS) Conference in Helsinki, Finland. The presentation slides are posted on the following website: http://www.eemods15.info/programme/tabi_1/

For the Research Exchange Programme (REP), I presented results from these and other projects on the ship energy flow simulator to a group of researchers at NTNU. In return, I got to learn about their research, and also learn about a broad range of marine topics at NTNU Ocean Week. I believe that this REP requirement is a great idea, and the visit was one of the most informative and enjoyable parts of my year as an ERCIM Fellow.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

J. Potter, "A Modelica library for manual tracking," in *Int. Modelica Conf.* (Versailles, France), pp. 1–9, Sep. 2015.

Abstract:
Many systems require a human to perform real-time control. To simulate these systems, a dynamic model of the human's control behavior is needed. The field of manual control has developed and validated such models, and their implementation in Modelica could support researchers of human-machine systems. This paper presents a Modelica library with models from the manual control literature. Python-based tools allow users to perform, in real time, the manual tracking tasks they design in Modelica. Parameter values in the manual controller models can be automatically tuned to either maximize tracking performance, or to match recorded control input from a user experiment.

J. Potter, G. Zou, T. Ahonen, K. Tammi, "Improving Simulated Ship Energy Efficiency using Variable-Speed Circulator Pumps," in *Energy Efficiency in Motor Driven Systems Conf.* (Helsinki, Finland), pp. 1–8, Sep. 2015.

Abstract:
Improving ship energy efficiency aims at reducing both operation cost and environment-damaging emissions. In this paper, a ship energy flow simulator is used to investigate potential energy savings in the steam system of a modern cruise ship. The focus is on achievable saving potential by changing the number, and type, of circulator pumps used to harvest heat from the engine exhaust gas. In the current ship design, single fixed-speed pump circulates water through two exhaust gas boilers. The pump runs at full power when one or both engines are running. This paper investigates using 3 alternative pump configurations: the same number of pumps operating at variable speeds, twice as many pumps operating at fixed speed, and twice as many pumps operating at variable speeds. The different pump configurations are simulated by using exhaust gas data from a commercial cruise ship. Simulation results show that the alternative configurations increase the net power recovered from the exhaust gas. It is estimated that the improvements could save between $20000 and $100000 per year of operation.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

International Modelica Conference
Dates: 21.9.2015 – 23.9.2015
Location: Versailles, France
Presentation: "A Modelica Library for Manual Tracking"
Description (modified from the conference website): The Modelica Conference is the main event for users, library developers, tool vendors and language designers to share their knowledge and learn about the latest scientific and industrial progress related to Modelica and to the Functional Mockup Interface. The program covered modeling of complex physical and cyber-physical systems, as well as tools, for a wide range of research and industrial applications. All contributions were peer-reviewed and selected by the Program Committee. In addition to traditional paper presentations and poster sessions, the conference featured several Modelica tutorials for beginners and advanced users, as well as vendor presentations, and an exhibition.

Energy Efficiency in Motor Driven Systems (EEMODS) Conference
Dates: 15.9.2015 – 17.9.2015
Location: Helsinki, Finland
Presentation: "Improving Simulated Ship Energy Efficiency using Variable-Speed Circulator Pumps"
Description (modified from the conference website): EEMODS 2015 provided a forum to discuss and debate the latest developments in the impacts of electrical motor systems on energy and the environment, the energy efficiency policies, standards (ISO 50.001) and programmes adopted and planned, and the technical and commercial advances made in the dissemination and penetration of energy-efficient motor systems.

NTNU Ocean Week
Dates: 4.5.2015 – 7.5.2015
Location: Trondheim, Norway
Description: NTNU Ocean Week was an event to showcase the latest developments in marine and maritime science and innovation. The presenters were experts from academia, industry, and government, with a wide variety of backgrounds and main topics of research. All shared the common goal of improving marine operations to maintain both the ocean's environmental condition and its economic importance.

Ship Energy Efficiency Technologies (SET) Seminar
Date: 27.5.2015
Location: Espoo, Finland
Description: This seminar focused on energy saving technologies and applications in shipping. The seminar featured technical experts within the Finnish shipping industry and applied research groups. The seminar was associated with the Tekes Arctic Seas Program. The SET consortium consists of four industrial parties (ABB, Aker Arctic, Alfa Laval, Deltamarin) and two research parties (Aalto University, VTT).

IV – RESEARCH EXCHANGE PROGRAMME (REP)

Norwegian University of Science and Technology (NTNU)
Dates: 4.5.2015 – 8.5.2015
Host: Professor Tor Arne Johansen
Coordinator: Torstein Ingebrigtsen Bø
Description: Scientific coordinator Kari Tammi and I visited researchers in marine operations at NTNU. The researchers presented their work, and gave us a tour of their impressive experimental testing facilities. During our visit, we attended the NTNU Ocean Week conference (see description above), and learned about a wide variety of marine research, operations, and products. I did not previously have experience with marine topics, so this conference served as an excellent introduction. At the end of the visit to NTNU, Kari gave a presentation about the Ship Energy Flow Simulator as a whole, and I gave a presentation about my work on specific parts of the simulator, entitled “Using and improving the steam system model in a ship energy flow simulator.”