26th annual INCOSE international symposium
Edinburgh, UK
July 18 - 21, 2016

Emergent Failure Modes and What to Do about Them

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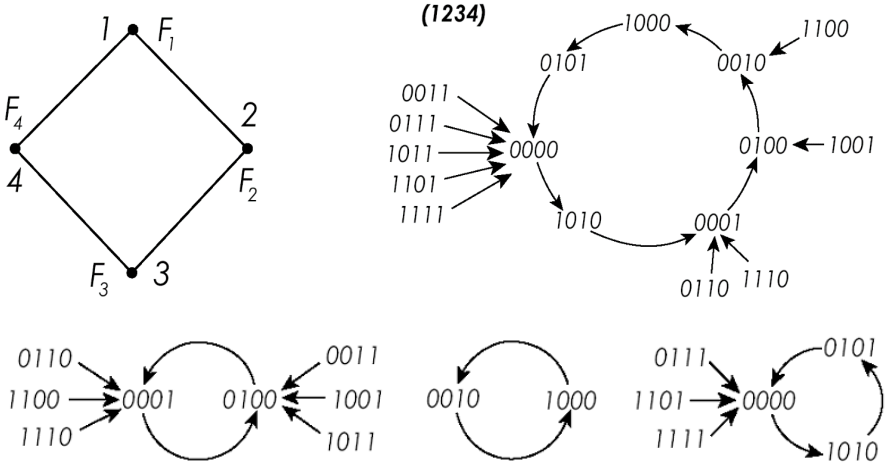
Emergence can be bad

https://www.google.com/search?q=super+bowl+power+outage&source=lnms&tbm=isch&sa=X&ved=0CAkQ_AUoA2oVChMI5MK7kLDRyAIVvCqeCh0TPwSX&biw=1366&bih=628&dpr=1.71#imgrc=XiOWlVhrFNqFsM%3A http://www.noaanews.noa

Emergence Happens!

$$\text{nor}_3(x_1,x_2,x_3) = \neg\ (x_1 \vee x_2 \vee x_3),$$



Start with the Fundamentals

- What is a system?
- What is knowledge?
  - How is computer knowledge different from human knowledge?
- Can a machine really think?
- What happens when you put humans and thinking machines together in a system?
  - How should we design such systems?
  - How can we test and evaluate such system?

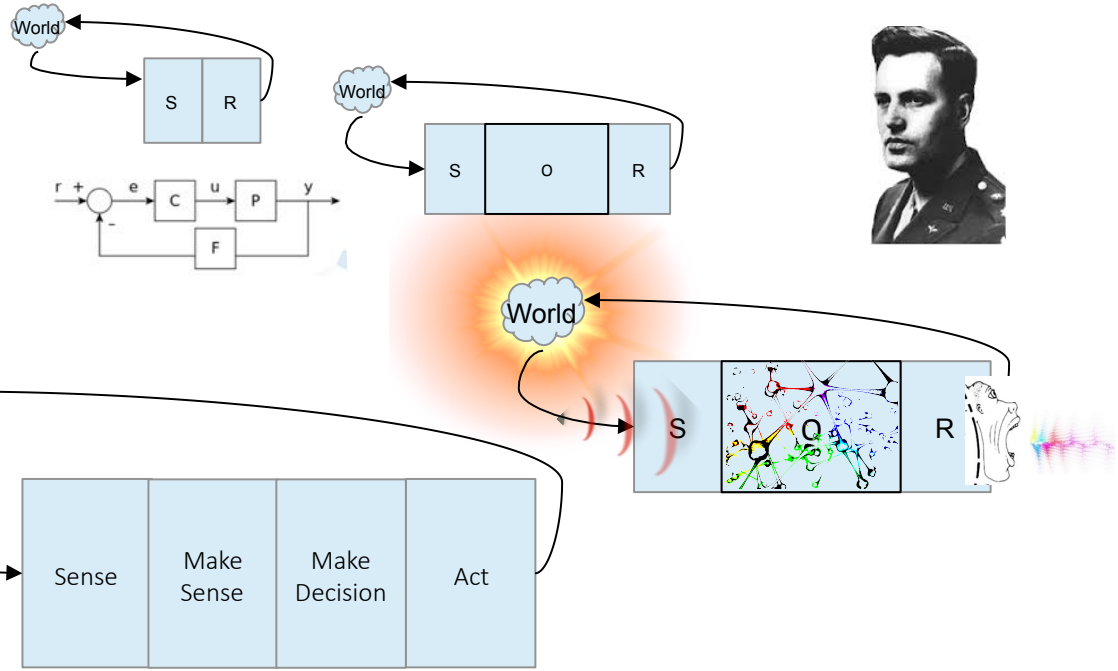
Definition of a System

- A collection of elements
- Interconnected
- Interacting
- Pursuant to a common principal or shared objective

A collection of interacting elements organized by a common principle, or pursuant to a common objective

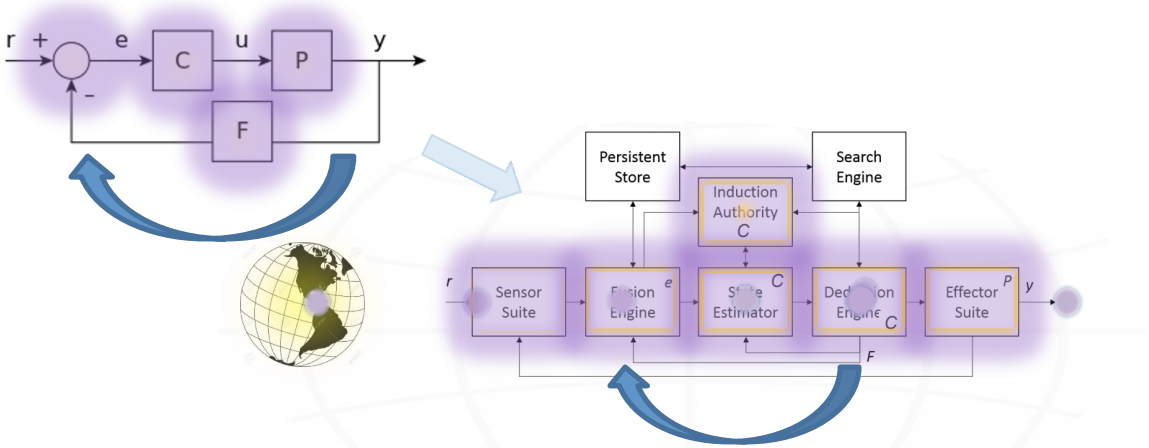
Paraphrased from definitions on INCOSE website

Evolution of Control Theory



Process *taxonomy*

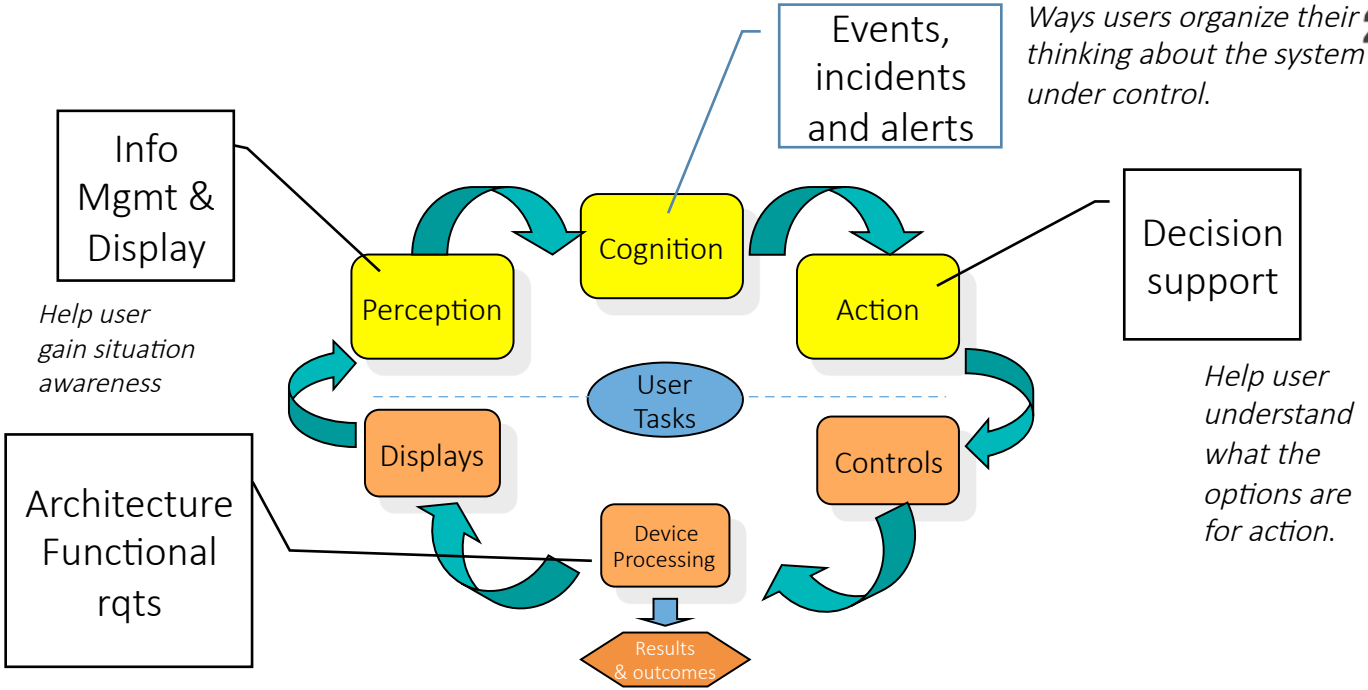
Control Theory



Intelligent Control Theory

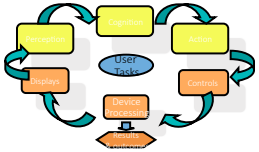
- If there are more parameters in the internal representation (model, simulation) than there are observables, we say *intelligence* is required/ demonstrated
  - *Something* is required to identify and estimate the parameters
  - Missing parameters are not deducible from sense data
- Theory of simulation meets the need for a theory of internal representation...Graph theory is the mathematical formalism

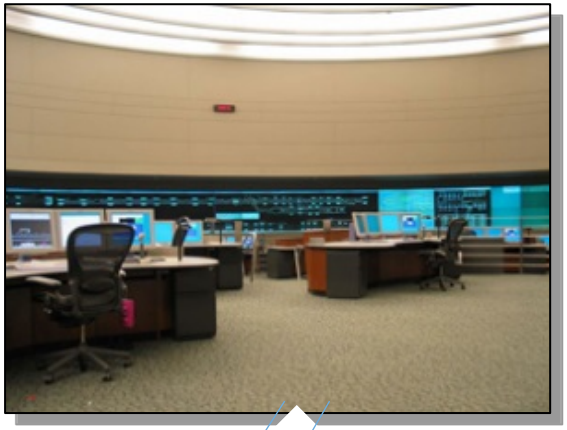
User-Device Interaction Model

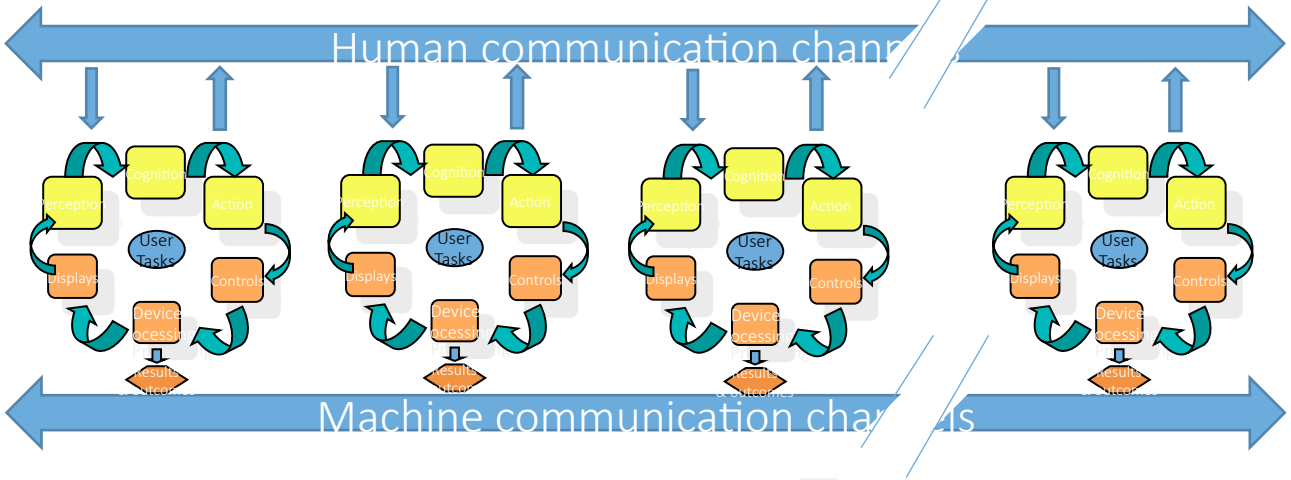


*After diagram by Robert A North, PhD, Human-Centered Strategies, LLC, based on FDA UPCARE model

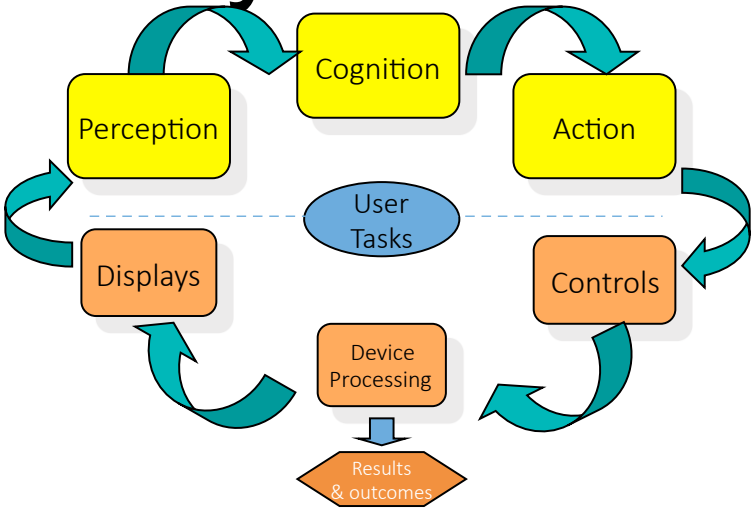
A Control Center is a *network* of

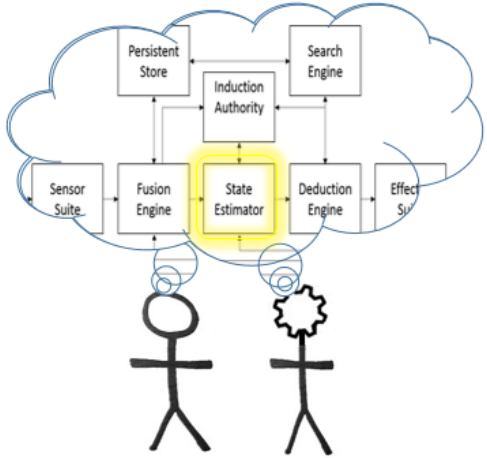


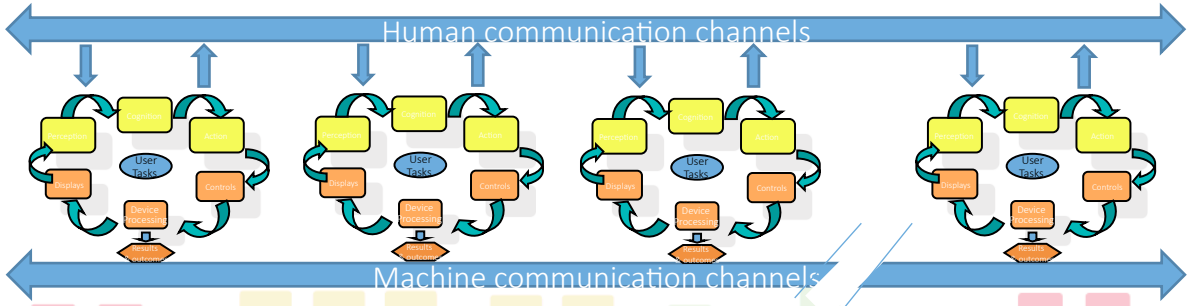




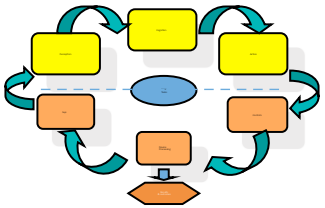
All Systems Look Like This

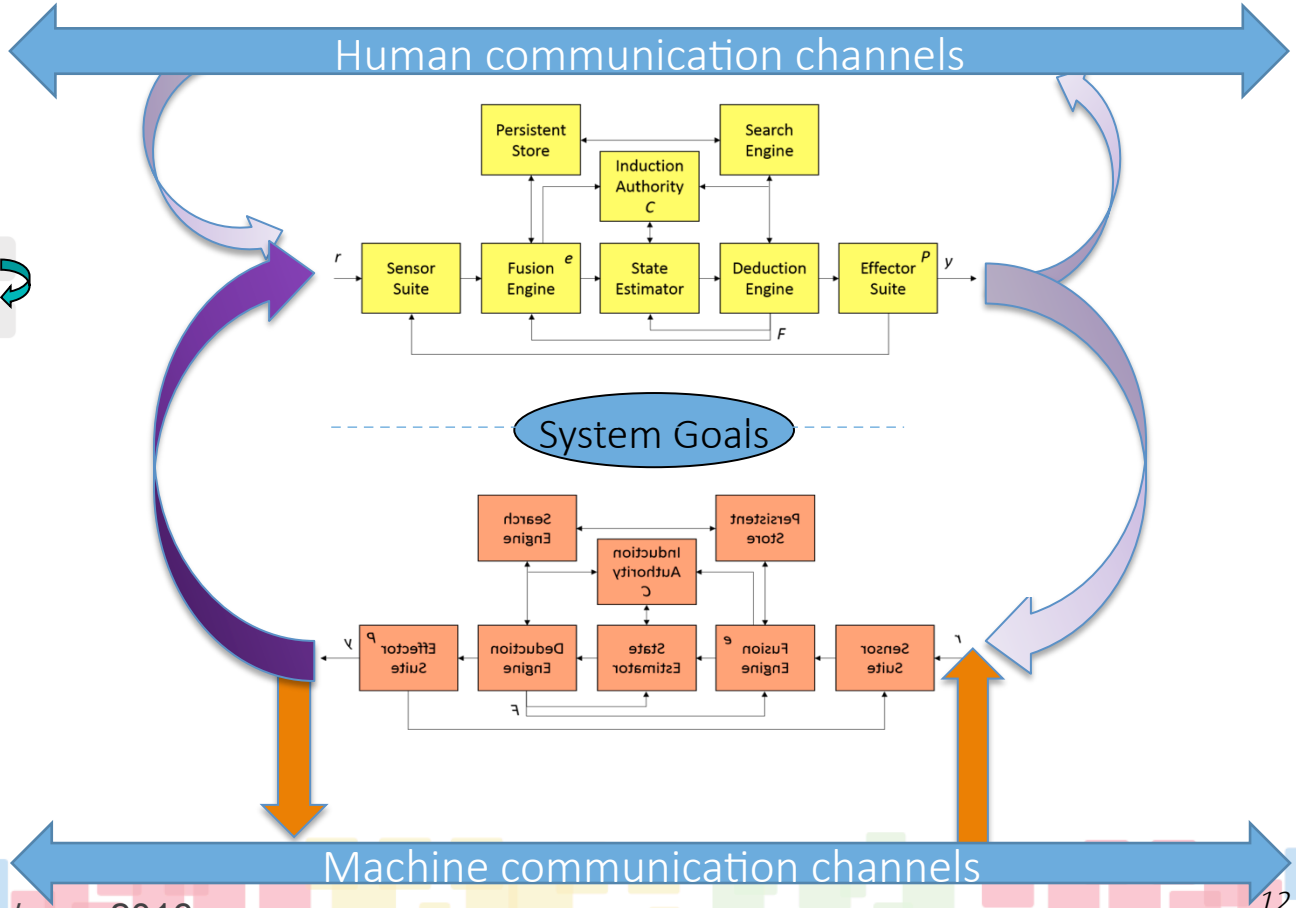






Model of User-Device Interaction





Human-System Function Allocation

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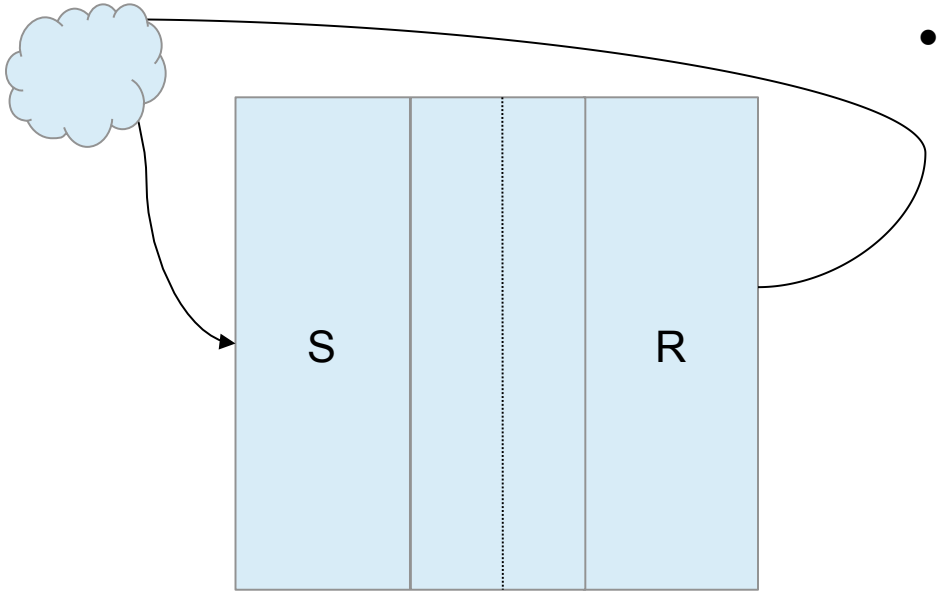

- Note that we have not specified the human or machine components in this depiction of closed-loop control, only the functional requirements
  - induction and deduction
  - internal representation (simulation)
  - estimates of missing parameters

Emergent Failure Modes

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- EFM are real artifacts of systems design and implementation.
- The analysis of complex systems (including SOA/SoS) shows the unpredictable and nearly inevitable character of EFM.

And what to do about it

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- Design systems so human and machine components work together
- Focus on representing where the human – machine entity is, relative to its goal
- Apportion control processes to human and machine components to exploit human strengths to detect, diagnose and redress emergent failures
- Assure that proposed system design conforms to Intelligent Control Theory process architecture

Control Theory