מכון טכנולוגי חולון
Holon Institute of Technology

Applying MBSE in Industrial Practice Vision and Reality Sep 23rd, 2021

DR. MICHAEL WINOKUR

HEAD OF SYSTEMS ENG., FACULTY OF TECHNOLOGY MANAGEMENT

HOLON INSTITUTE OF TECHNOLOGY, HOLON, ISRAEL

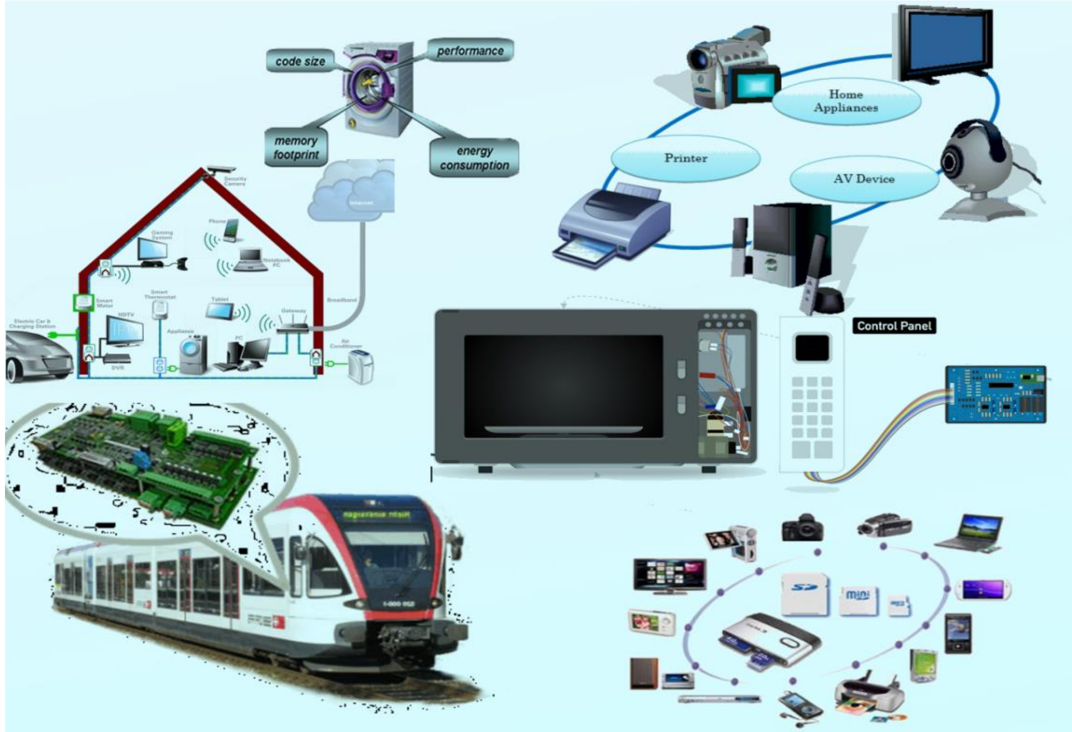
Personal Data

- BSc Electric and Electronic Eng. Technion, MSc Nuclear Eng. Technion,
- PhD Systems Eng. Imperial College Univ. London
- Philips, Medical Systems , Eindhoven - 1976
- Israel Aerospace Industries (IAI), Director of Systems Engineering, 1986 - 2017
- Technion and Tel Aviv Univ ; External Systems Associate Prof. Since 1999
- HIT - Establishment of Specialization in Embedded Systems, 2014
- HIT – Faculty of Technology Management Dean, 2018-2019
- HIT – Head of Systems Engineering – Full Time Faculty since , 2018

Presentation Focus

The presentation will address the issue of Model-Based Systems Engineering (MBSE) application in industrial practice.

What is the vision, what is the reality and what can be expected in the near future for the application of MBSE in the development of complex cyber-physical systems.



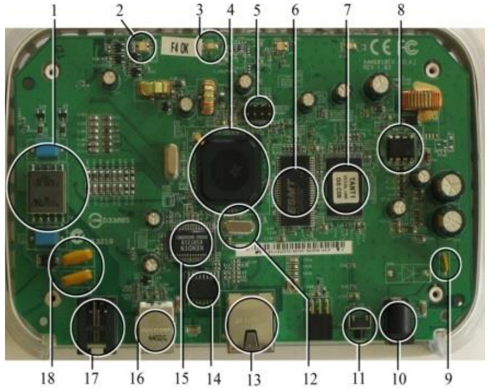
Presentation topics

- Embedded Systems, IoT and Cyber Physical Systems (CPS)
- Models for System Development
- Vision Vs. Reality
- Tools and Examples
- Future Directions
- Questions and Discussion

Embedded Systems

An embedded system is an HW-SW system designed to perform a group of dedicated functions and often with real-time limitations. It is integrated as part of a complete system that includes hardware and mechanical parts.

(Based on Wikipedia)



ADSL modem/router

Embedded Systems vs. IoT

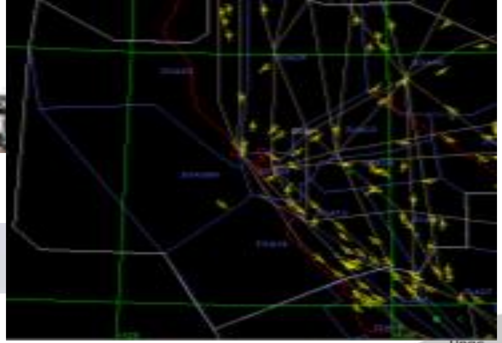
IoT is the extension of Internet connectivity for physical devices and everyday objects. Using embedded electronic systems, Internet connectivity, and other forms of hardware (such as sensors), these devices can communicate and interact with others over the Internet, and can be monitored and controlled remotely.

(Based on Wikipedia)

Cyber Physical Systems

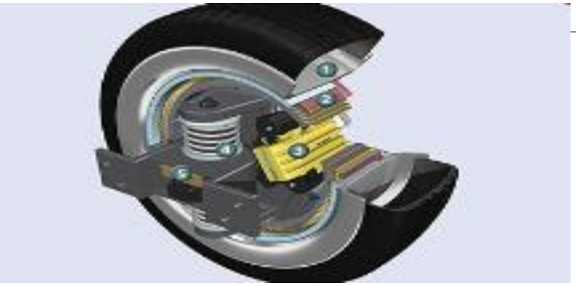
Orchestrating networked computational resources with physical systems

Avionics

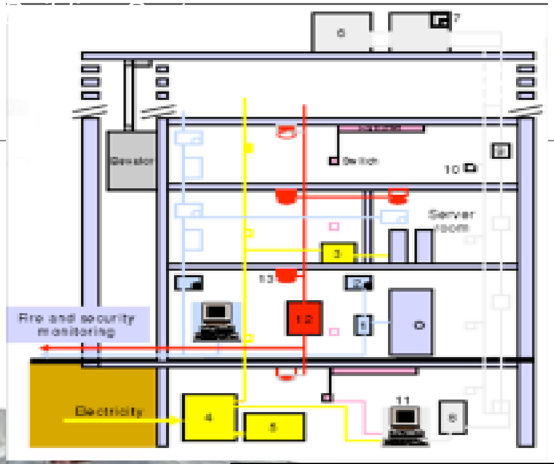


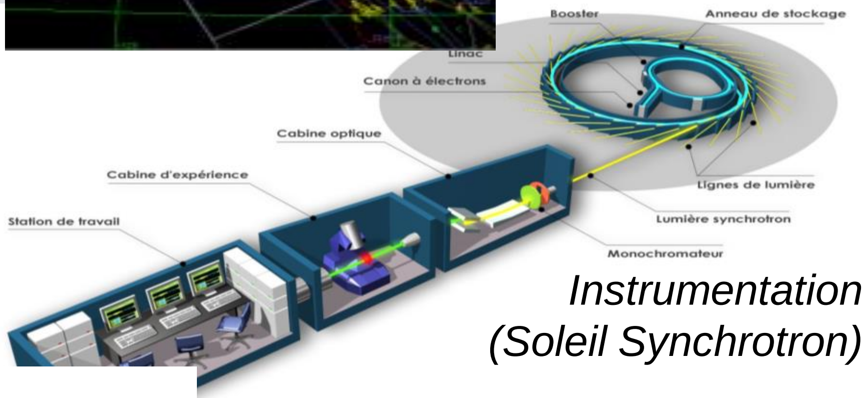
Slide: Courtesy of Prof. Alberto Sangiovanni-Vincentelli. [UC Berkeley]

Automotive

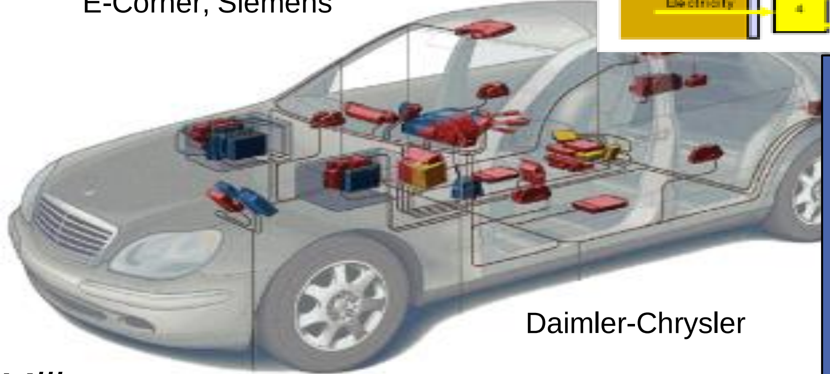


E-Corner, Siemens



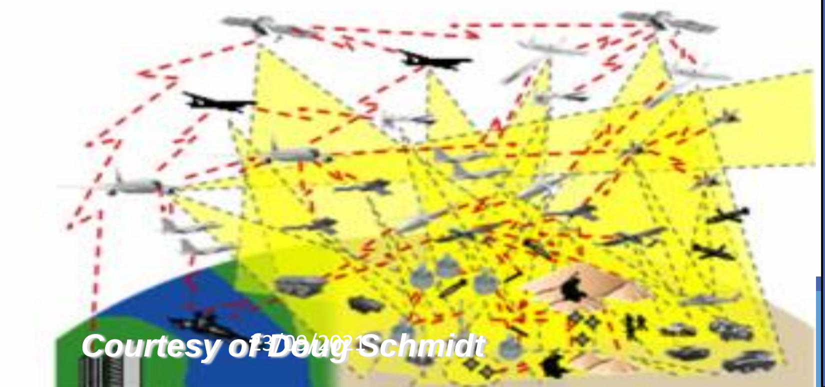


Instrumentation (Soleil Synchrotron)



Daimler-Chrysler

Military systems:



Courtesy of Doug Schmidt

Power generation and distribution

Courtesy of General Electric

Cyber Physical Systems – Useful Definitions

- Cyber-Physical Systems (CPS) comprise interacting digital, analog, physical, and human components engineered for function through integrated physics and logic . (*)
- Ongoing advances in science and engineering improve the link between computational and physical elements by means of intelligent mechanisms, increasing the adaptability, autonomy, efficiency, functionality, reliability, safety, and usability of cyber-physical systems. (e.g., collision avoidance, robotic surgery , deep-sea exploration , augmentation of human capabilities) (**)

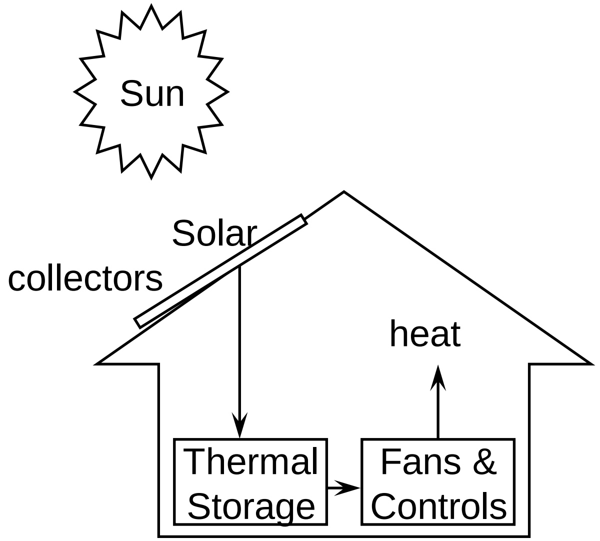
(*) https://www.nist.gov/el/cyber-physical-systems

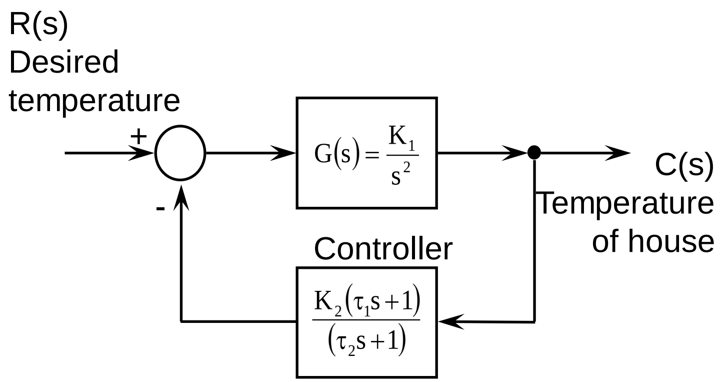
https://www.sebokwiki.org/wiki/Cyber-Physical_Systems_(glossary)

(**) https://en.wikipedia.org/wiki/Cyber-physical_system

The need to Build Models in Specification and Design (Engineering Models)

- Prior to building complex systems, engineers build abstract models that represent the structure and behavior of the system to be built.
- Being abstract, models are easier to handle and understand than real entities.
- Accurate notation in model construction allows you to verify the model's ability to meet the requirements of the actual system
-





MBSE for CPS : Vision vs Reality

Vision:

Applying Model Based Systems Engineering will accelerate the process of developing robust and economical Cyber Physical Systems

Functional Modeling Methods (the 70's)

SADT

http://en.wikipedia.org/wiki/Structured_analysis_and_design_technique

IDEF

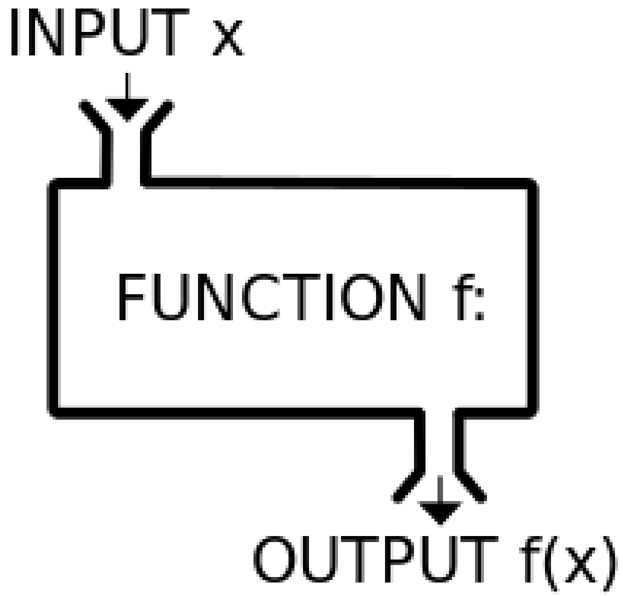
http://en.wikipedia.org/wiki/IDEF0

FFBD

http://en.wikipedia.org/wiki/Functional_flow_block_diagram

DFD (Decomposicion Funcional)

http://en.wikipedia.org/wiki/Data_flow_diagram



The 80's

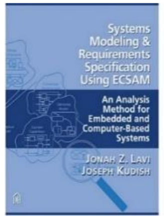
Complex projects (such as Lavie in Israel) promote the development of modeling tools and methods

Very intensive activity on the subject:

- STATECHARTS
- STATEMATE tool
- ECSAM modeling method

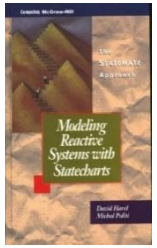
Systems Modeling & Requirements Specification Using ECSAM: An Analysis Method for Embedded and Computer-Based Systems

by Jonah Z. Lavi and Joseph Kudish



Modeling Reactive Systems with Statechart: The Statemate Approach

by David Harel and Michal Politi



A comprehensive article describing the development:
Statecharts in the Making: A Personal Account- Prof. David Harel

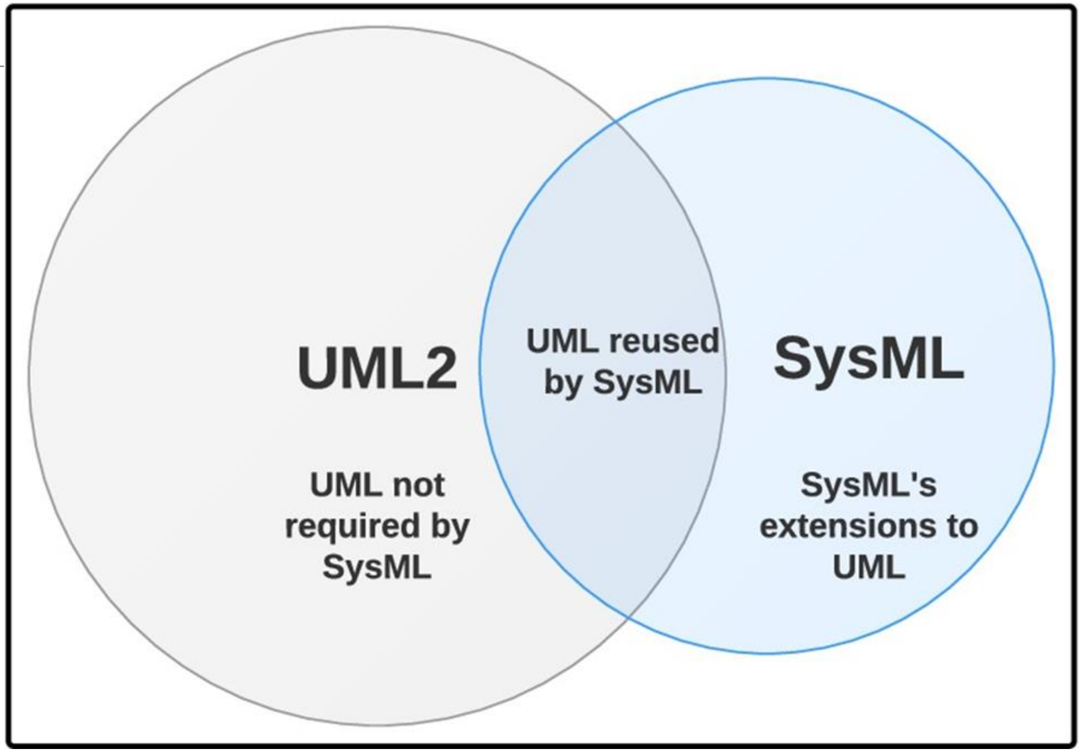
90’s and 2000’s

Unified Modeling Language -UML in the software

SysML: A derivative of UML for systems

Additional initiatives:

- OPM (language and tools) led by Prof. Dov Dori at the Technion https://en.wikipedia.org/wiki/Object_Process_Methodology
- MODELICA Language and tools https://www.modelica.org



OMG Systems Modeling Language (OMG SysML™), Version 1.6. (2019)

90’s and 2000’s (continued)

Large EC-funded consortium to implement the tools in real projects, e.g.:

- Speeds
- Danse

Modeling tools use in Engineering Disciplines

Modeling in engineering disciplines with the help of computerized tools are standard in Industrial use and Academic Courses teaching.

Examples:

- Modeling and automatic production of software using UML
  Really?
- CAD-CAM in Mechanical Engineering: Design, Analysis and Simulation (Example: https://www.youtube.com/watch?v=VJpB4szpfTY
- CAD-CAM in Electronics: A modeling tool from the design stage to implementation

MBSE for CBS : Vision vs Reality

Reality:

- For 30 years there has been the development of tools, modeling languages and international standardization efforts
- Courses on the subject are taught in academia and systems engineering forums
- Wide spread use in industry does not "take off"
- Common situation: Using drawing tools for drawing, without formal language, without analysis and without simulation and textual specifications
- Exceptions:
  - Automated tools for managing textual requirements and generating specifications
  - Showcase projects or Complex components

Can we break the deadlock ?

Main causes of the problem

Man-machine interface of CPS modeling tools is relatively inconvenient

A complex learning curve of the modeling tools and languages

High complexity of updating the model when there are changes during the project

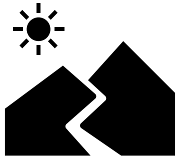
Practitioners and management perception that the investment required to build and maintain the model outweighs the expected benefits

Main causes of the problem (Cont.)

Regulation demand for "document signature" pushes back to a document driven culture (e.g. Medical devices, Automotive, Aerospace)

A widening cultural gap between SW and Systems Modeling:

- In Software Development , "UML is not the default option for modeling"…. "textual modeling tools are blooming"…. From a Note published by Prof. Jordi Cabot, 20/9/2021: https://www.linkedin.com/posts/jcabot_uml-activity-6845600165596819456-CqSb
- Agile SW development values Crafting above Engineering (e.g. Jacobson, Spence and Seidewitz Industrial Scale Agile - from Craft to Engineering (2016) https://queue.acm.org/detail.cfm?id=3012428
- Are we experiencing a rift between It/ Web and Cyber Physical MBD ?



Promising New Directions

- Improvements in Tools Usability
- “Agile” MBSE for CPS
- Digital Twin Implementation

Recent Tool and Methods Usability Improvements

MATHWORKS company recognizes the problems and opportunity for system development including SYSTEM COMPOSER

First version distributed for use in 2019

Many members of the OMG consortium identify the problem and initiate in 2017 a new initiative for SysML v2.

In 2019, at HIT, we jumped back into the "research subject pool" with the help of the new generation of tools.

Research by M.Sc students Avi Zaguri and Lior Mantin

Tools and methods selected:

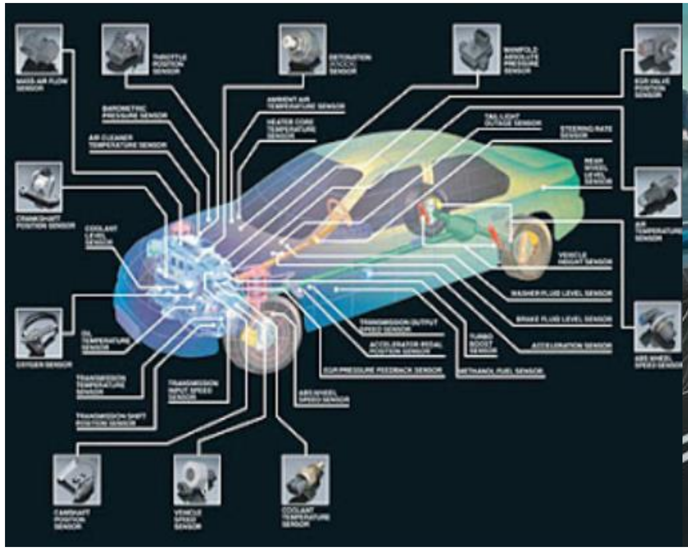
- Modeling tools: System Composer and Enterprise Architect
- Modeling Methods/languages: ECSAM and SysML
- Diagram tools: Visio

The relationships between the languages / methods of the modeling tools and the drawing tools that researched:

1. System Composer with ECSAM
2. Enterprise Architect with SysML
3. Visio with ECSAM

" 360-degree Car Damage Monitoring"

"360-degree car damage monitoring" - a high-complexity integrated system with sub-systems with medium / high complexity



"Smart train carriages management"

"Smart train carriages management" - an integrated system with medium / high complexity with many identical subsystems with low complexity

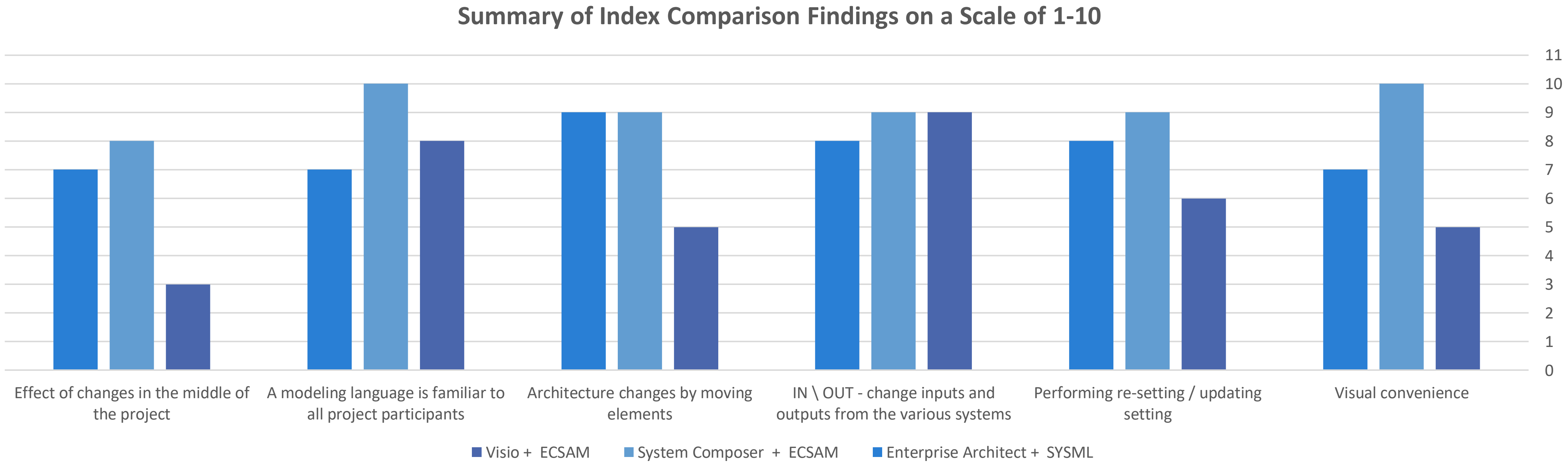


Indicators for examining research questions

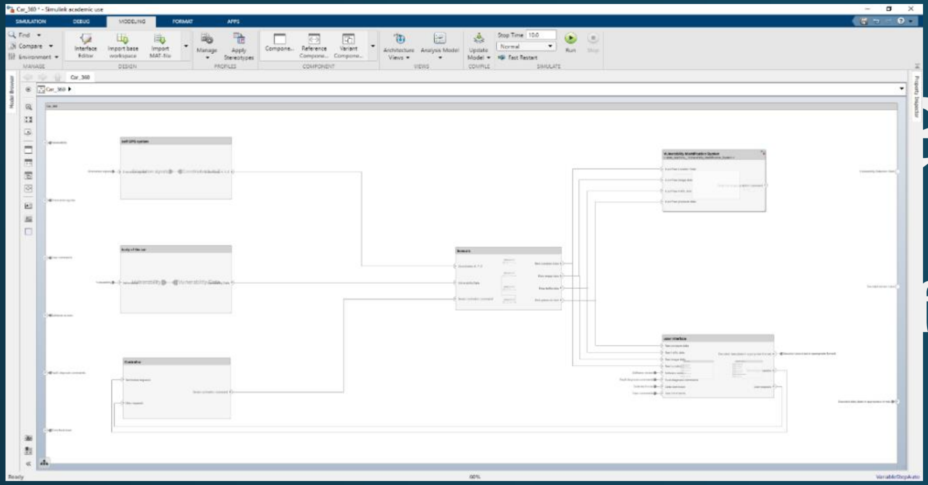
INDICATORS	WEIGHTS
VISUAL CONVENIENCE	20%
PERFORMING RE-SETTING / UPDATING SETTING	20%
CHANGE INPUTS AND OUTPUTS IN THE VARIOUS SYSTEMS - IN \ OUT	10%
ARCHITECTURE CHANGES BY MOVING ELEMENTS	10%
A MODELING LANGUAGE IS FAMILIAR TO ALL PROJECT PARTICIPANTS	10%
EFFECT OF CHANGES IN THE MIDDLE OF THE PROJECT	30%

Simulation Capability

Summary of research results



תוצאת סיכום מדדים משוקלל	כלי ושיטה
9	System Composer + ECSAM
7.5	Enterprise Architect + SysML
5.3	Visio + ECSAM



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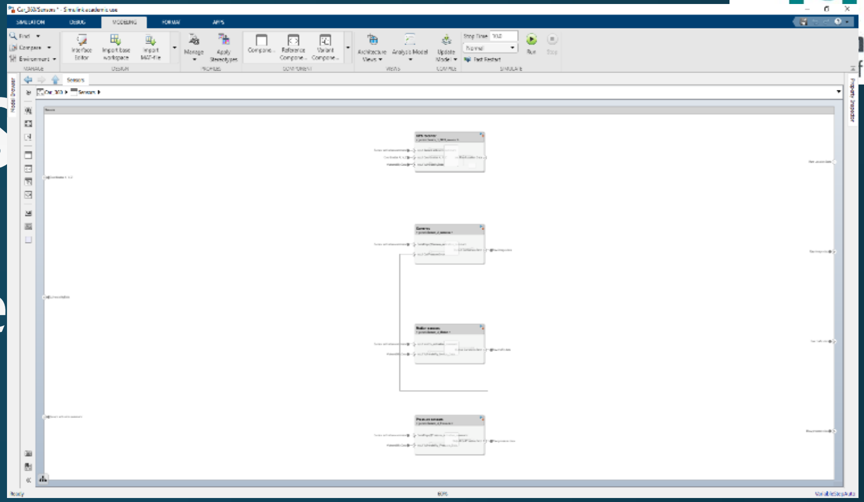
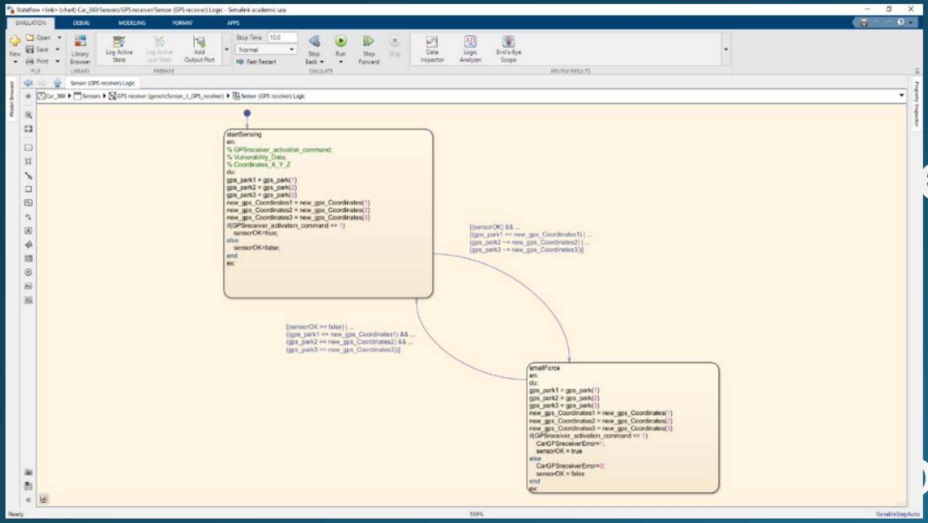


- Complex simulation capabilities, with capabilities for analyzing, building models, and running simulations in a simple way



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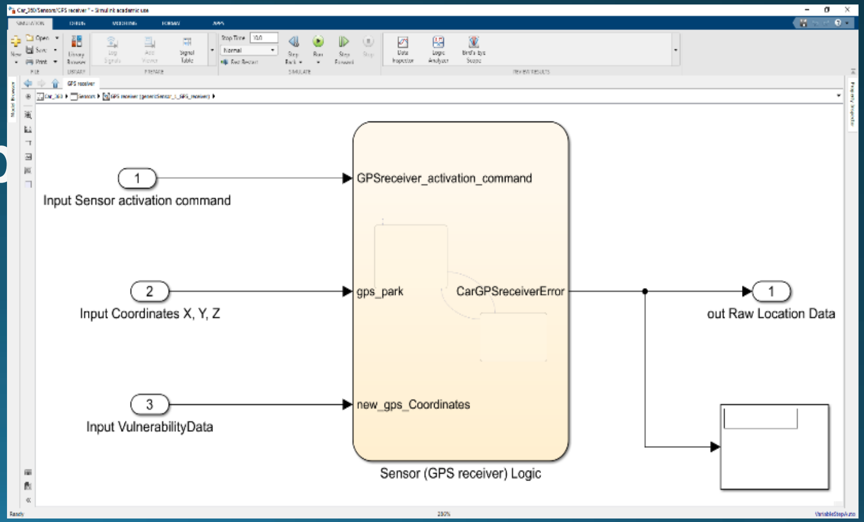

Main Conclusions of the Research

There was no need for a special tool use course

The usability of emerging modeling tools makes it possible to reduce the investment time in "free drawings"

Working with a single modeling tool-set that includes all aspects enables overall system modeling as well as detailed components modelling and integration

The objective to perform systemic simulations, as comprehensive as possible, as early as possible in the project, using automation is close at hand

There is a great chance of assimilation in industry in complex projects - further research is planned and collaboration with industry

Promising Directions

- Improvements in Tools Usability
- “Agile” MBSE for CPS
- Digital Twin Implementation

“Agile” CBS Engineering Modelling Tips

- Use what's useful (“light” modelling) :
  - "Choose the cherries in the basket" (Pick and choose what to model)
  - Address partial views of the models (“One at a time”)
- Create Executable Models:
  - Continuos Modelling, Simulation, Model Testing and Correction
  - Automatic SW / HW generation for critical components
- Recently published book:

B. P. Douglass Agile Model-Based Systems Engineering Cookbook – March 2021

https://www.packtpub.com/product/agile-model-based-systems-engineering-cookbook/9781838985837

Digital Twins as a Catalyst for MBSE

A digital twin is a virtual representation that serves as the real-time digital counterpart of a physical object or process

The definition of digital twin originated from NASA to improve physical model simulation of spacecraft in 2010 . https://en.wikipedia.org/wiki/Digital_twin

“digital twin technology can be expected to become a central capability in MBSE …. Specifically, digital twins can be exploited in upfront engineering (e.g., system conceptualization and model verification), testing (e.g., model-based system validation), maintenance and smart manufacturing.” Leveraging Digital Twin Technology in Model-Based Systems Engineering. Azad M. Madni et al. 2019. https://www.mdpi.com/2079-8954/7/1/7/htm

Questions

Thank you for the attention !

Dr. Michael Winokur, michaelw@hit.ac.il