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Relationships Management for the Integration of OPM and Modelica

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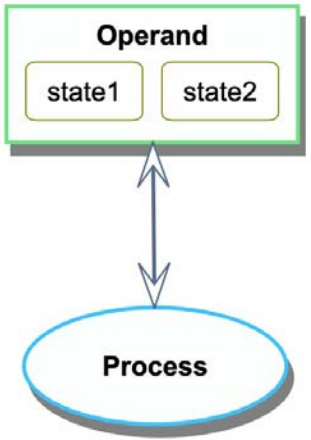
Complementarity

1. According to the Oxford Languages, complementarity is “a relationship or situation in which two or more different things improve or emphasise each other's qualities”.

2. To facilitate a consistent data exchange between conceptual modelling and simulation it is necessary to conduct a deeper study of relationships.

OPM overview

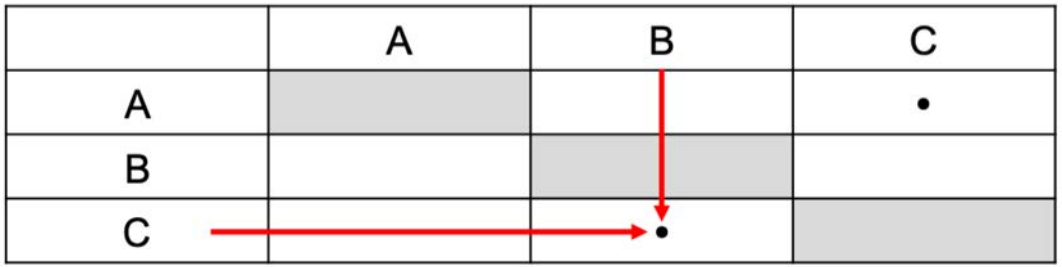
- based on the ISO 19450
- developed by Dov Dori
- has 3 core entities of a system in OPM methodology: objects, processes, and related states.
- “objects” can be defined as stateful objects
- OPM also has 13 core relationshios: structural relationships and procedural relationships



DSM-Based Approach

DSM is a “network modeling tool used to represent the elements comprising a system and their interactions, thereby highlighting the system’s architecture (or designed structure)” (Eppinger and Browning, 2012)

- N-Squared matrix (N rows and N columns)
- Each element is input – receiver, or customer – supplier
- Things “flow” from column heading to row heading



Ontologies integration

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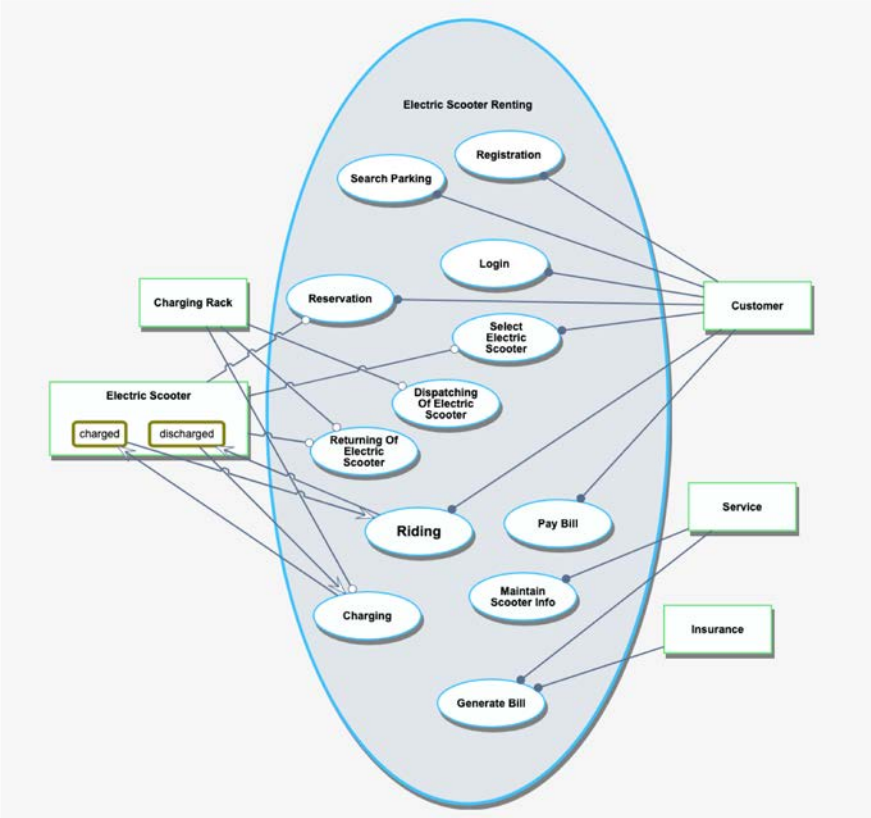
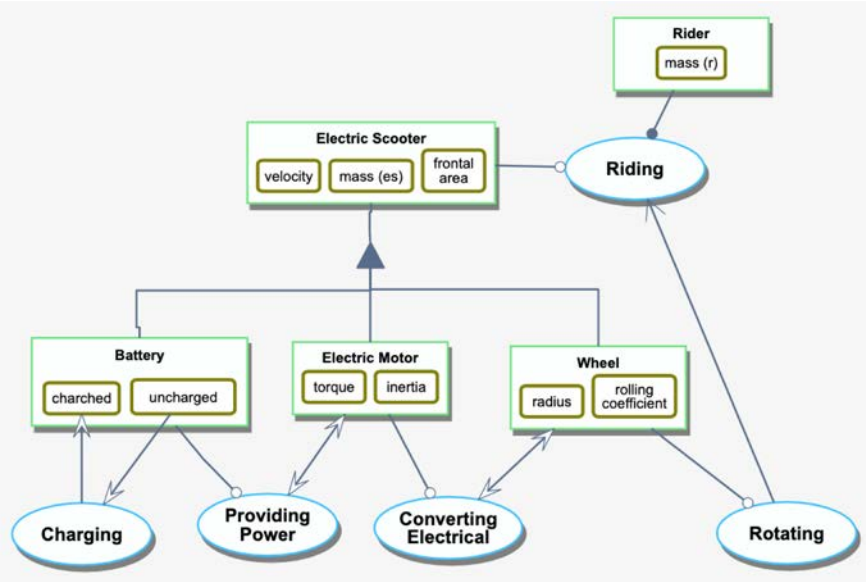
		OPM			Modelica							
		(1) Object	(2) Process	(3) State	(4) Model (block)	(5) Component	(6) Variables	(7) Parameters	(8) Constants	(9) Equations	(10) Attributes	(11) Physical types
OPM	(1) Object		1	1	1	1			1			
	(2) Process	1		1	1							
	(3) State	1	1		1		1	1	1			
Modelica	(4) Model (block)	1	1	1		1	1	1	1	1		
	(5) Component	1			1		1	1	1	1		
	(6) Variables			1	1	1				1		1
	(7) Parameters			1	1	1				1	1	1
	(8) Constants	1		1	1	1				1	1	1
	(9) Equations				1	1	1	1	1			
	(10) Attributes							1	1			
	(11) Physical types						1	1	1			

ConOps: Electric Scooter Renting

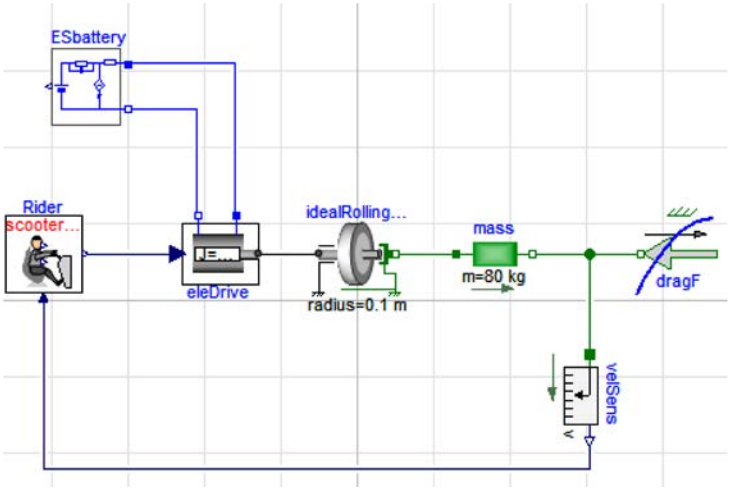


Use-case: Electric Scooter



OPM	(1) Electric Scooter	(2) Rider	(3) Battery	(4) Electric Motor	(5) Wheel	(6) Driving forward	(7) Charging	(8) Providing power	(9) Converting EP to rotation	(10) Rotating	(11) Velocity	(12) Mass (R)	(13) Mass (ES)	(14) Frontal area	(15) Uncharged	(16) Charged	(17) Torque	(18) Inertia	(19) Radius	(20) Rolling coefficient
(1) Electric Scooter			1	1	1	1					1		1	1						
(2) Rider						1														
(3) Battery	1						1	1							1	1				
(4) Electric Motor	1							1	1								1	1		
(5) Wheel	1								1	1									1	1
(6) Driving forward	1	1																		
(7) Charging			1																	
(8) Providing power			1	1																
(9) Converting EP to rotation				1	1															
(10) Rotating					1	1														
(11) Velocity	1																			
(12) Mass (R)																				
(13) Mass (ES)	1																			
(14) Frontal area	1																			
(15) Uncharged			1																	
(16) Charged			1																	
(17) Torque				1																
(18) Inertia				1																
(19) Radius					1															
(20) Rolling coefficient					1															

Use-case: Electric Scooter



Modelica	(1) Driver model	(2) Battery model	(3) Electric Drive	(4) Ideal Rolling Wheel	(5) Drag Force (aerodinamical)	(6) Total Mass	(7) Air density	(8) Scooter frontal area	(9) Rolling coefficient	(10) Aerodynamic drag coef	(11) Wheel radius	(12) Speed sensor	(13) Moment of inertia	(14) Torque	(15) Power	(16) Discharging coefficient
(1) Driver model												1				
(2) Battery model																1
(3) Electric Drive	1	1											1	1	1	
(4) Ideal Rolling Wheel			1						1							
(5) Drag Force (aerodinamical)						1	1	1		1	1					
(6) Total Mass				1	1											
(7) Air density					1											
(8) Scooter frontal area					1											
(9) Rolling coefficient				1												
(10) Aerodynamic drag coef					1											
(11) Wheel radius				1												
(12) Speed sensor					1											
(13) Moment of inertia																
(14) Torque																
(15) Power		1														
(16) Discharging coefficient																

Use-case: Electric Scooter

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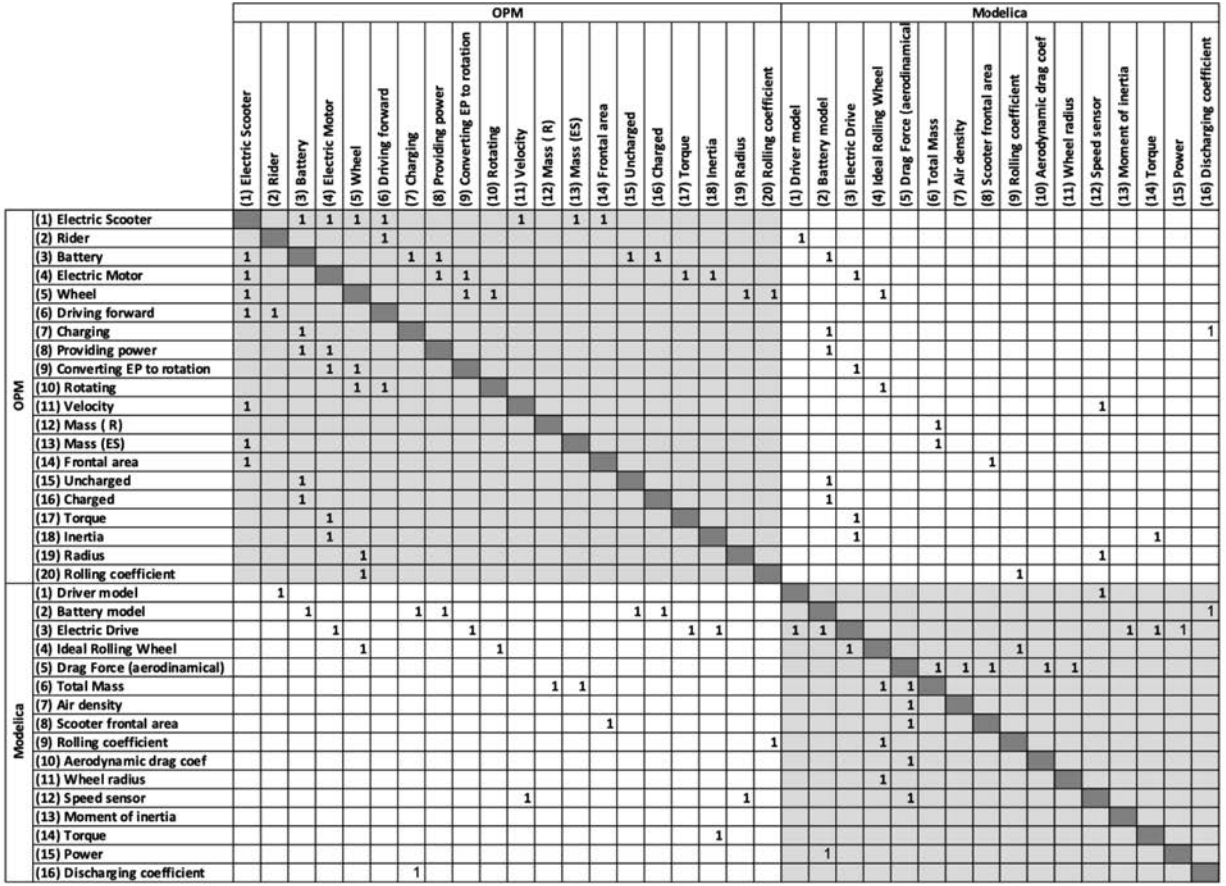

		OPM																			Modelica														
		(1) Electric Scooter	(2) Rider	(3) Battery	(4) Electric Motor	(5) Wheel	(6) Driving forward	(7) Charging	(8) Providing power	(9) Converting EP to rotation	(10) Rotating	(11) Velocity	(12) Mass (R)	(13) Mass (ES)	(14) Frontal area	(15) Uncharged	(16) Charged	(17) Torque	(18) Inertia	(19) Radius	(20) Rolling coefficient	(1) Driver model	(2) Battery model	(3) Electric Drive	(4) Ideal Rolling Wheel	(5) Drag Force (aerodinamical)	(6) Total Mass	(7) Air density	(8) Scooter frontal area	(9) Rolling coefficient	(10) Aerodynamic drag coef	(11) Wheel radius	(12) Speed sensor	(13) Moment of inertia	(14) Torque	(15) Power	(16) Discharging coefficient
OPM	(1) Electric Scooter			1	1	1	1					1			1	1																				
	(2) Rider						1															1														
	(3) Battery	1						1	1								1	1					1													
	(4) Electric Motor	1							1	1									1	1				1												
	(5) Wheel	1								1	1									1	1				1											
	(6) Driving forward	1	1																																	
	(7) Charging			1																			1													1
	(8) Providing power			1	1																		1													
	(9) Converting EP to rotation				1	1																		1												
	(10) Rotating					1	1																		1											
	(11) Velocity	1																															1			
	(12) Mass (R)																										1									
	(13) Mass (ES)	1																									1									
	(14) Frontal area	1																											1							
	(15) Uncharged			1																			1													
	(16) Charged			1																			1													
	(17) Torque				1																			1												
	(18) Inertia				1																			1											1	
	(19) Radius					1																											1			
	(20) Rolling coefficient					1																								1						
Modelica	(1) Driver model		1																														1			
	(2) Battery model			1				1	1							1	1																			1
	(3) Electric Drive				1					1								1	1			1	1											1	1	1	
	(4) Ideal Rolling Wheel					1					1													1						1						
	(5) Drag Force (aerodinamical)																										1	1	1		1	1				
	(6) Total Mass												1	1											1	1										
	(7) Air density																									1										
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	(9) Rolling coefficient																				1				1											
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	(13) Moment of inertia																																			
	(14) Torque																		1																	
	(15) Power																					1														
	(16) Discharging coefficient							1																												

Discussion and Conclusion

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1. We are proposing an approach that was used for the integration of design and manufacturing teams and data, to evaluate how it can be adapted to the earlier phases of system development, to facilitate a consistent data exchange between conceptual modelling and simulation.

2. It is necessary to conduct a deeper study of relationships.

3. We demonstrate that the DSM-based methods can be used as an effective tool to clarify the principles of the OPM and Modelica integration and to illustrate the importance of relationship management in the integration process. We use the example of an electric scooter to explain the approach.

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Thank You!

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