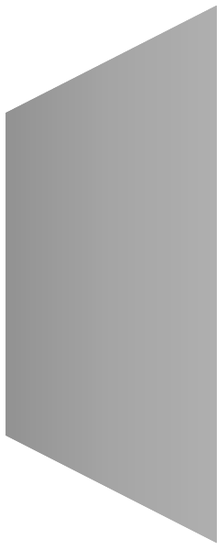
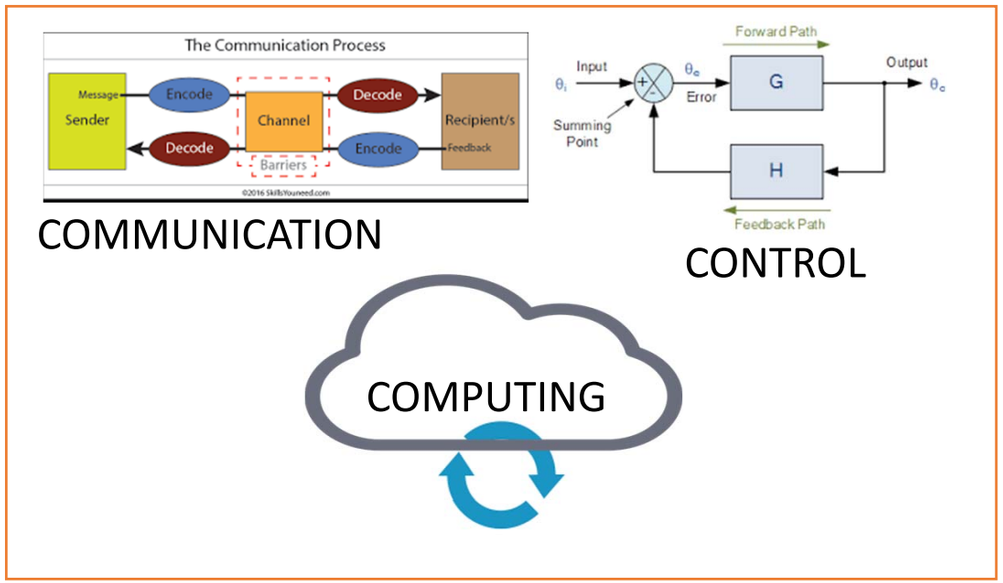
Cyber Physical Systems| Introduction, Foundations & Considerations

Presentation

CYBER

PHYSICAL





Agenda

Introduction | Evolution | Foundations | Views | Considerations | Summary

Abhilash Gopalakrishnan

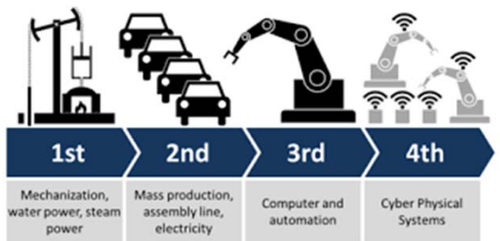
Source:
Picture -

Cyber Physical Systems| Drivers

The Need

Forces driving revolution

Medical Devices	*Smart Manufacturing*	*Smart Cities*	*Autonomous Vehicles*	*Cloud Computing*	*Internet Of Things*	*Artificial Intelligence*	*Modelling & Simulation*



Applications in Industry 4.0, Smart Grids and Smart Cities

The shift from centralized to more distributed styles is evident in Smart Grids, Industry 4.0, Industrial internet and IoT, Society 5.0. Its about best of Centralized and Distributed Architectures thus leading to better solutions.

Key Number

- 50 Billion Connected Devices by 2020
- More devices than people- More M2M

" Software Systems have passed through five ages corresponding to each decade starting from 1980 towards Intelligent, Connected system in 2020 " – Eoin Woods.

Distributed Architectures are central to the revolution

Cyber Physical Systems| Examples

Learning from Examples

AN AIRBAG

Correct instructions to execute wen system detest crash.

The instructions need to be completed within 20ms so as to ensure airbag is fully inflated before the driver hits the steering wheel

AIRCRAFT SYSTEMS

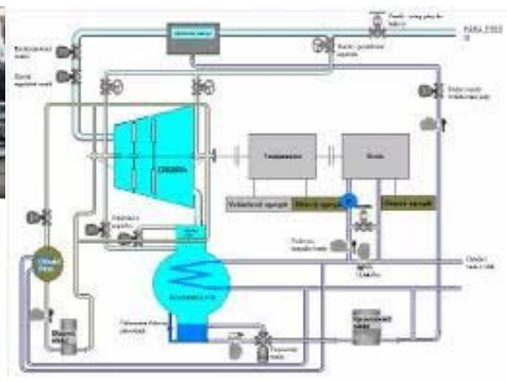
The Charge discharge of batteries needs to be controlled so as not to prevent overheating of the battery.

Battery overheating can lead to fire. The system needs to be certified by Aviation Authorities.

MEDICAL

Medical Systems is about safety and hence human critical.

Cyber physical systems can support continuous remote monitoring of ailing patients and also support possible chances of medical errors due to high mental workloads



TURBINE CONTROL

Need to ensure the load to handle turbine.

Conditions are analysed and load conditions ensured and acted upon in terms of turn around time of 20 milliseconds.

'CPS are engineered systems that are built from and depend on seamless integration of computational algorithms & physical components.'– NSF

Cyber Physical Systems| Evolution

Systems Existed, What has changed?

Computer Science

Physical Sciences

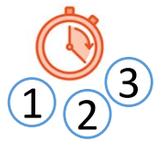
Followed Independent Paths and abstracted away behaviours important into one discipline and not relevant in another

Timeless Nature of Programming

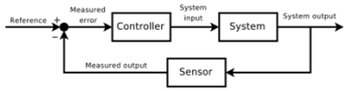
Importance of Time in physical processes

Associate time to computing elements

Scheduling Theory



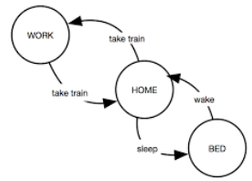
Control Theory



Keep system parameters in region (set point)

As complexity of interactions between domains increase, that led to new techniques of Modelling these as Hybrid Systems

Hybrid Systems



States model computational & physical state.
Transitions model computation actions & physical evolutions

Many Disciplines Involved

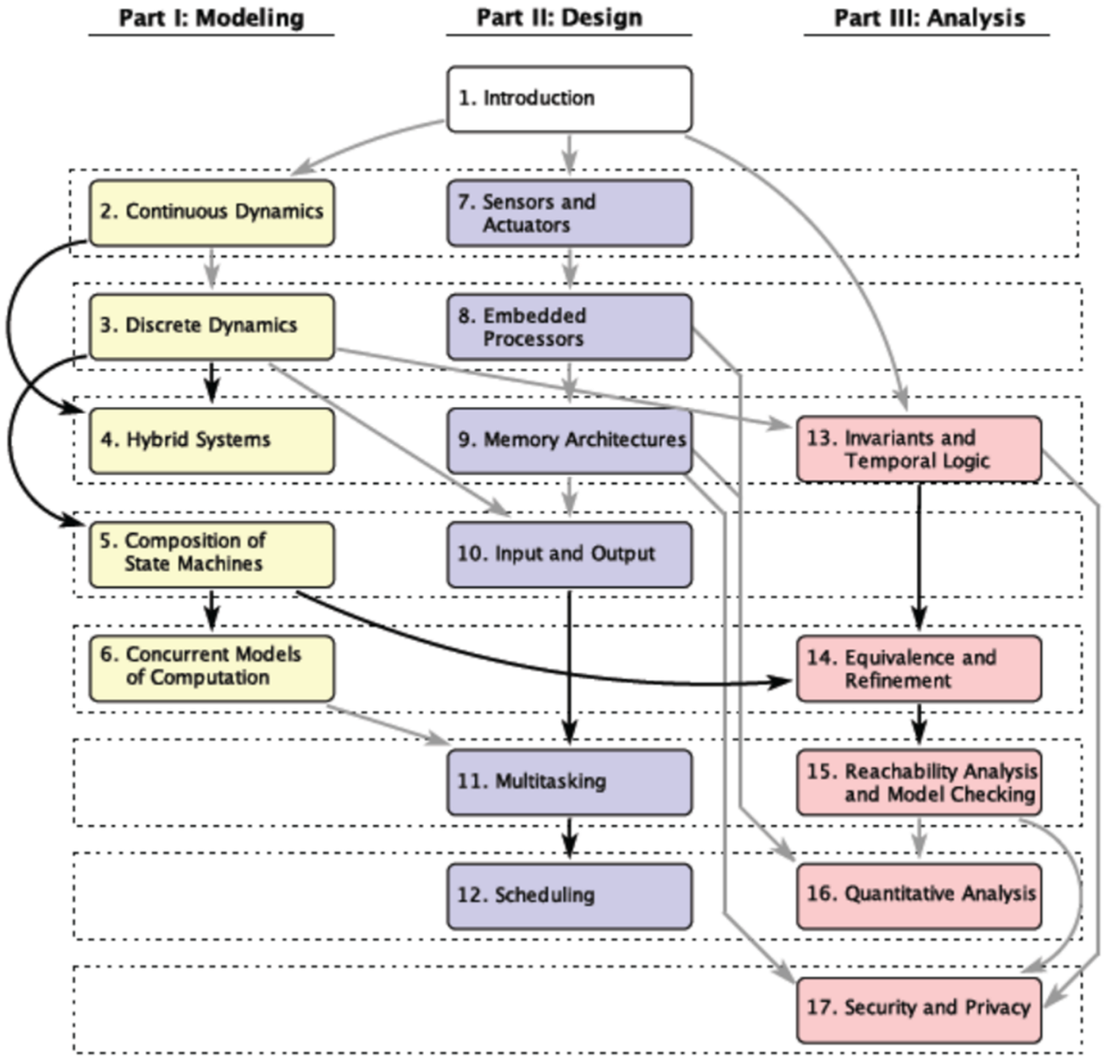
Functional | Aerodynamics | Thermal | Mechanical

The interactions across disciplines need to be analyzed as to ensure the assumptions of each discipline and modes are not invalidated by the other discipline and its modes. The challenge is to understand their behavior, develop techniques to verify their reliability, security, safety.

Two drivers involved are applications and theoretical foundations!

Cyber Physical Systems| Modelling Design and Analysis

Foundations



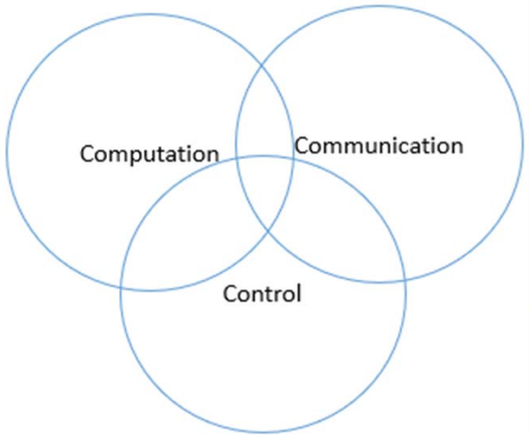
One view of Cyber Physical Systems involve the Modeling, Design and Analysis which considers:

2. *Continuous Dynamics*
3. *Discrete Dynamics*
4. *Hybrid Systems*
5. *State machines composition*
6. *Concurrent computation*
7. *Sensors and Actuators*
8. *Embedded Computing*
9. *Memory*
10. *Input and Output*
11. *Multitasking*
12. *Scheduling*
13. *Temporal Logic*
14. *Equivalence and Refinement*
15. *Reachability and Model checking*
16. *Quantitative analysis*
17. *Security and Privacy*

Several Considerations as part of CPS

Cyber Physical Systems| A Practitioner View

Convergence of Computation, Control and Communications



Characteristic	Systems	IT Applications
Time to market	1 Year and reducing	Much less, even in the range of months
Target Market	Specific market segments driven by reliability and cost factors	Targeted at applications more to improve productivity.
Expected Lifetime	10-30 years	1-5 years
Relevant owners	Phase wise owners from operator, engineer, end customer, decommissioning engineer	Owners could vary across projects.
Legacy support/Backward Compatibility Requirements	Strong requirements due to huge investments required	Weak requirements due to the fact that an IT implementation could reduce current operating cost.
Shutdown permitted	Shutdown only permitted as part of planned maintenance. Else could lead to losses	Shutdown is permitted within tolerance benchmarks.
Safety Critical	Yes, considering human lives and huge investments to be protected	Few implementations are safety critical, but not necessarily

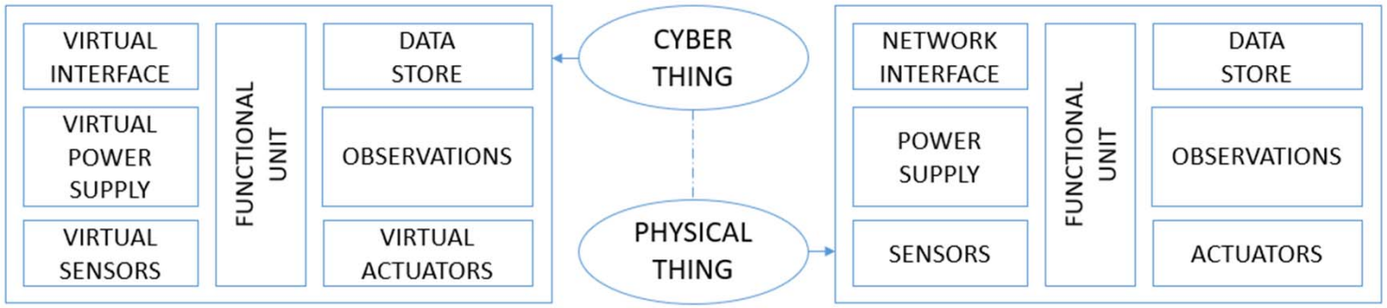
A more practitioner view includes the convergence of 3 Cs

1. *Computation*
2. *Control*
3. *Communications*

For example A CPS includes:

Cyber Thing
Physical Thing

The major elements include power supply, sensors, communication interface, data store, observations and actuators

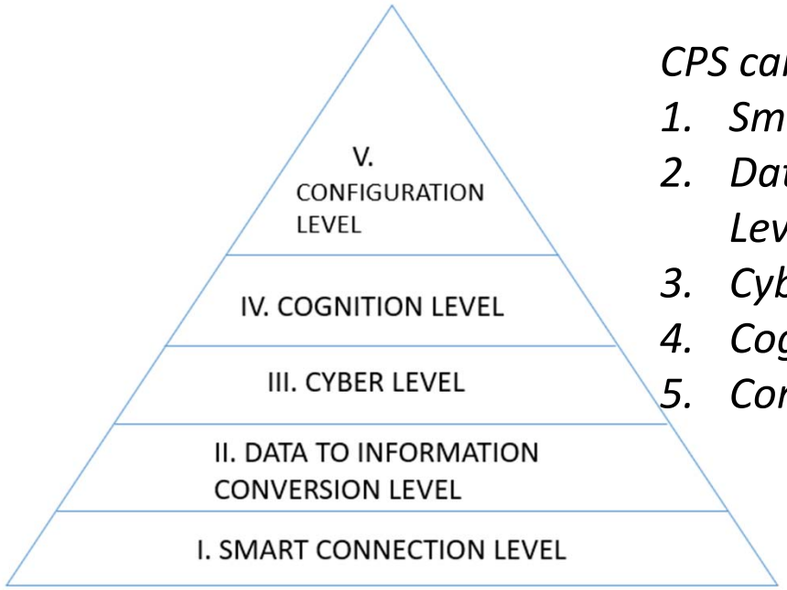


The challenges include interactions with humans. The physical state leading to information and these leading to decisions further translating to actions are the most important aspects of Cyber Physical systems seamlessly integrating both worlds.

A simplified view of CPS

Cyber Physical Systems| Considerations

Major role in evolution of Systems

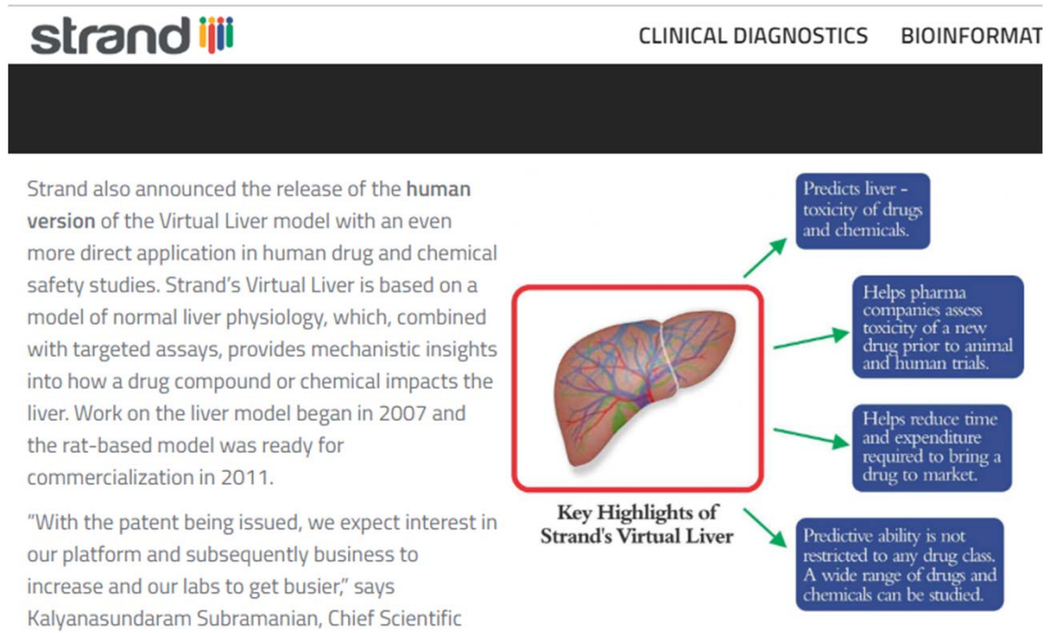


CPS can be seem as multiple levels

1. *Smart Connection Level*
2. *Data to Information Conversion Level*
3. *Cyber Level*
4. *Cognition Level*
5. *Configuration Level*

The distributed system architectures including cloud computing, Internet of Things (IoT), and the improvements in machine learning and Artificial Intelligence has significant impact on these systems enabling faster evolution.

It is possible to also evolve and validate the models with support from machine learning and a high level of cognition is required for interaction with humans and also with other systems thus enabling more autonomy.



Virtual Lever Model from Strand Life Sciences

Taking Models outside of Labs as part of CPS

Cyber Physical Systems| Summary

Key take away

‘CPS are engineered systems that are built from and depend on seamless integration of computational algorithms & physical components.’– National Science Foundation.

Cyber Physical Systems considers significant elements of Modelling discrete, continuous and hybrid systems and considers embedded systems and signal processing considerations for control of systems. They involve a convergence of Computing, Communication and Control and considers Cyber things and physical things working together.

Technologies including cloud computing, Internet of Things (IoT), and the improvements in machine learning and Artificial Intelligence has significant impact on these systems enabling faster evolution.

The research challenges include Design considering reliability, A Systems Perspective, and Human considerations including safety and trustworthiness.

Interesting Projects
Ptolemy
4DIAC

Cyber Physical Systems| References

Books and Material

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