Full system Co-simulation for analysis and design of vehicular mechatronic systems

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Project aims

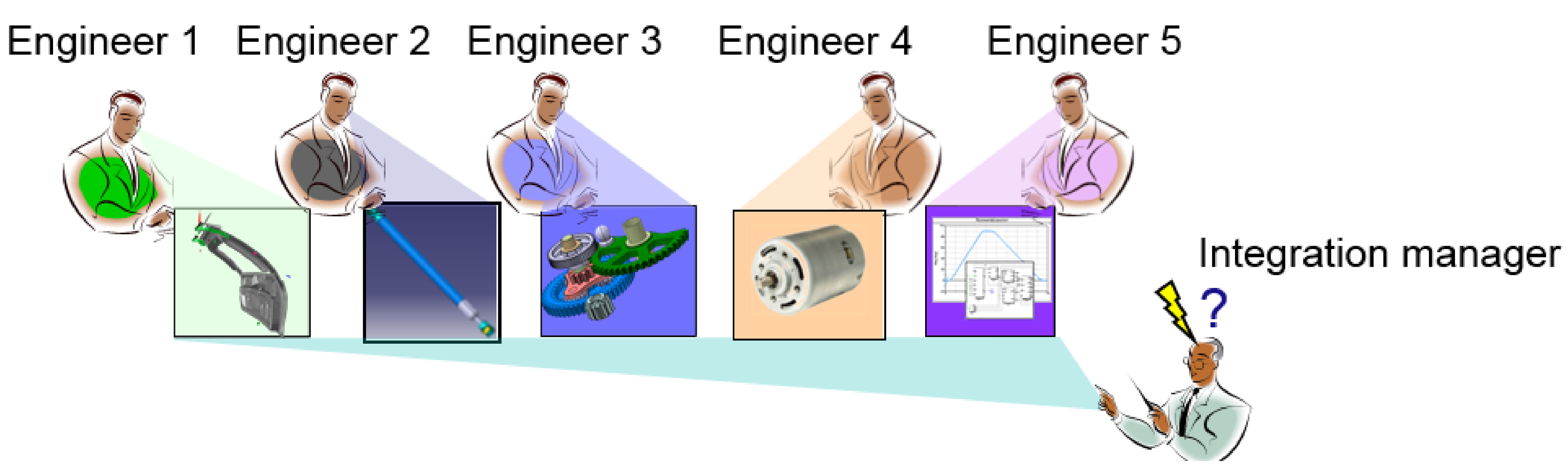
- Allow for system analysis and design early in development process
- Allow for simultaneous hardware and software development through system simulation of the components.
- Allow testing of combinations of software and hardware components.

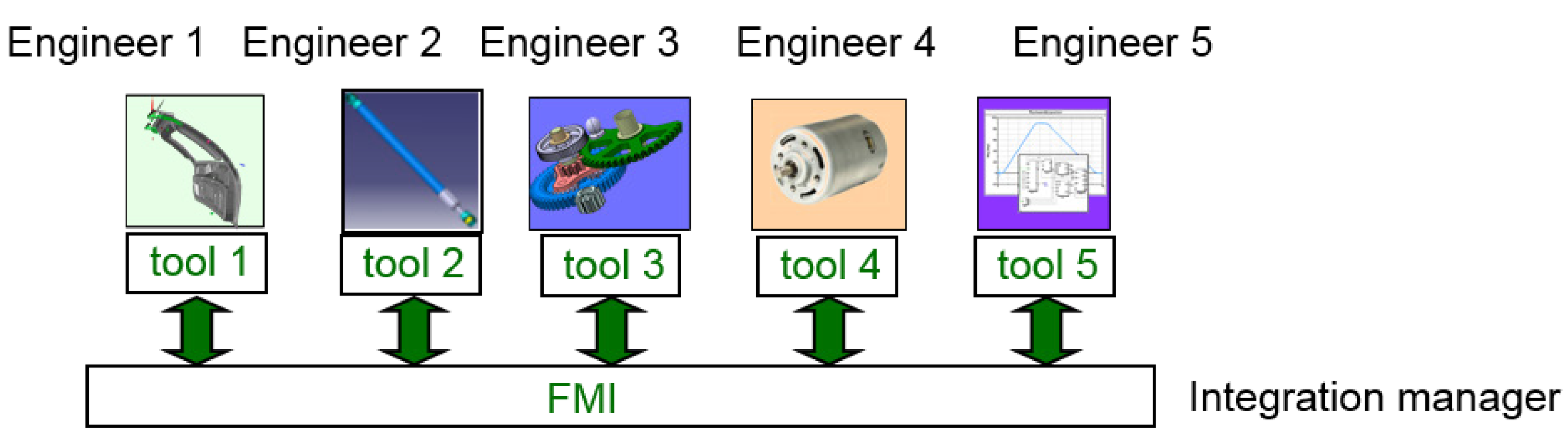
Purpose

Complex mechatronics systems used in the automotive industry are required to improve fuel efficiency, manoeuvrability, safety, and ease of use.

They are prone to systemic errors due to interactions. Reliable system simulations are needed to detect these during the early design process.

The simulation software packages of today are reliable for any one given component but not for full system simulations.

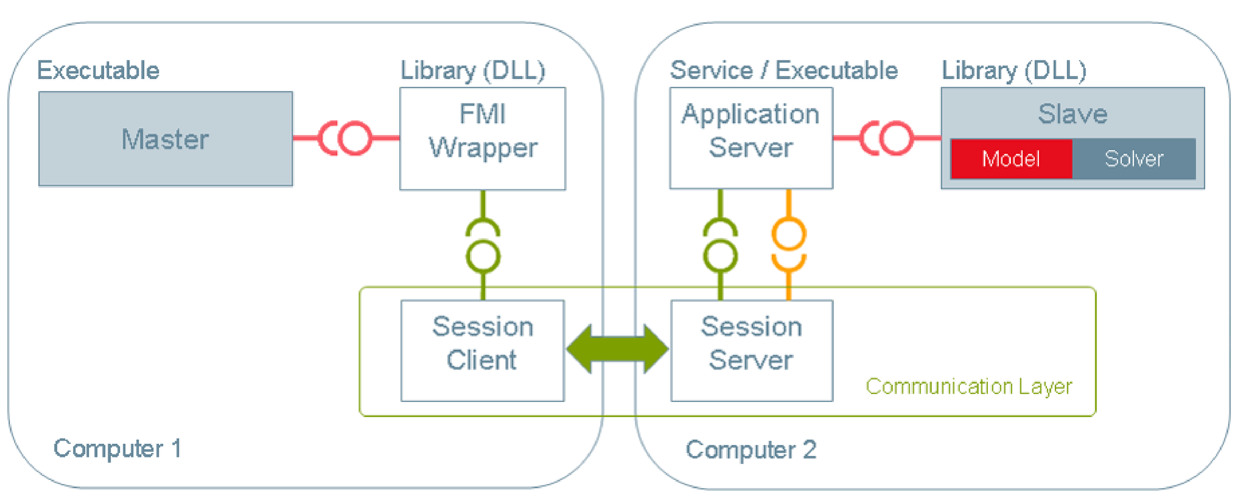




The project is important as it promotes integration testing ranging from pure HIL, via a mix of HIL and SIL to pure SIL in which the complete powertrain is in a simulated environment, this will enable the automotive industry to reduce the number of prototypes and redesigns of solutions in a late stage of the product development as a result of integration testing. It will also increase the efficiency of the systems as a large design space

System Architecture

We intend to systematically rely on FMI to allow software and ECUs to communicate in a uniform way and interchangeably within a client-server architecture. These clients and servers are simple applications which map the FMI API directly to communication protocols. They dynamically load FMUs and translate requests from clients to FMI function calls for the FMU.



Strong coupling

Isolated dynamics:

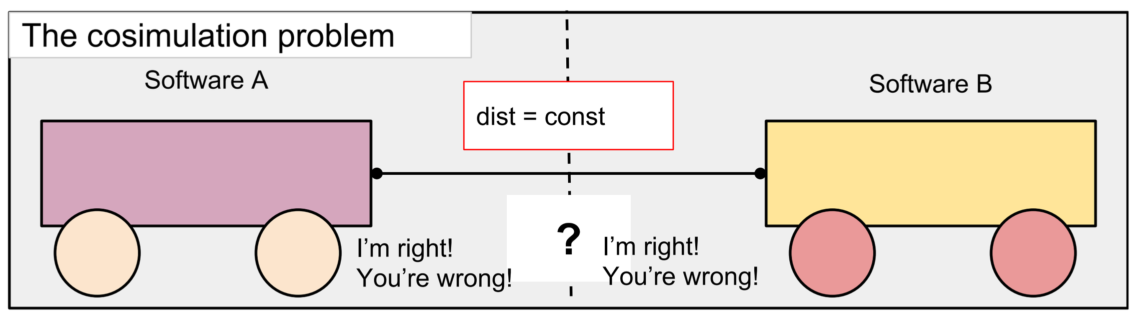
$$M^{(i)}\ddot{x}^{(i)} = f^{(i)}, i = 1, 2, \text{ different integrators: } x^{(i)}_{k+1} = \Phi^{(i)}(x^{(i)}_k, f^{(i)}_k)$$

Boundary conditions and constraints:

$$g(x^{(1)}_{k+1}, x^{(2)}_{k+1}) = 0, \text{ and Jacobian } G^{(i)} = \frac{\partial g(x^{(1)}, x^{(2)})}{\partial x^{(i)}}$$

Coupled dynamics assuming workless constraints

$$x^{(i)}_{k+1} = \Phi^{(i)}(x^{(i)}_k, f^{(i)}_k + G^{(i)T}\lambda),$$



The coupling forces λ are the solution of the equation:

$$\left[\sum_i G^{(i)}[\tilde{M}^{(i)}G^{(i)T}]\right]\lambda = b.$$

This is solved by the master. But we need the "directional Jacobians":

$$[\tilde{M}^{(i)}G^{(i)T}] = \epsilon^{-1}\left\{\Phi^{(i)}(x^{(i)}_k, f^{(i)}_k + G^{(i)T}\epsilon) - \Phi^{(i)}(x^{(i)}_k, f^{(i)}_k)\right\},$$

i.e., the change of velocity in system i due to a small force additional force in a given direction.

Each slave must do that for all coupled variables, i.e., do a tentative step. That is expensive, but embarrassingly parallel.

Once λ is computed, we can step each system for good, and they will be nearly in sync. A stability proof is being developed.

This is inspired from discrete-time variational mechanics.

Partners

Modelon, Volvo, Scania, algoryx