WP1.2 MPC

WP Leader: Lieve Helsen

Presentation by David Blum

Expert Meeting Rome, Italy
August 31 – September 1, 2019

IBPSA Project 1

WP1.2 Goals and Work Plan

THE GOALS

Use Modelica, an equation-based object-oriented modelling language, to:

1. Develop a **framework** to test and assess MPC performance
2. Develop an open-source **Library for MPC**
3. Compare and **benchmark** different **MPC formulations**

THE WORK PLAN

WP1.2 Model Predictive Control (MPC)

Task 1.2.1:
Develop a framework to test and assess MPC performance

Task 1.2.2:
Compare and benchmark MPC algorithms

Task 1.2.3:
Develop a Modelica library for MPC

ACTION PLAN DEFINED IN Aachen

Focus points defined for the period between Aachen and Rome:

Virtual Testing Framework (BOPTEST):
Continued development and prototype testing

Emulator Models:
Development, documentation and review, including checklist for review process, use in BOPTEST

Key Performance Indicators (KPI):
Finalizing specifications, KPI calculator in BOPTEST

Modelica Library for MPC:
Initiate library development

WP1.2 Contributors

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Affiliation	Team members
KU Leuven (WP Leader)	Lieve Helsen, Filip Jorissen, Damien Picard, Iago Cupeiro, **Jan Drgona (now at PNNL)**, Javier Arroyo
LBNL	David Blum, Michael Wetter
PNNL	Draguna Vrabie, Sen Huang, Yan Chen
NREL	Kyle Benne, Yanfei Li
SDU	**Krzysztof Arendt (no longer)**, Christian Veje, **Toa Yang**
ENGIE Lab	Valentin Gavan
3E	Roel De Coninck
IK4	Jesus Febres, Susana Lopez
Sintef	**Harald Walnum**

WP1.2 Status Work

STATUS WORK

Coordination Meetings since Aachen Meeting

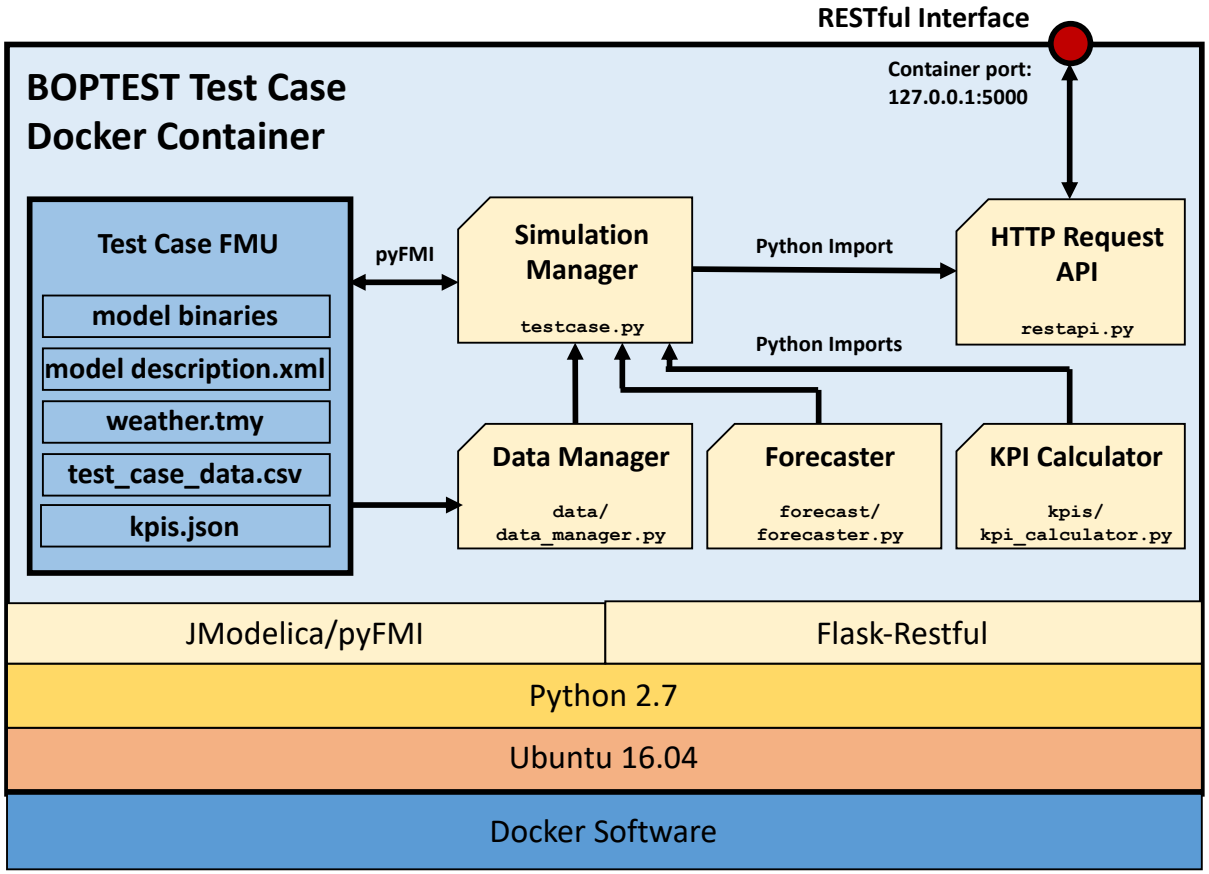
May 8, June 13, & August 13, 2019:

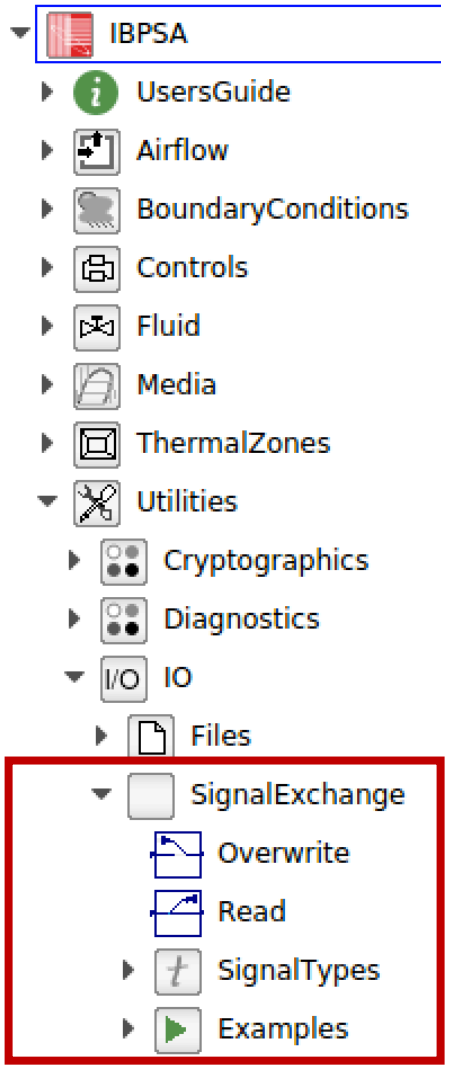
- Updates and discussion on Emulators
- BOPTEST
- KPIs
- Modelica library for MPC
- Joint papers
- IEA-EBC Annex 81 ‘Smart data-driven solutions for high-performance buildings’

STATUS WORK

Task 1.2.1: Development of a framework to test and assess MPC performance – BOPTEST Virtual Testbed

- Prototype Software **(BS 1-1, 1-2)**





https://github.com/ibpsa/project1-boptest – Prototype
https://github.com/NREL/alfalfa – Web-Hosted Architecture

STATUS WORK

Task 1.2.1: Development of a framework to test and assess MPC performance – BOPTEST Virtual Testbed

- Detailed Building Emulators **(BS 2-1)**

Emulator	Developer	Developed	Documented	Reviewed by	BOP-TEST ready
BESTEST hydronic (1z)	Filip	Ready, from IDEAS	Being finalized	Dave: yes	In development
BESTEST air-based (1z)	Dave	Ready, from Buildings	In development	Filip	Ready
8z residential hydronic heating	Valentin	Ready	1st version	Krzysztof/Toa: ongoing	
8z residential hydronic heating + air cooling	Valentin	Ready	1st version	Krzysztof/Toa: ongoing	
Air-based commercial (1z)	Dave	Almost ready	In development	Jesus	
Hydronic commercial (1z)	Krzysztof	Ready	In development	Valentin: ongoing	
5z air-based commercial	Dave	Internal review, From BUILDINGS	1st version	Yanfea (Filip)	Ready
mz hybrid office (simple)	Iago	In IDEAS	In development	Valentin	In development
mz hybrid office (complex)	Filip	In development	Not yet	PNNL?	
mz air-based prototype (complex)	Sen	Ready	1st version	Iago	In development

STATUS WORK

Task 1.2.2: Comparison and benchmarking MPC algorithms

- MPC Description Template
  (control engineering versus physical notation)
  - Draft 1 **(Ready)**
- Core KPIs Quantification
  - Calculation module in BOPTEST **(Ready)**
  - Finalize KPI specification **(BS 2-3)**
  - Subjective/Complex KPI reporting **(BS 2-3)**
- Scenarios
  - Boundary conditions defined by emulators in FMUs **(Ready)**
  - Robustness towards forecast errors **(Discussed in Aachen, Ongoing)**
  - Initial and future test cases and periods definitions **(BS 2-3)**
- Method(s) of Reporting and Dissemination **(BS 2-3)**

STATUS WORK

Task 1.2.3: Development of a Modelica library for MPC

- All physical equations need to be at least twice continuously differentiable with bounded derivatives on compact sets
- Separate Library that uses the IBPSA Library
- Compliant with JModelica → no integer problems

- Overview of available models **(Ready)**
- Library development
  - Initiate library at https://github.com/ibpsa/modelica-ibpsa-mpc **(Ready)**
  - Merge process from IBPSA library **(BS 2-2, joint with WP1.1)**
  - Continuous integration testing **(BS 2-2, joint with WP1.1.)**
  - Library population **(Ongoing)**

STATUS WORK

Publications

- Paper BS2019

Prototyping The BOPTEST Framework For Simulation-Based Testing Of Advanced Control Strategies In Buildings

David Blum, Filip Jorissen, Sen Huang, Yan Chen, Javier Arroyo, Kyle Benne, Yanfei Li, Valentin Gavan, Lisa Rivalin, Lieve Helsen, Draguna Vrabie, Michael Wetter, Marina Sofos

STATUS WORK

Publications

- Paper SBE 2019

IBPSA Project 1 : BIM/GIS and Modelica framework for building and community energy system design and operation
ongoing developments, lessons learned and challenges

Wetter, Michael; van Treeck, Christoph; Helsen, Lieve; Saelens, Dirk; Robinson, Darren; Maccarini, Alessandro; Schweiger, Gerald

STATUS WORK

Publications

- Paper Modelica Conference 2019 presented

Integrated Modelica Model and Model Predictive Control of a Terraced House Using IDEAS

Filip Jorissen, Lieve Helsen

STATUS WORK

Publications

- Journal paper: internal review phase

All you need to know about model predictive control for buildings

Ján Drgoňa, Javier Arroyo, Iago Cupeiro Figueroa, Krzysztof Arendt, David Blum, Donghun Kim, Enric Perarnau Ollé, Juraj Oravec, Lieve Helsen

STATUS WORK

Publications

- Conference paper: in preparation

Scaling of different optimization tools

Gerald Schweiger, Filip Jorissen, Lieve Helsen

STATUS WORK

Other potential interesting initiatives

- 1st World Championship (June 2019) in Cybernetic Building Optimization (Japan)
  They built an emulator with a BACnet interface and a BMS front-end. Their goal is to measure the skills of building operators using a realistic emulator
- IEA-EBC Annex 81 'Smart Data-Driven Solutions for High Performance Buildings'
- BS2021 organized by Flemish team (incl. Lieve & Dirk) – workshops!

WP1.2: Plan for break out sessions

THE PLAN FOR BREAK OUT SESSIONS – DAY 1

BS 1-1	**Topic 1.1 - BOPTEST 1**		50 min
	BOP-TEST hands-on practicum - test case development	Dave Blum / Javier Arroyo	\
BS 1-2	**Topic 1.2 - BOPTEST 2**		90 min
	BOP-TEST hands-on practicum - test case interaction and controller testing	Dave Blum / Javier Arroyo	\

THE PLAN FOR BREAK OUT SESSIONS – DAY 2

BS 2-1	**Topic 2.1 - EMULATORS**		70 min	
	Emulator development updates	All emulator developers	10 min	S
	Detailed discussion of specific emulators.	TBD	60 min	I
BS 2-2	**Topic 2.2 - LIBRARY FOR MPC**		85 min	
	MPC Library first results, sync process with IBPSA and IbpsaMPC, joint 1.1 and 1.2	Filip Jorrisen		
BS 2-3	**Topic 2.3 - USE CASES, SCENARIOS, and OTHER TOPICS**		70 min	
	Discuss plans for MPC testing, comparison, and reporting	Javier Arroyo / Dave Blur	20 min	V
	Finalize IAQ KPI	Yan Chen	10 min	V
	Propose peak power KPI	Dave Blum	10 min	I
	Additional discussions for handling of qualitative or more complex KPIs	Javier Arroyo	20 min	S
	Database of research groups that are working on MPC (model-based/data-based)	All	10 min	
BS 2-4	**Topic 2.4 - ACTION PLAN**		60 min	
	Action plan	Dave Blum		
	Extra time on additional topics if needed			