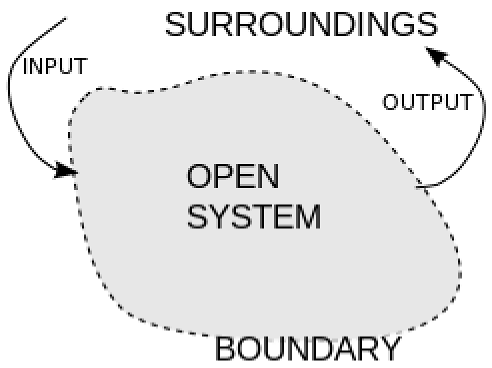
Applications of Artificial Intelligence

Dr. Animesh Chaturvedi
Assistant Professor: IIIT Dharwad
Young Researcher: Heidelberg Laureate Forum
Postdoc: King's College London & The Alan Turing Institute
PhD: IIT Indore MTech: IIITDM Jabalpur

Systems Engineering and Artificial Intelligence

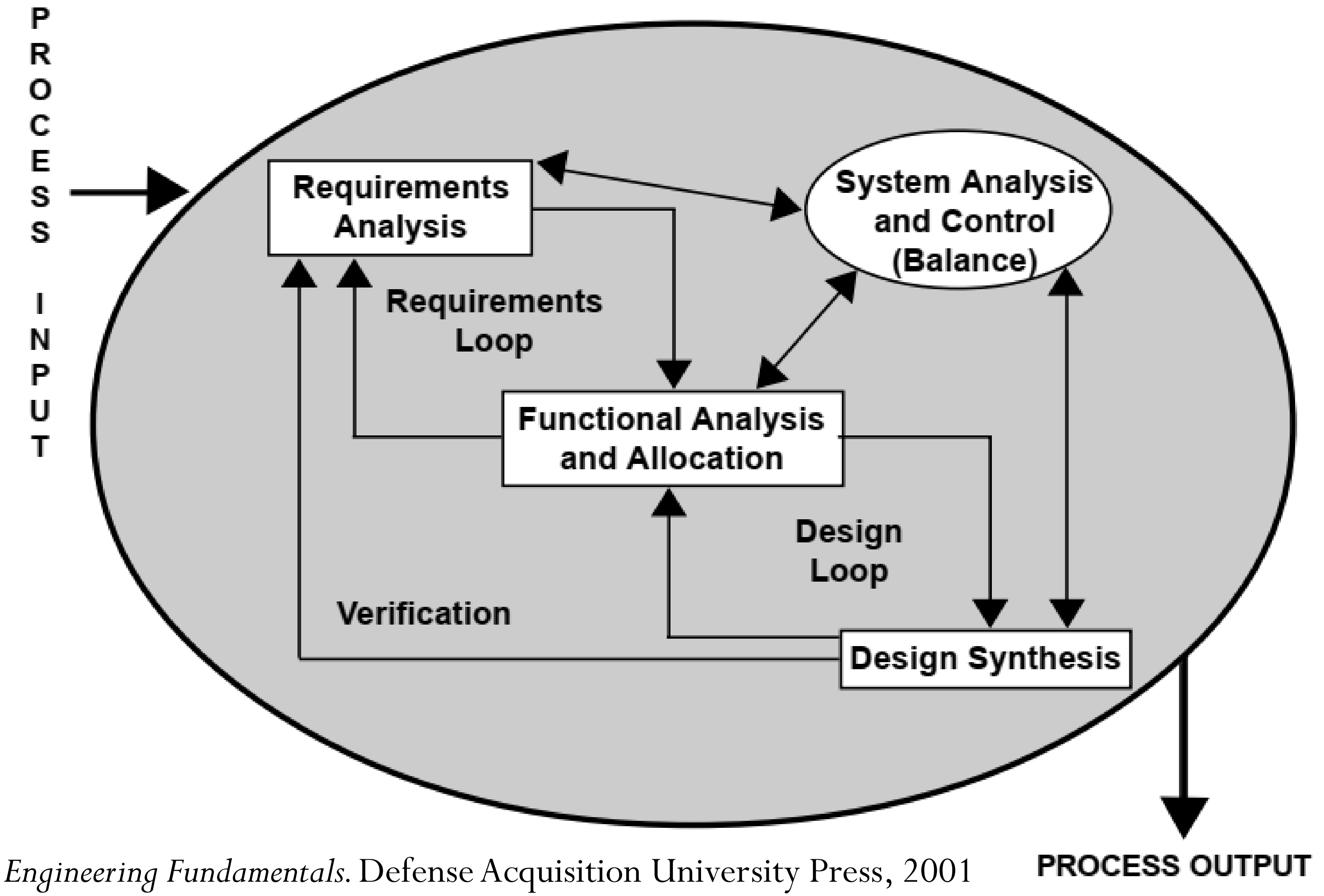
Systems Engineering

- An interdisciplinary domain
- Composed of many components (or entities) interacting with each other.
  - power grid, transportation or communication systems,
  - social and economic organizations (like cities),
  - organisms, a living cell, the human brain, and
  - an ecosystem, climate, entire universe.
- Behavior is hard to model with dependencies, relationships,
  - interactions between their components or
  - interactions between system and its environment



https://en.wikipedia.org/wiki/Complex_system

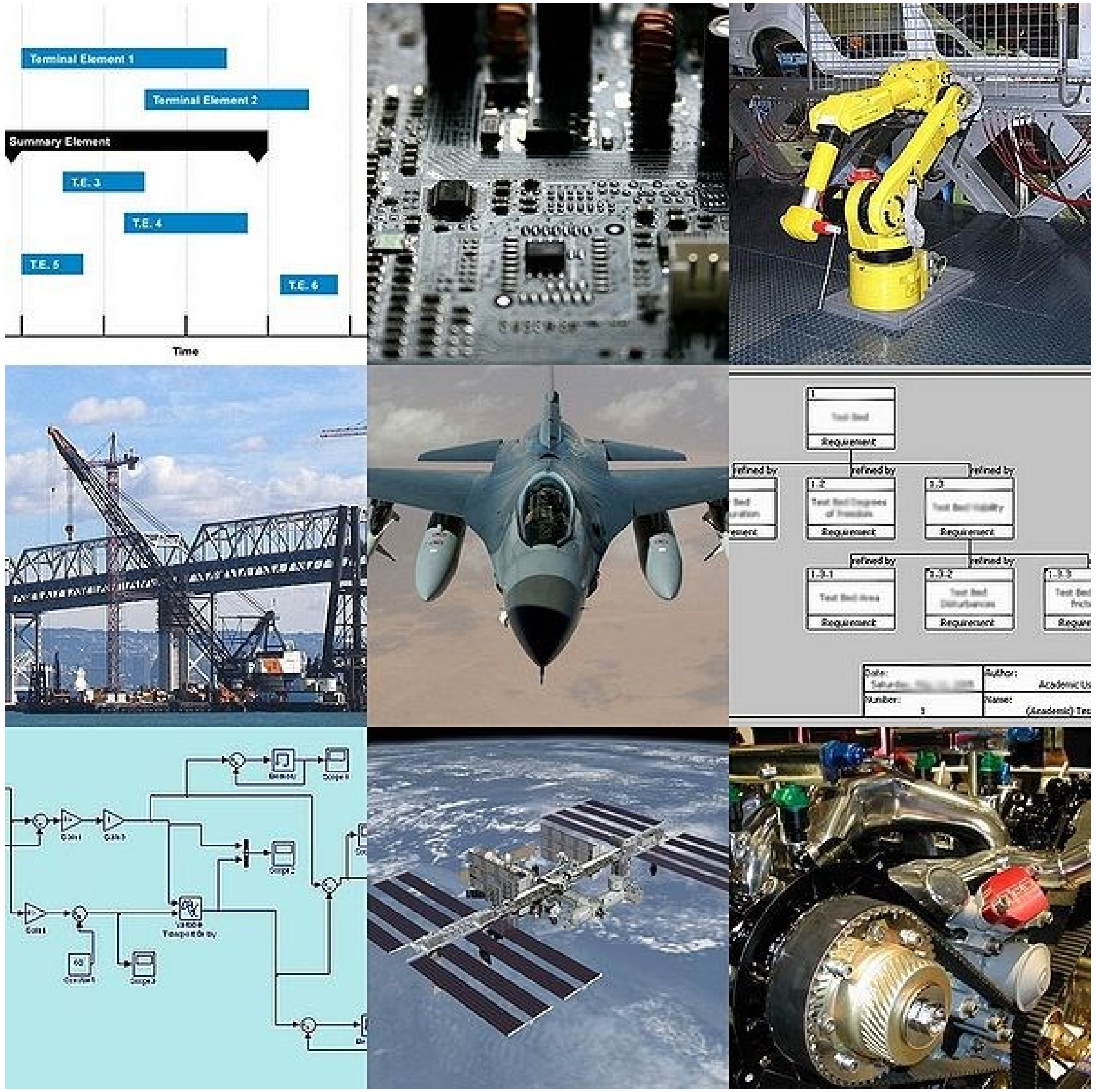
Systems Engineering Processes



[4] *Systems Engineering Fundamentals.* Defense Acquisition University Press, 2001

Systems Engineering Examples

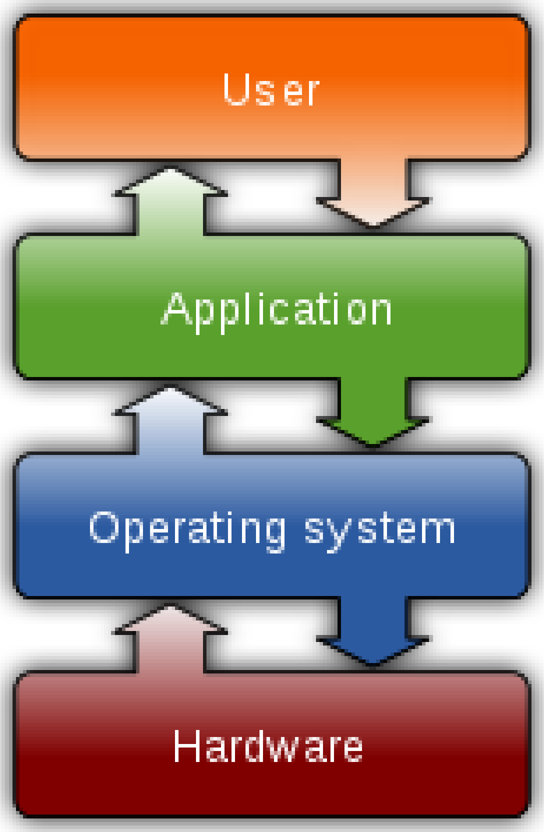
- Systems engineering helps in complex projects: spacecraft design, computer chip design, robotics, software integration, and bridge building.
- ➢ Modeling,
- ➢ Simulation,
- ➢ Requirements analysis,
- ➢ Scheduling,
- ➢ Manage complexity

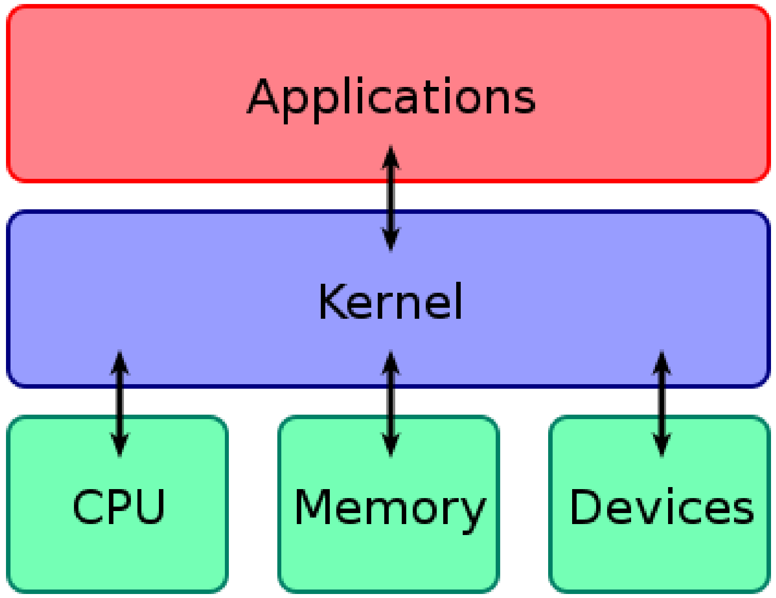


https://en.wikipedia.org/wiki/Systems_engineering

Systems Engineering Example: Operating system

- Kernel manages the connection between application software with the hardware of a computing machine.

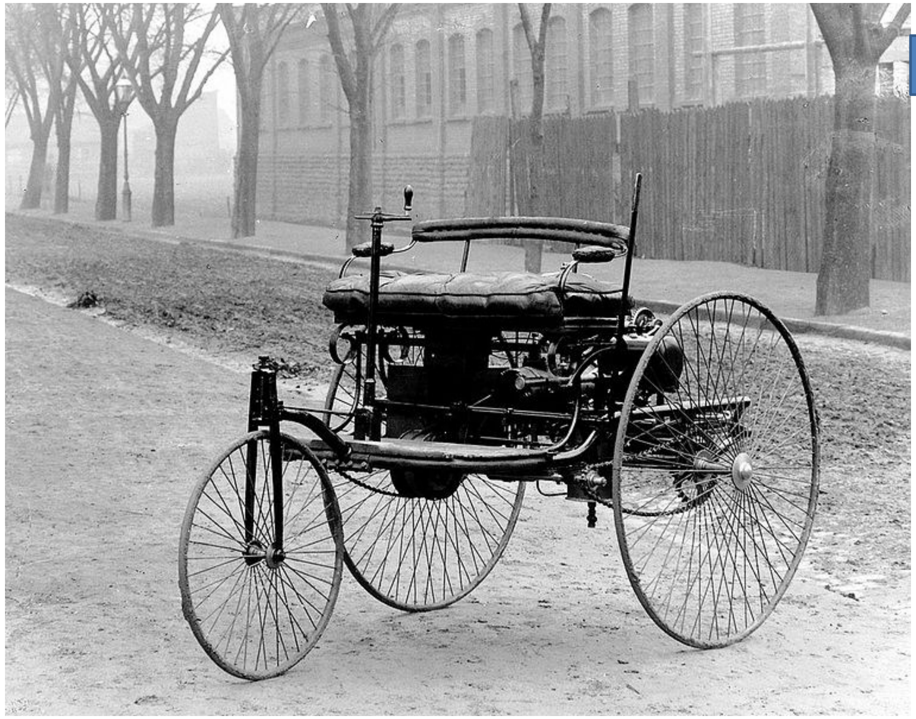




https://en.wikipedia.org/wiki/Operating_system

SysEng and AI: Automobile systems

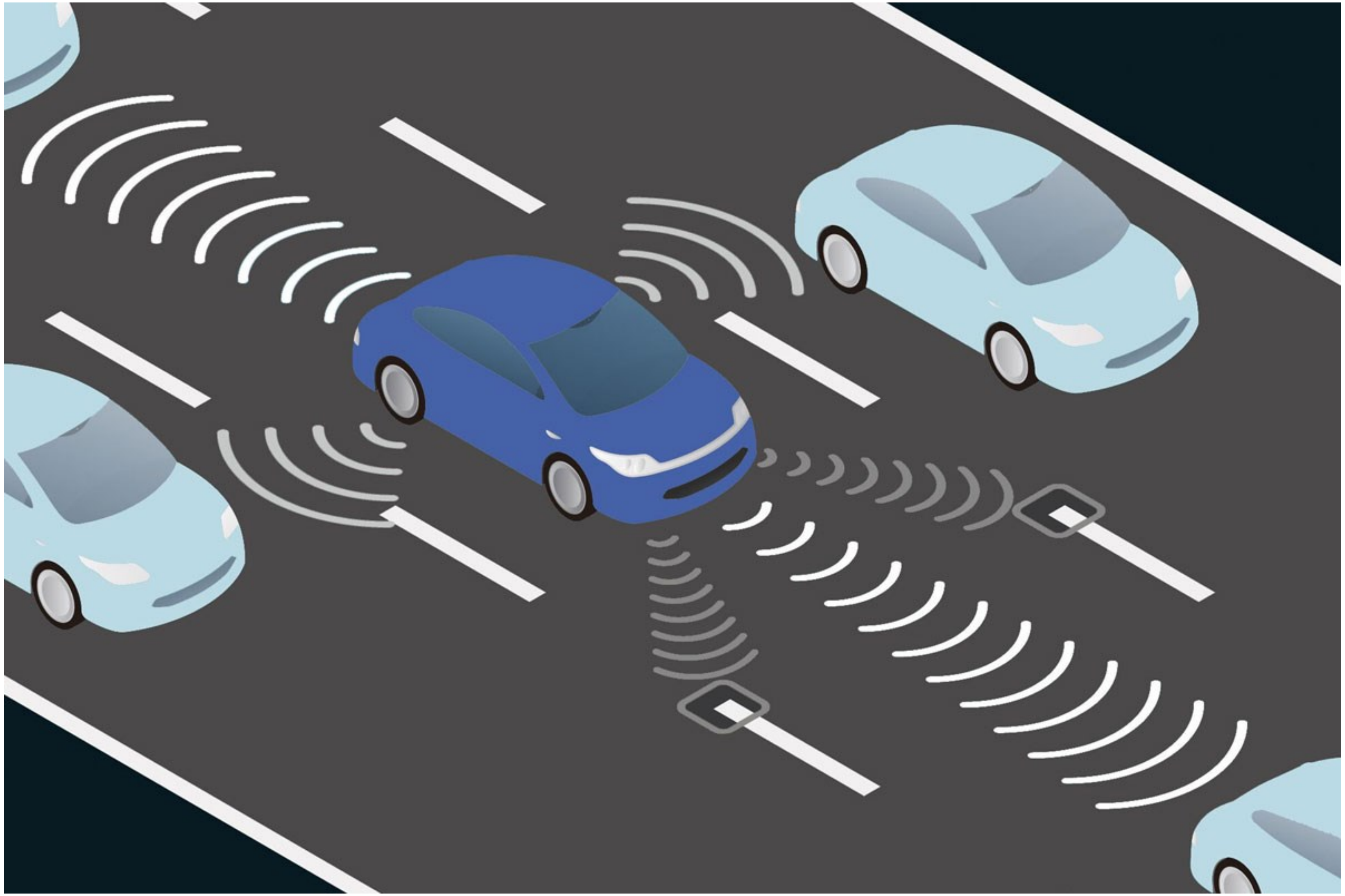
- Automobile systems from 1 engineer to 1000s of engineer working to built modern automobile



https://en.wikipedia.org/wiki/File:1885Benz.jpg

Autonomous Automobile Systems based on AI

Autonomous Automobile Systems based on AI



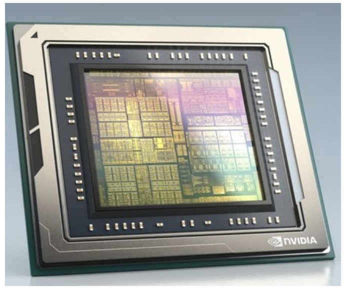
Autonomous Driving Cars based on AI

- aka. Self-driving car
- a vehicle that is capable of sensing its environment and moving safely with little or no human input.
- Self-driving cars combine a variety of sensors to perceive their surroundings, such as radar, sonar, GPS, odometry, and inertial measurement units.
- Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage.

- https://www.youtube.com/watch?v=tlThdr3O5Qo
- https://www.youtube.com/watch?v=0GnysB0rO3s

https://en.wikipedia.org/wiki/Self-driving_car

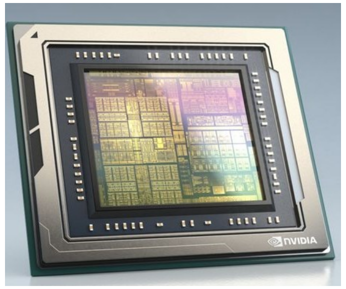
NVIDIA DRIVE AGX



- Software-Defined Platform for Autonomous Machines
  - **deep neural networks** run simultaneously in autonomous vehicles and robots
- The platform is powered by a new system-on-a-chip (SoC) called Orin, which consists of 17 billion transistors and is the result of four years of R&D investment.
- The Orin SoC integrates NVIDIA's next-generation GPU architecture and Arm Hercules CPU cores.
- deliver 200 trillion operations per second — nearly 7x the performance of NVIDIA's previous generation Xavier SoC.
- Orin is designed to handle the large number of applications (e.g. deep learning and computer vision)

https://nvidianews.nvidia.com/news/nvidia-introduces-drive-agx-orin-advanced-software-defined-platform-for-autonomous-machines

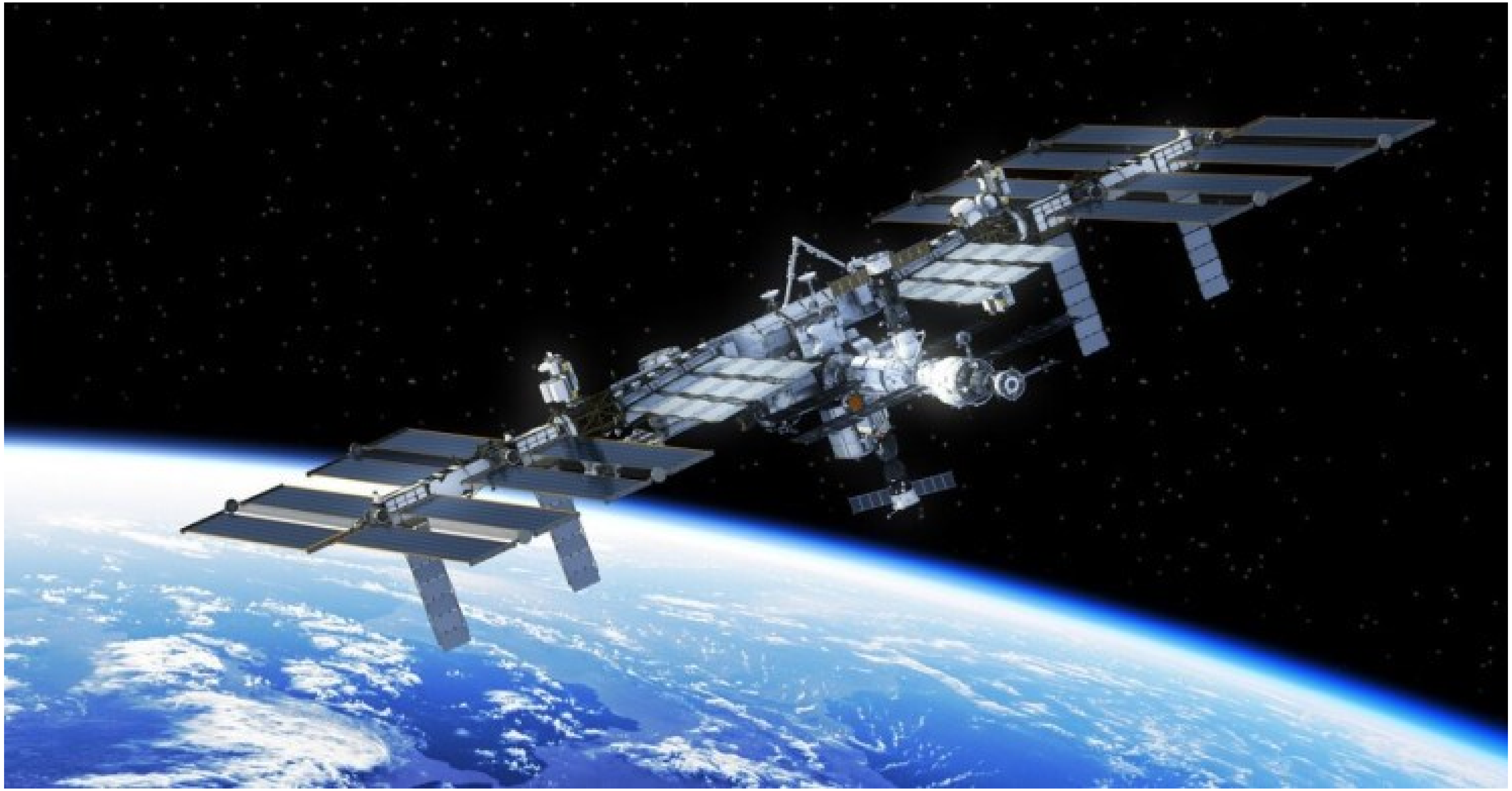
NVIDIA DRIVE AGX



- Developed to enable architecturally compatible platforms that scale full self-driving vehicle, enabling to develop large-scale and complex families of software products.
- "Creating a safe autonomous vehicle is perhaps society's greatest computing challenge," said Jensen Huang, founder and CEO of NVIDIA.
- "The amount of investment required to deliver autonomous vehicles has grown exponentially, and the complexity of the task requires a scalable, programmable, **software-defined AI platform** like Orin."

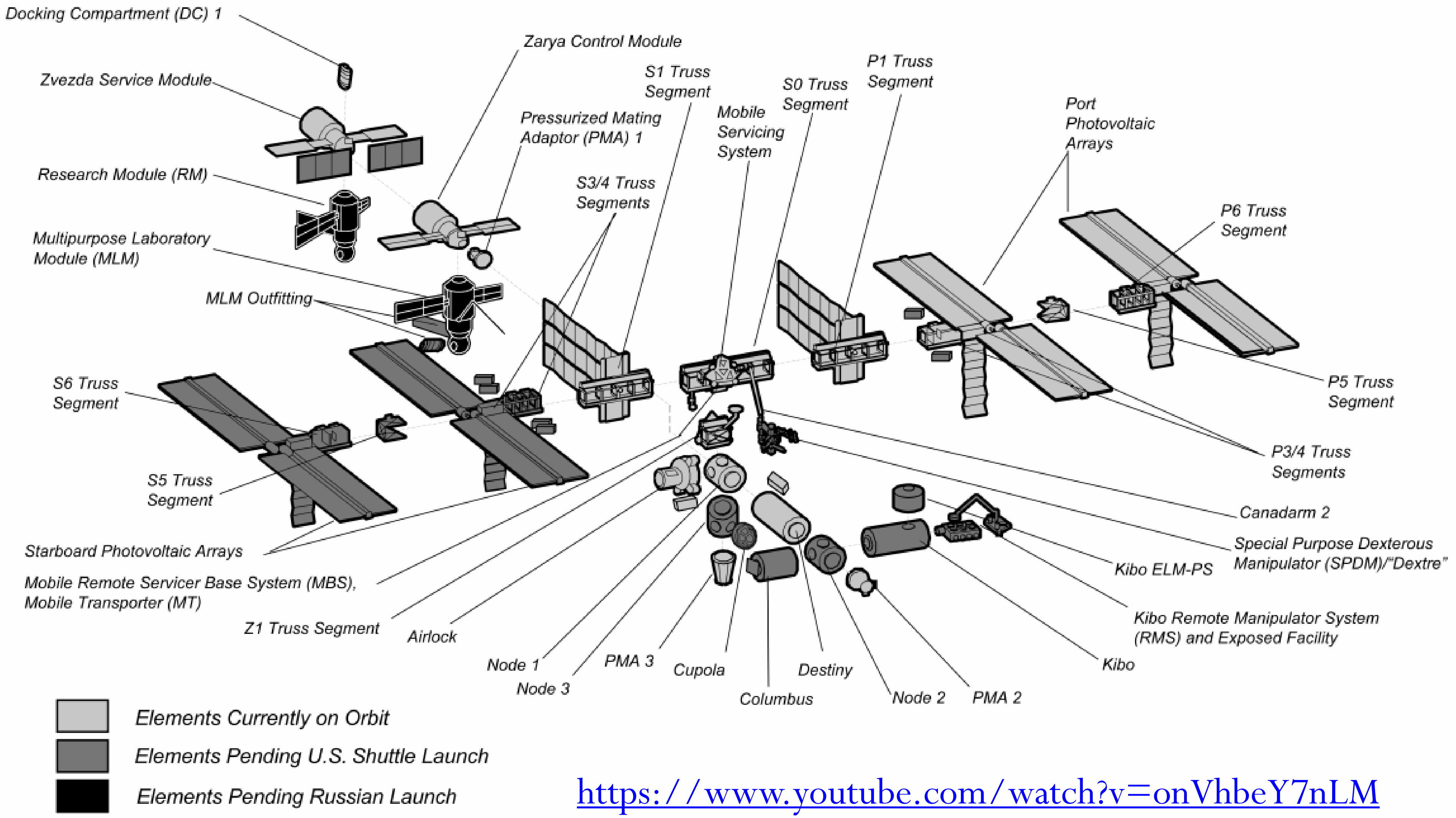
https://nvidianews.nvidia.com/news/nvidia-introduces-drive-agx-orin-advanced-software-defined-platform-for-autonomous-machines

International Space Station (ISS) uses AI



https://en.wikipedia.org/wiki/Systems_engineering

ISS Components uses AI



https://www.youtube.com/watch?v=onVhbeY7nLM

[7] *International Space Station Basics*, National Aeronautics and Space Administration (NASA).

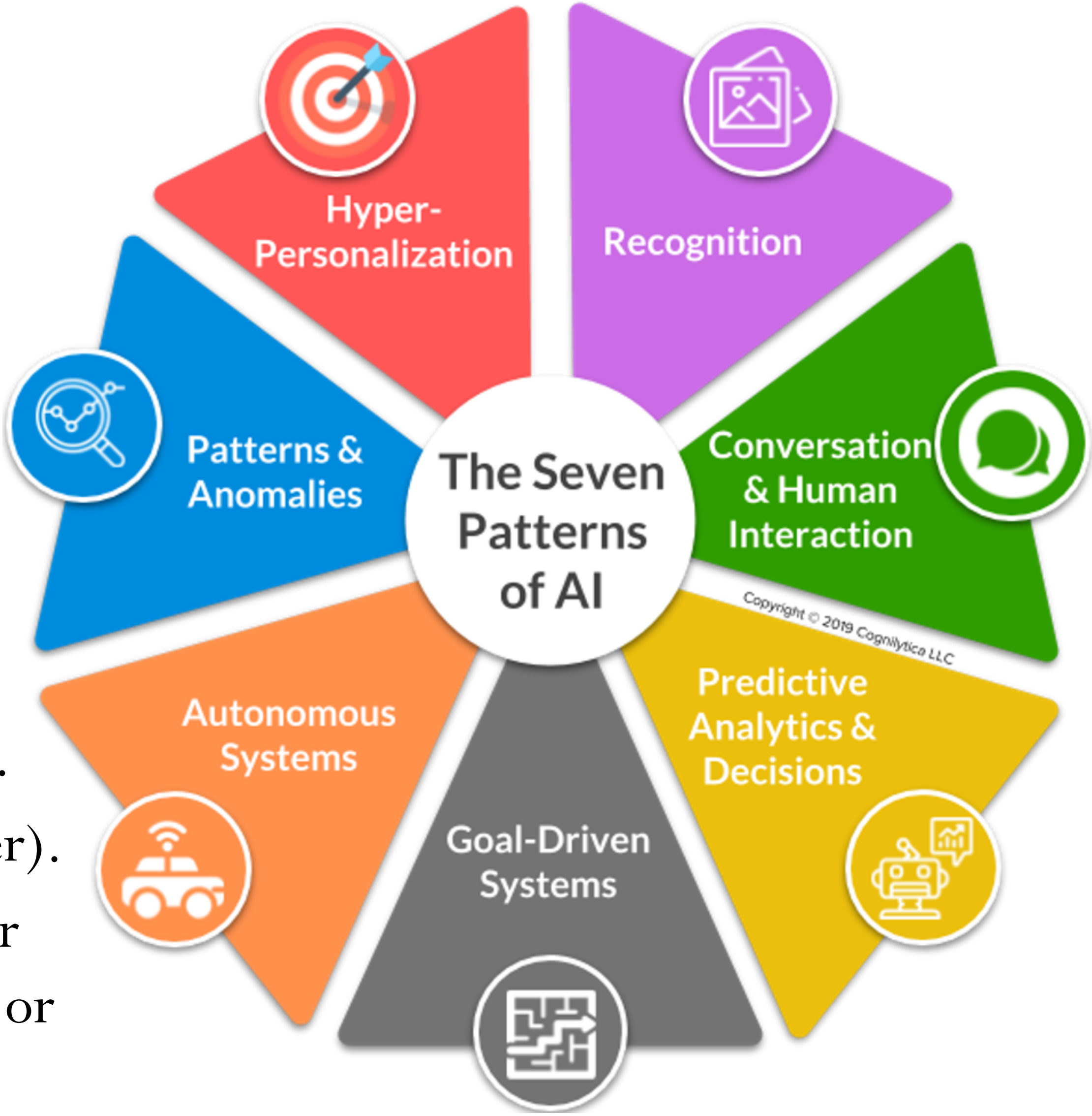
Drone to launch Satellite in space

- **Aevum** believes its **Ravn X drone**, which is said to be the world's biggest **drone**, is now capable of sending low-Earth orbit **satellites** into space
- https://www.youtube.com/watch?v=6YoKuObNPsw

Systems theory for AI

Systems theory and AI

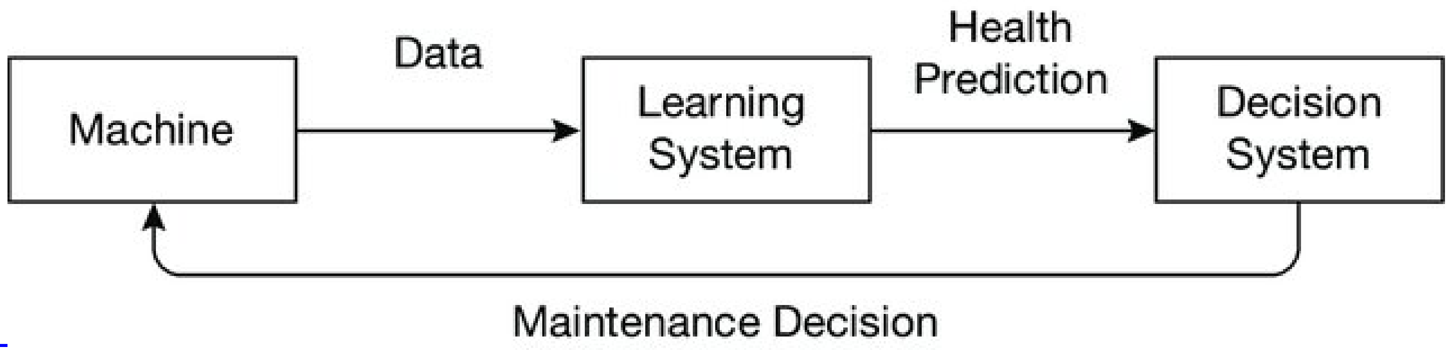
- Interdisciplinary study of interconnected component or entities, which can be natural or machine.
- System has following properties
  - It is bounded by space and time.
  - It gets influenced by its environment.
  - It has structure and purpose, and functioning.
  - It expresses Synergy (means working together).
  - It expresses Emergence (means properties or behaviors appears only when the component or entities interact).



https://en.wikipedia.org/wiki/Systems_theory
https://www.forbes.com/sites/cognitiveworld/2019/09/17/the-seven-patterns-of-ai/?sh=6823c87112d0

Systems theory and Machine Learning

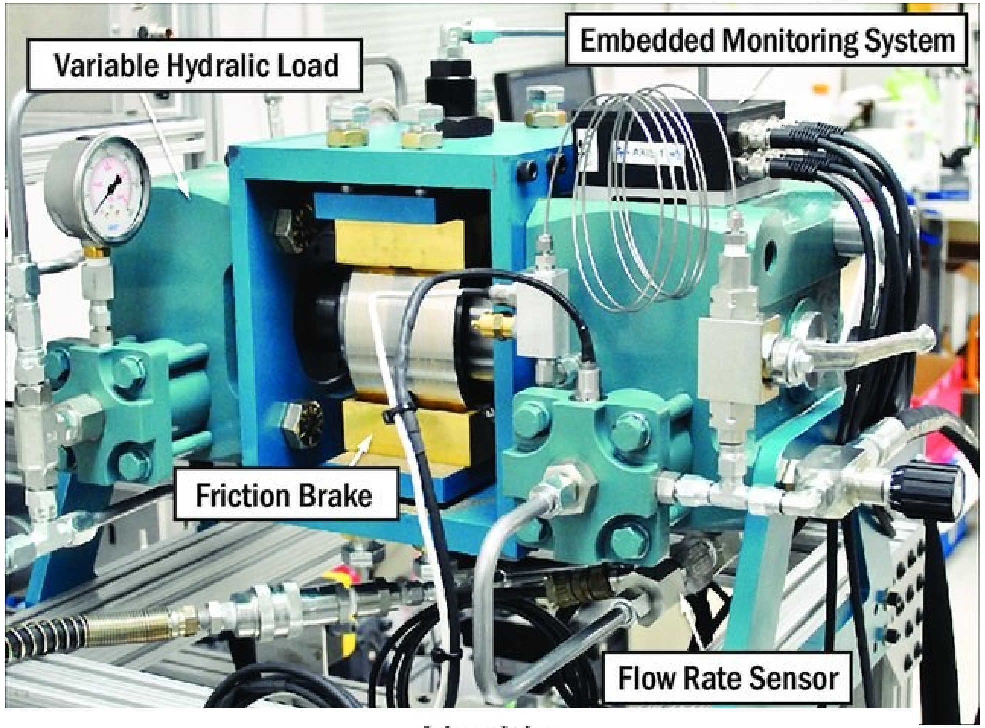
- It model a system's dynamics, constraints, conditions, principles (purpose, measure, methods, **tools**), and resource **optimization**.
- Change in a system’s component or entities may affect other entities or the whole system.
- **Predict** changes in patterns of behavior.
- System **learns and adapts** with its environment.
- Systems support and maintain other systems to prevent failure.

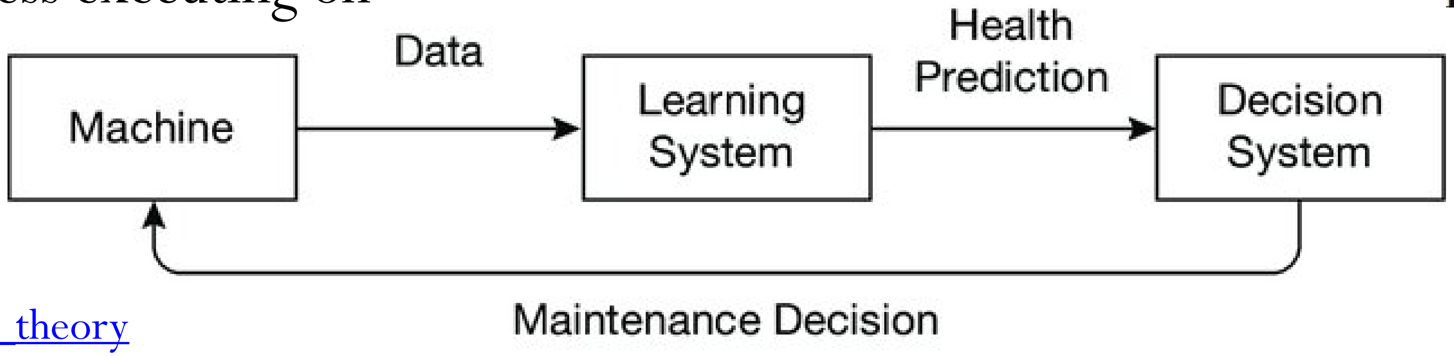


https://en.wikipedia.org/wiki/Systems_
Cody, Tyler, Stephen Adams, and Peter Beling. "Motivating a systems theory of AI." Insight 23.1 (2020): 37-40.

Dynamic/Active or Passive System

- Dynamic or Active systems has components that interact in behaviors and processes.
- Passive systems has components that are being processed.
- Example
  - a program/code file is passive and
  - same code is a active process executing on RAM and CPU.



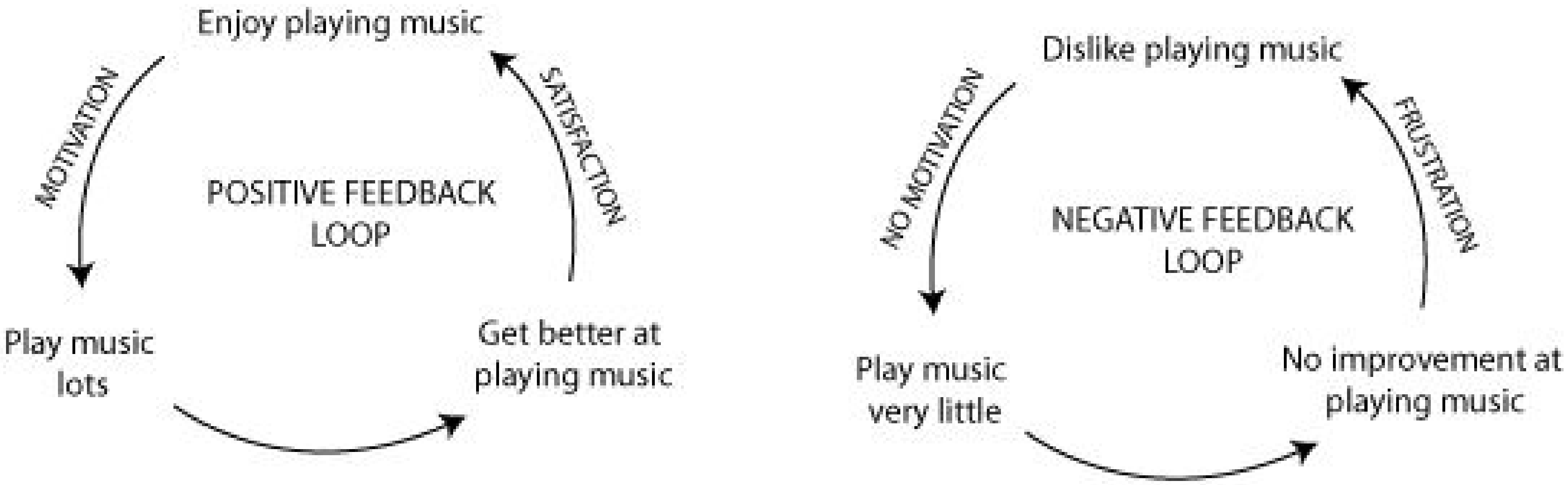


https://en.wikipedia.org/wiki/Systems_theory

Cody, Tyler, Stephen Adams, and Peter Beling. "Motivating a systems theory of AI." Insight 23.1 (2020): 37-40.

Fundamental Concepts

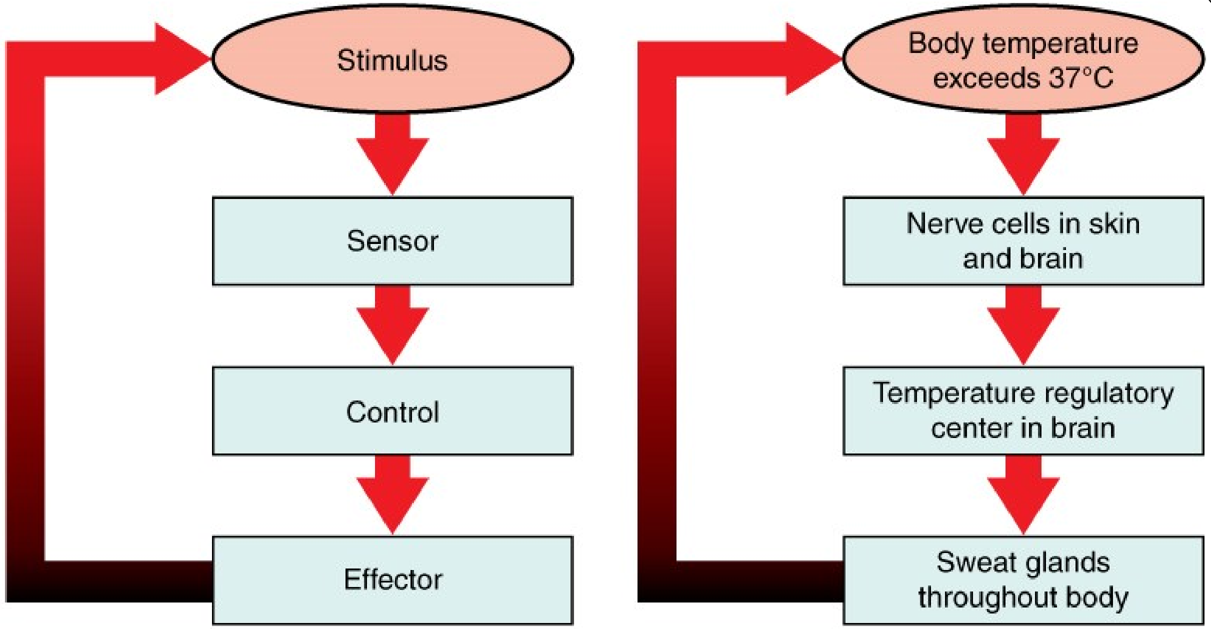
- System has interconnected component.
- Boundaries: Outer components of a system in an environment.
- Feedback loop: Process to self-correct based on reactions from other systems in the environment.

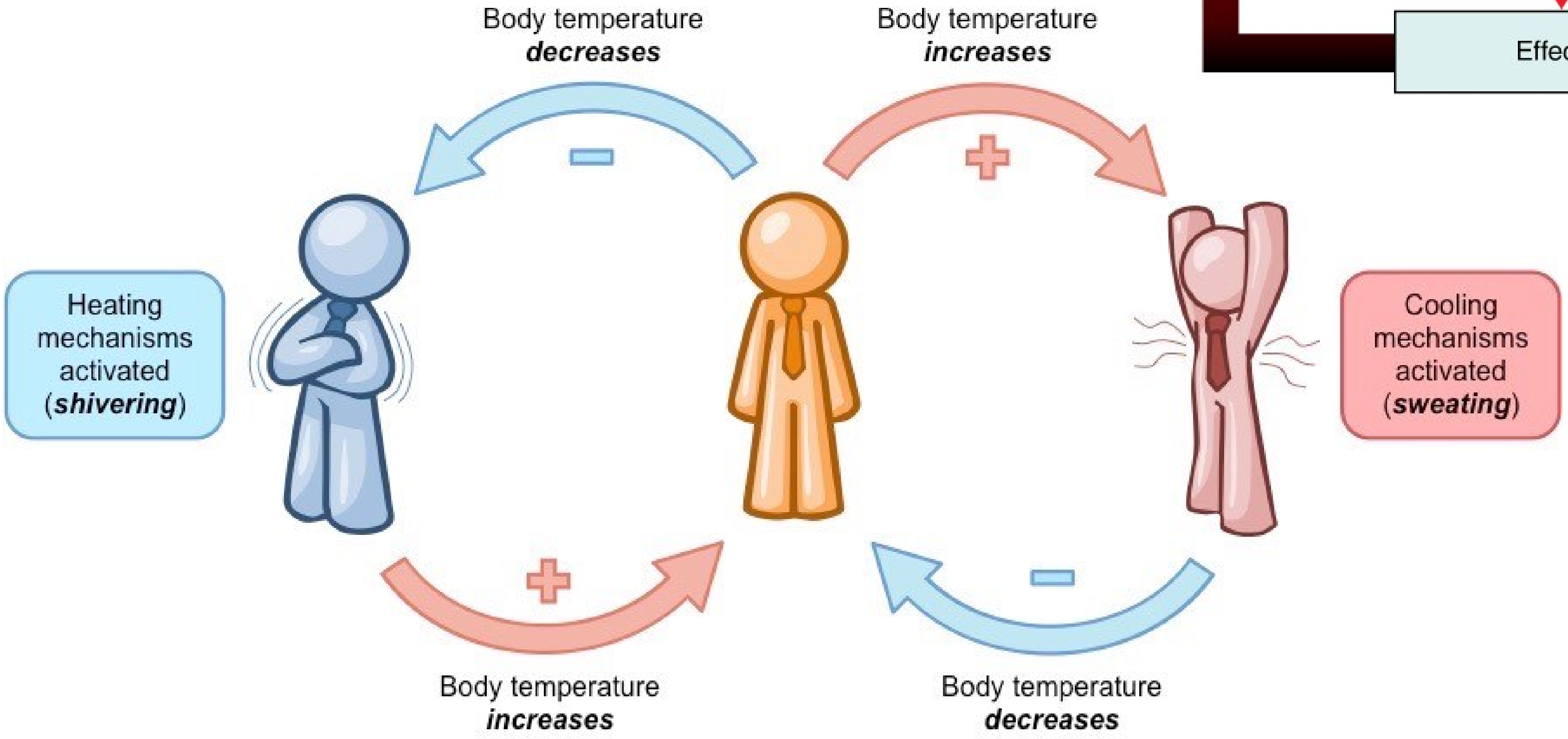


https://en.wikipedia.org/wiki/Systems_theory

Fundamental Concepts

- **Adaptation:** Tendency of making internal changes to protect itself and to maintain functionalities.

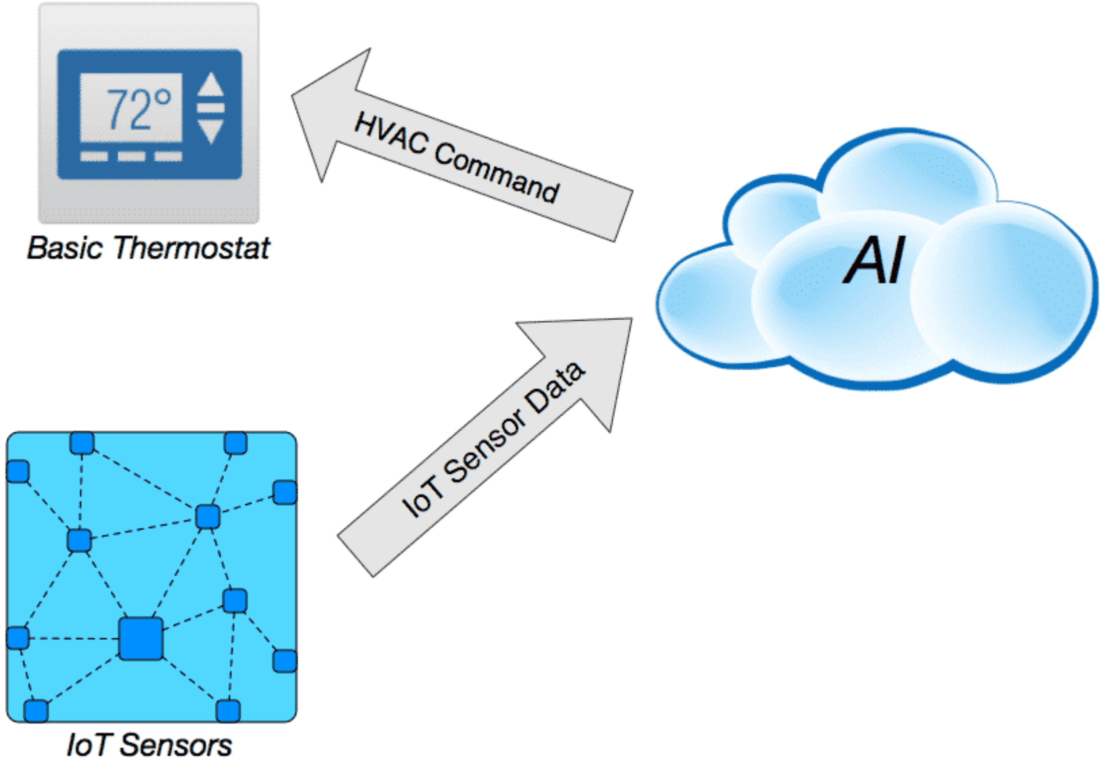


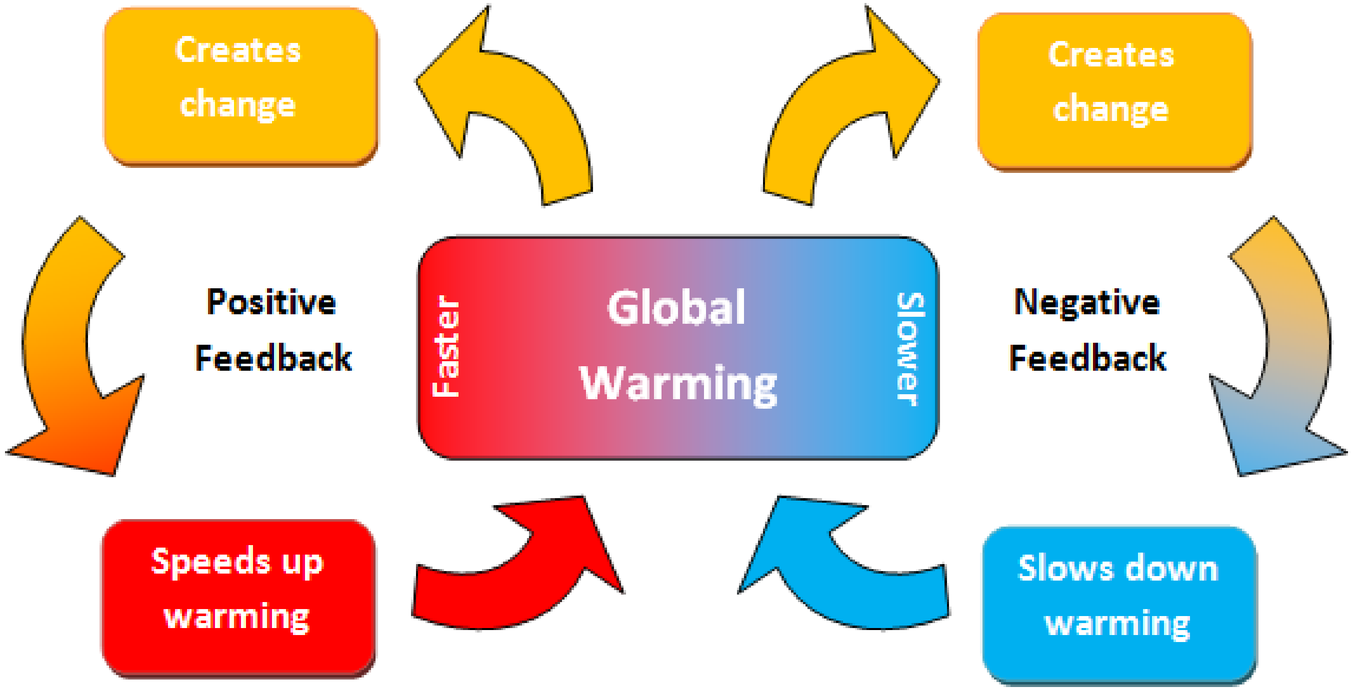


https://en.wikipedia.org/wiki/Systems_theory

Fundamental Concepts

- **Homeostasis:** Tendency to be resilient w.r.t external disruption and to maintain functionalities.

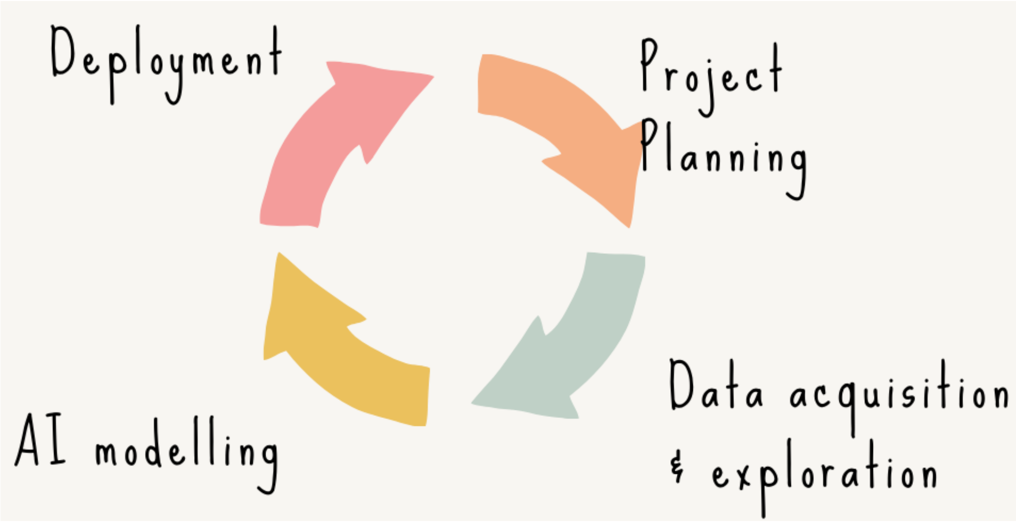


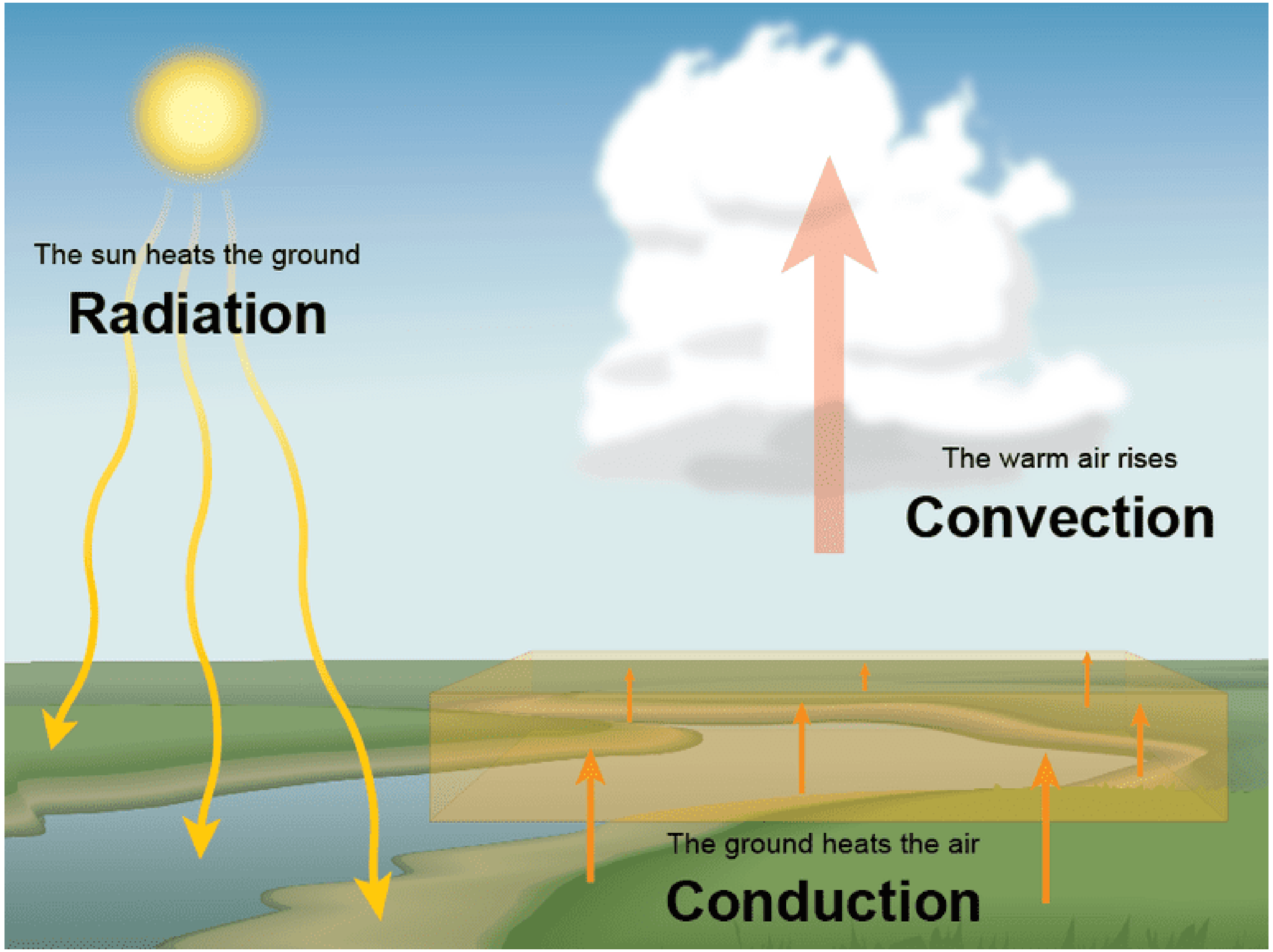


https://en.wikipedia.org/wiki/Systems_theory

Fundamental Concepts

- **Reciprocal transactions:** Cyclical interactions such that systems influence one another.
- **Throughput:** Rate of energy transfer between a system and its environment over time.

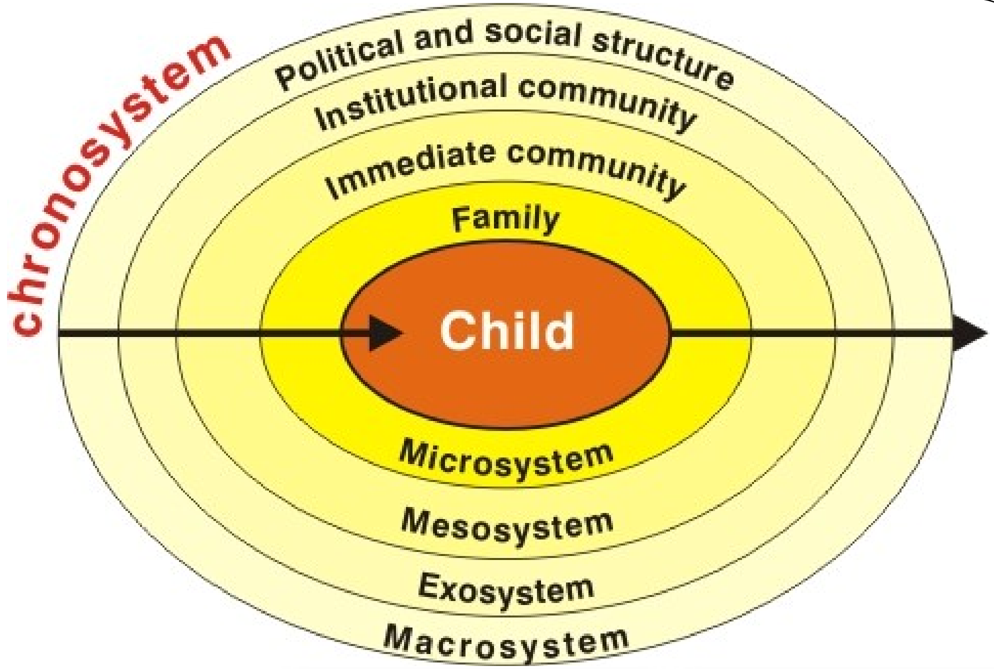


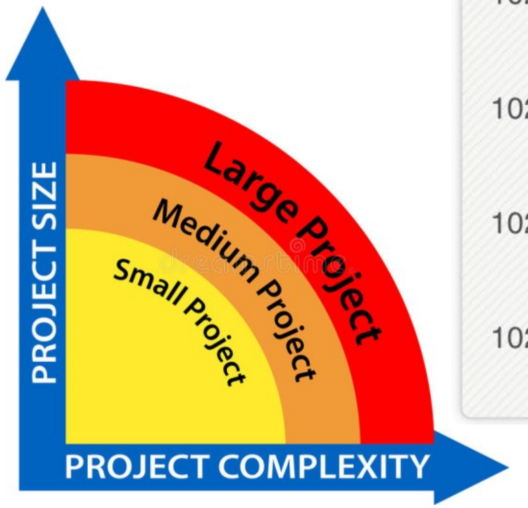


https://en.wikipedia.org/wiki/Systems_theory

Fundamental Concepts

- **Microsystem:** The system closest to the client.
- **Mesosystem:** Relationships among systems in an environment.
- **Exosystem:** A relationship between two systems that has an indirect effect on a third system.
- **Macrosystem:** A larger system that influences clients, policies, administration, and culture.
- **Chronosystem:** A system composed of significant life events affecting adaptation.



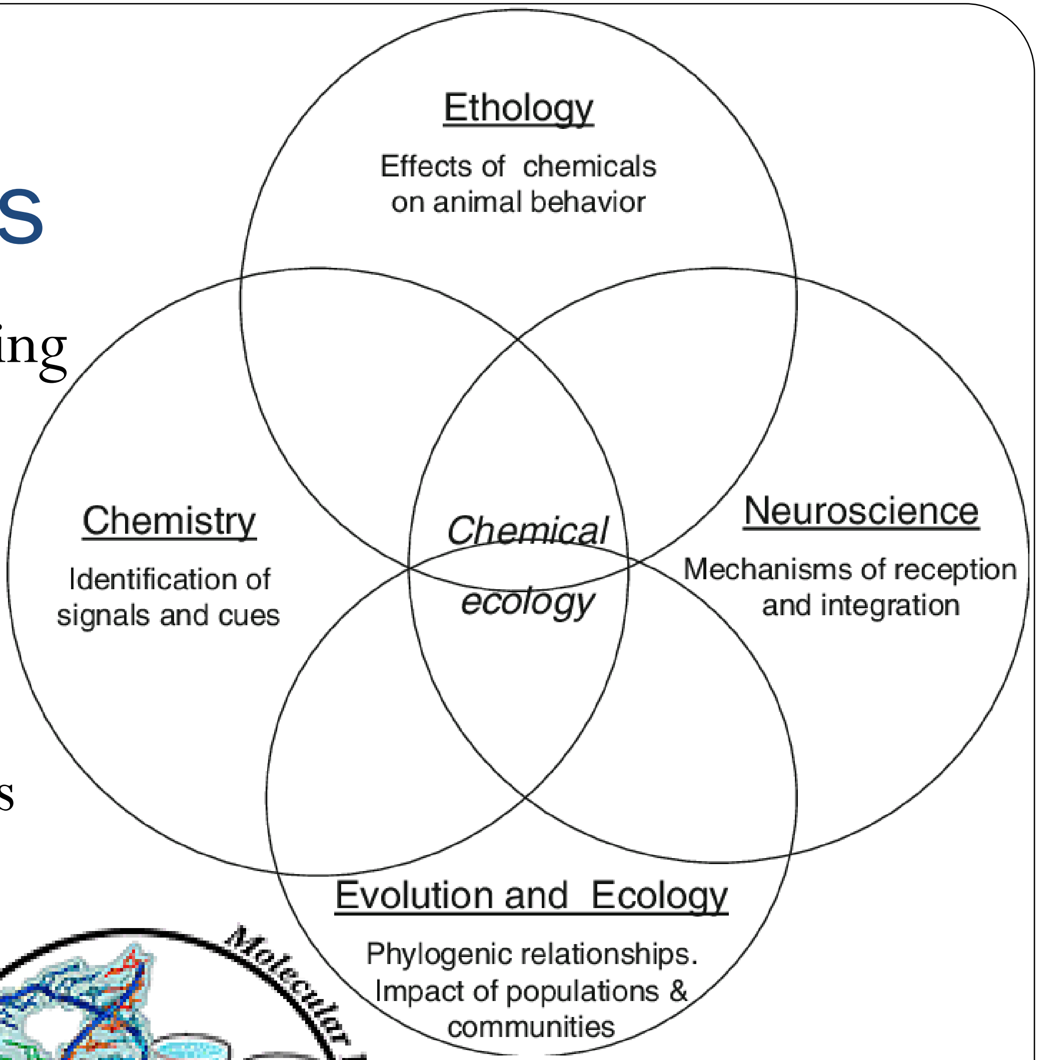


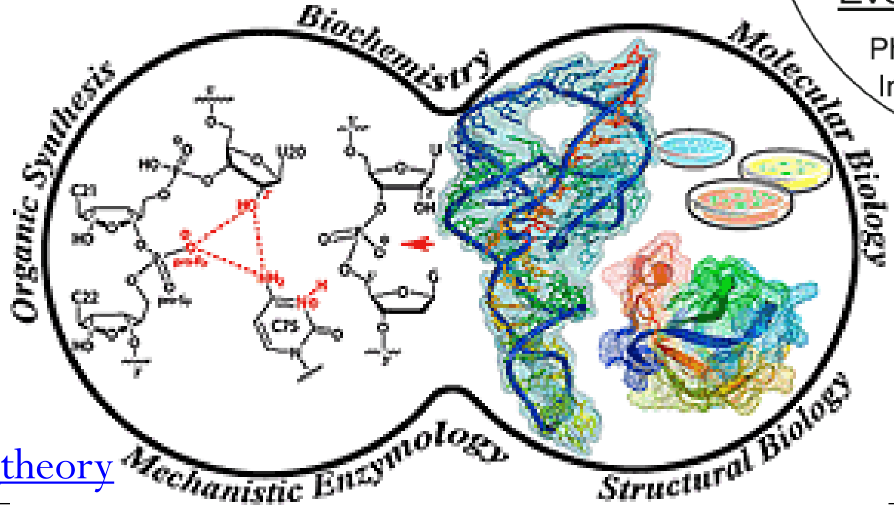
1024 bytes	=	**1 KB**	KB	=	**Kilobyte**
1024 KB	=	**1 MB**	MB	=	**Megabyte**
1024 MB	=	**1 GB**	GB	=	**Gigabyte**
1024 GB	=	**1 TB**	TB	=	**Terabyte**
1024 TB	=	**1 PB**	PB	=	**Petabyte**

https://en.wikipedia.org/wiki/Systems_theory

Systems Theory Applications

- **Systems biology** is bioscience research focusing on complex interactions in biological systems.
- **Systems chemistry** studies networks of interacting molecules.
- **Systems ecology** is a field of ecology (subset Earth science) that studies of ecological systems i.e. ecosystems.

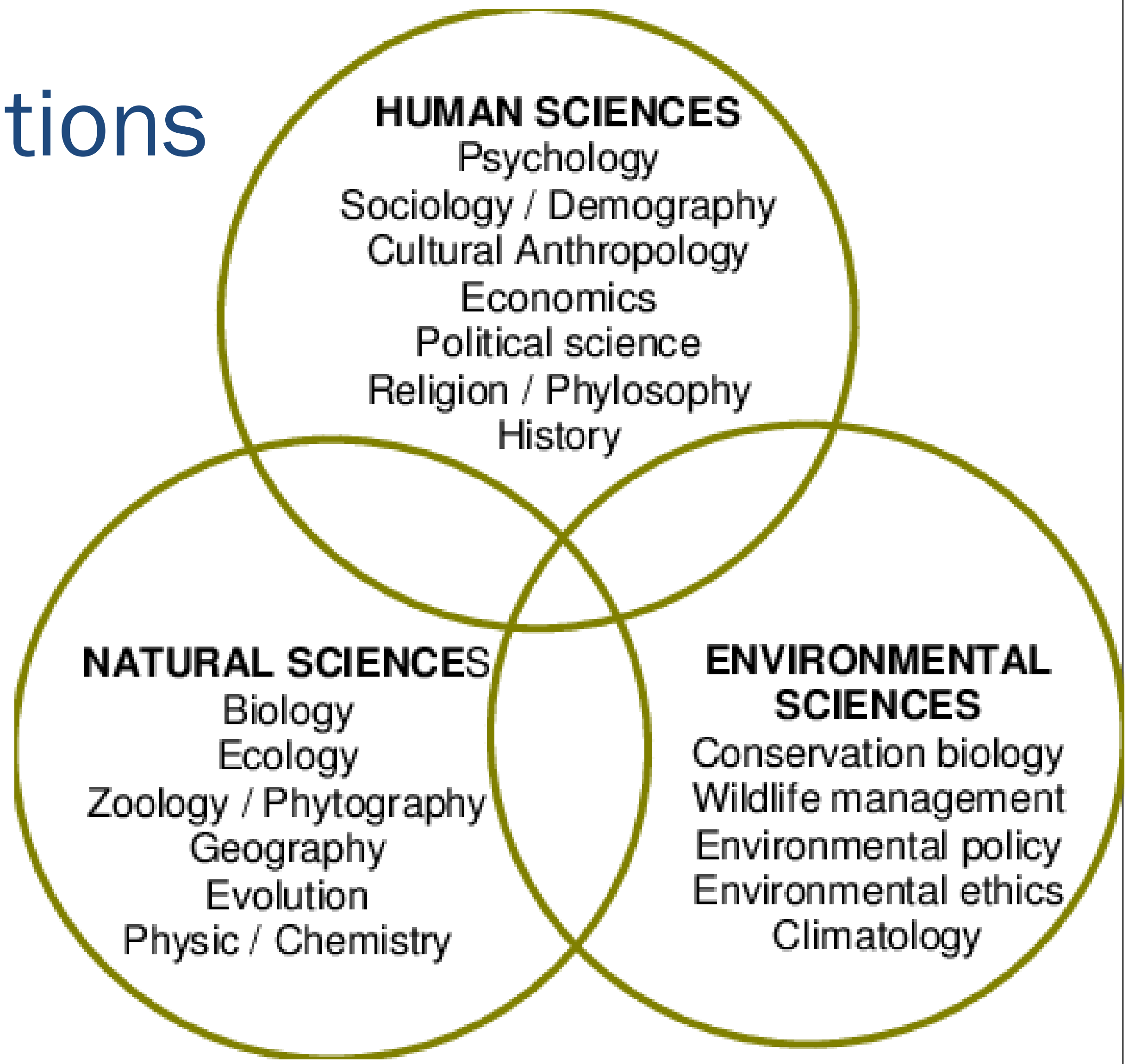




https://en.wikipedia.org/wiki/Systems_theory

Systems Theory Applications

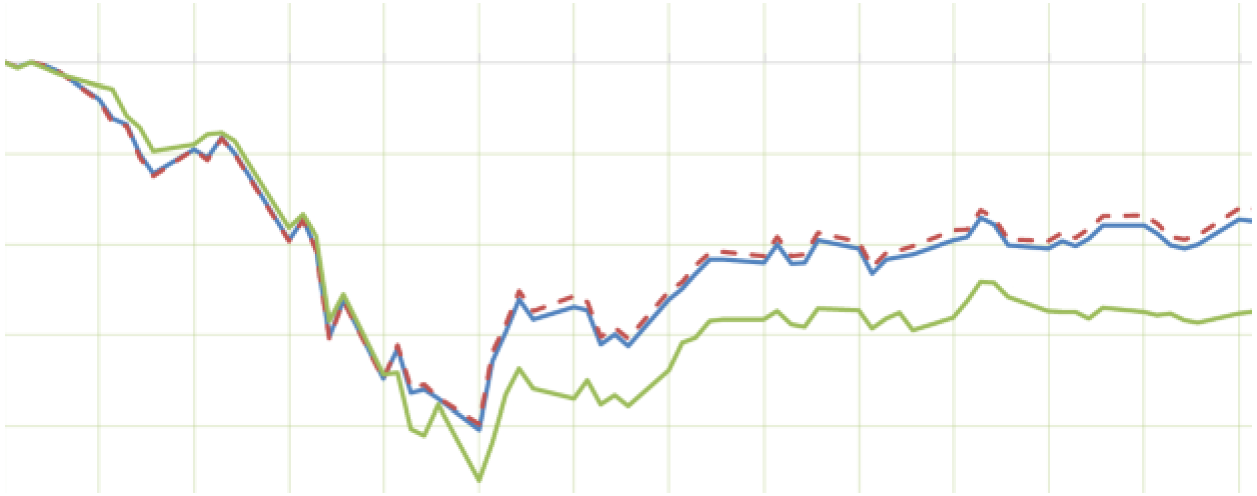
- **Systems psychology** studies human behavior and experience in complex systems.
- **Systems thinking** ability or skill to perform problem solving in complex system. With the Systems theory, the System Thinking can be learned.



https://en.wikipedia.org/wiki/Systems_theory

Systems Theory Applications

- **System dynamics** is a technique to study nonlinear characteristic of complex systems over time.
- **Systems engineering** enables the realization, deployment, and maintenance of successful systems with the applied engineering efforts.



https://en.wikipedia.org/wiki/Systems_theory

AI Application on
Interdisciplinary Science and Engineering

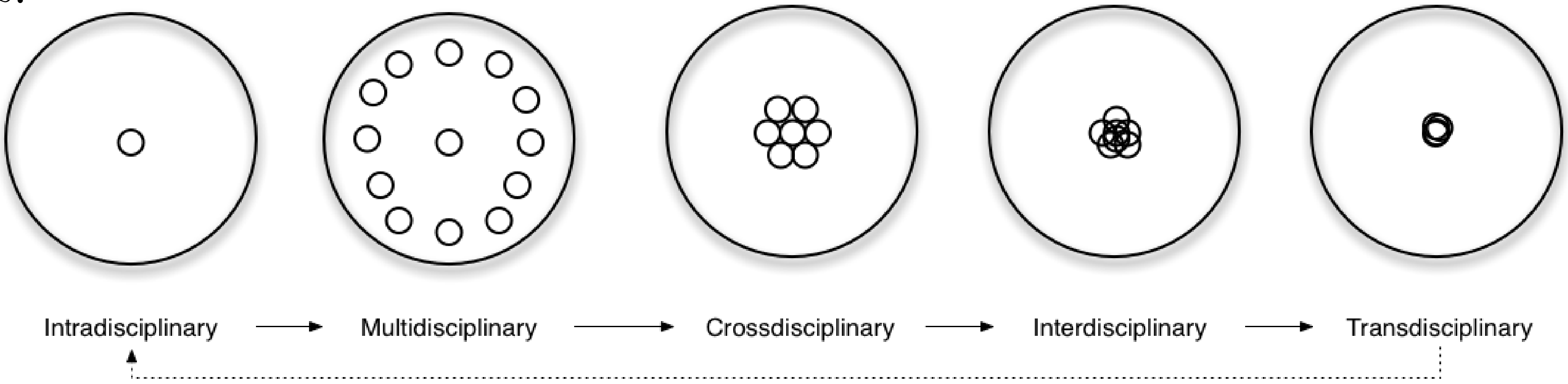
Interdisciplinary

- An organizational unit involving two or more academic disciplines,
- Dedicated journals, conferences and university departments.
- Three levels of cross-disciplinary research:
  - **Multidisciplinarity:** Pluridisciplinary level draws knowledge from different disciplines but stays within their boundaries.
  - **Interdisciplinarity:** Cross-disciplinary level analyzes, synthesizes and harmonizes links between disciplines.
  - **Transdisciplinarity:** Discipline-forming level integrates and transcends traditional boundaries.

[8] Choi BC, Pak AW. Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness. Clin Invest Med. 2006 Dec; 29(6):351-64. PMID: 17330451.
https://en.wikipedia.org/wiki/Interdiscipline

Disciplinarities:
intra, cross, multi, inter, trans

- Intradisciplinary: working within a single discipline.
- Crossdisciplinary: viewing one discipline from the perspective of another.
- Multidisciplinary: people from different disciplines working together, each drawing on their disciplinary knowledge.
- Interdisciplinary: integrating knowledge and methods from different disciplines, using a real synthesis of approaches.
- Transdisciplinary: creating a unity of intellectual frameworks beyond the disciplinary perspectives.



https://www.arj.no/2012/03/12/disciplinarities-2/

Interdisciplinary in System Engineering

- Interdisciplinary is an adjective
- "An interdisciplinary approach that encompasses the entire technical effort, and evolves into and verifies an integrated and life cycle balanced set of system people, products, and process solutions that satisfy customer needs. (EIA Standard IS-632, *Systems Engineering*, December 1994.)"
- "An interdisciplinary, collaborative approach that derives, evolves, and verifies a life-cycle balanced system solution which satisfies customer expectations and meets public acceptability. (IEEE P1220, *Standard for Application and Management of the Systems Engineering Process*, [Final Draft], 26 September 1994.)"
- "Systems engineering is an interdisciplinary engineering management process that evolves and verifies an integrated, life cycle balanced set of system solutions that satisfy customer needs."

[4] *Systems Engineering Fundamentals.* Defense Acquisition University Press, 2001

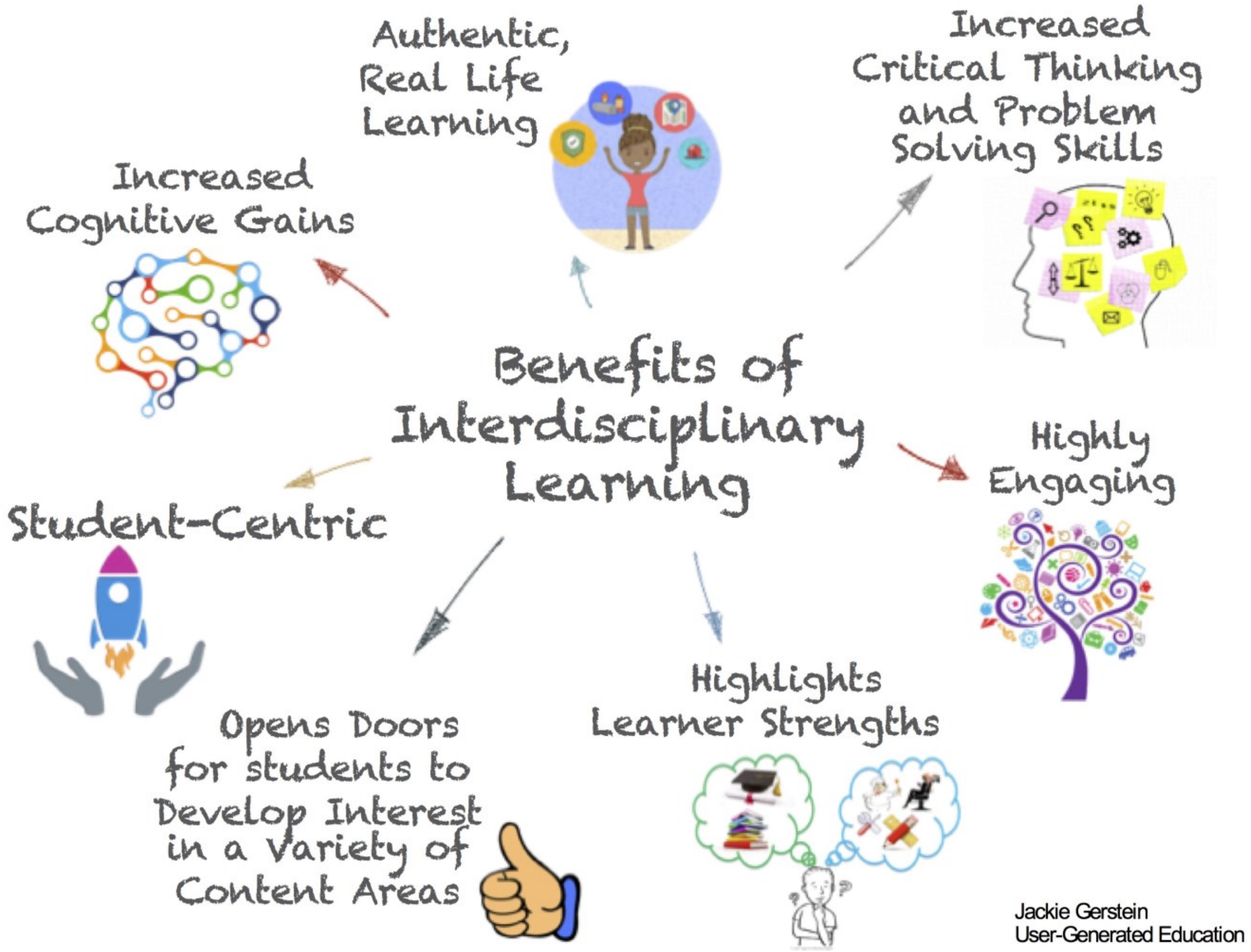
Interdisciplinary application of SysEng and AI

- aka. Interdisciplinary studies
- combination of two or more academic disciplines into one activity (e.g., a research project).
- Disciplines could be like
  - social science,
  - mechanical engineering,
  - electrical engineering,
  - computer science and engineering, etc.
- Inter-discipline examples Electromechanics, Mechatronics, Bioinformatics, Biomedical Engineering, Data Science/Analytics, Computational Social Systems etc.

https://en.wikipedia.org/wiki/Interdisciplinarity

Interdisciplinary Examples for AI applications

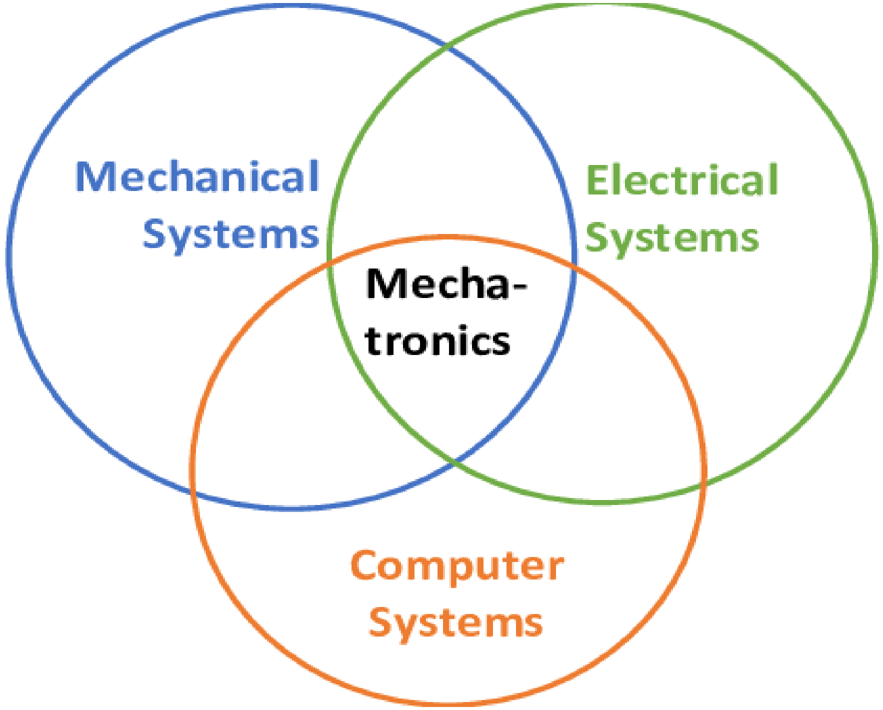
- Electromechanics focuses on the interaction of electrical and mechanical systems as a whole and how the two systems interact with each other.
- Mechatronics focuses on the engineering of electronic, electrical and mechanical engineering systems, and also includes a combination of robotics, electronics, computer, telecommunications, systems, control, and product engineering.



https://en.wikipedia.org/wiki/Electromechanics
https://en.wikipedia.org/wiki/Mechatronics

Electromechanics and Mechatronics

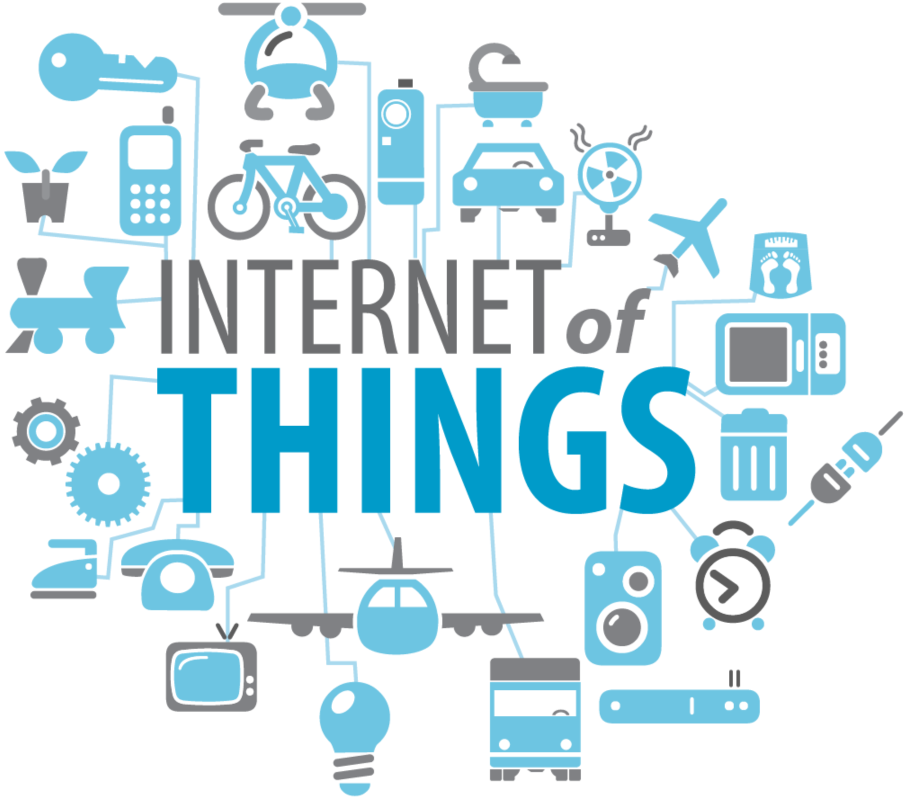
- An actuator is a component of a machine that is responsible for moving and controlling a mechanism or system, for example by opening a valve. In simple terms, it is a "mover".
- An actuator requires a control signal and a source of energy.
- A sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. A sensor is always used with other electronics.



https://en.wikipedia.org/wiki/Electromechanics
https://en.wikipedia.org/wiki/Mechatronics
https://en.wikipedia.org/wiki/Actuator

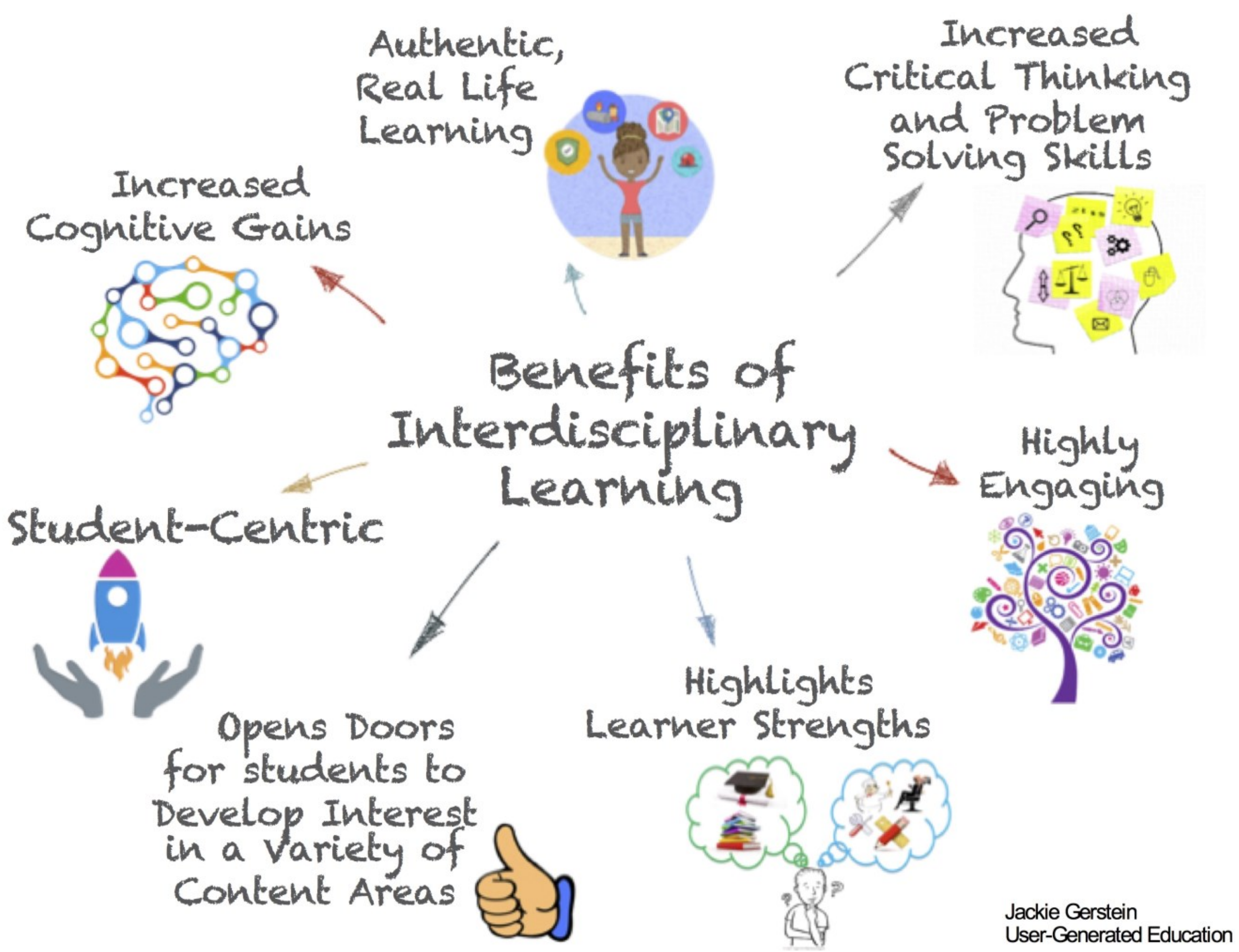
Internet of things (IoT) subdomain of AI

- The Internet of things (IoT) is the inter-networking of physical devices, embedded with **electronics, software, sensors, actuators, and network connectivity** which enable these objects to collect and exchange data.



Interdisciplinary Examples for AI applications

- Biomedical engineering (BME) is the application of engineering principles and design concepts to medicine and biology for healthcare purposes (e.g., diagnostic or therapeutic).
- Bioinformatics develops methods and software tools for understanding biological data, in particular when the data sets are large and complex.



https://en.wikipedia.org/wiki/Biomedical_engineering
https://en.wikipedia.org/wiki/Bioinformatics

Bio-Medical Engineering (BME) for applying AI

- Bioinformatics
- Biomechanics
- Biomaterials science or engineering
- Biomedical optics
- Tissue engineering
- Genetic engineering
- Neural engineering
- Pharmaceutical engineering
- Medical devices (Medical imaging, Implants, Bionics, and Biomedical sensors)
- Clinical engineering
- Rehabilitation engineering

https://en.wikipedia.org/wiki/Biomedical_engineering
https://en.wikipedia.org/wiki/Bioinformatics

Bioinformatics based on Data Science (DS)

- **Informatics:** set of digital codes and a language
- **Bioinformatics:** Study of biological (or life) information (digital code for studying properties of bio-systems)

Computer scientists, Mathematicians, Data Scientist etc.

Develop tools, software, algorithms

Store and analyze the data.

+

Biologists

collect molecular data: DNA & Protein sequences, gene expression, etc.

=

Bioinformaticians

Study biological questions by analyzing molecular data

Bioinformatics based on Data Science (DS)

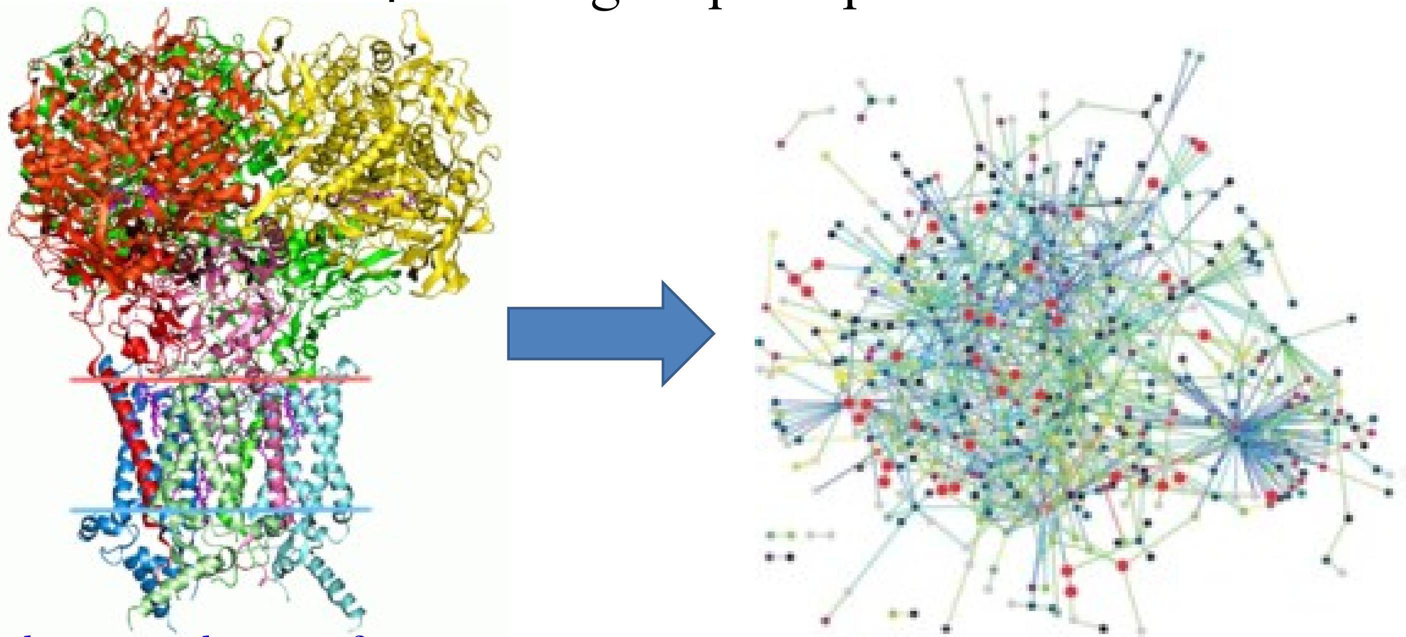
- Computers became essential in molecular biology when protein sequences, amino acid sequences, protein domains, protein structures etc.
- Sequences of genetic material are frequently used in bioinformatics and are easier to manage using computers than manually.
- DNA sequencing is still a non-trivial problem as the raw data may be noisy or afflicted by weak signals. Algorithms have been developed for base calling for the various experimental approaches to DNA sequencing.

5'ATGACGTGGGA3'
3'TACTGCACCCT5'

https://en.wikipedia.org/wiki/Bioinformatics

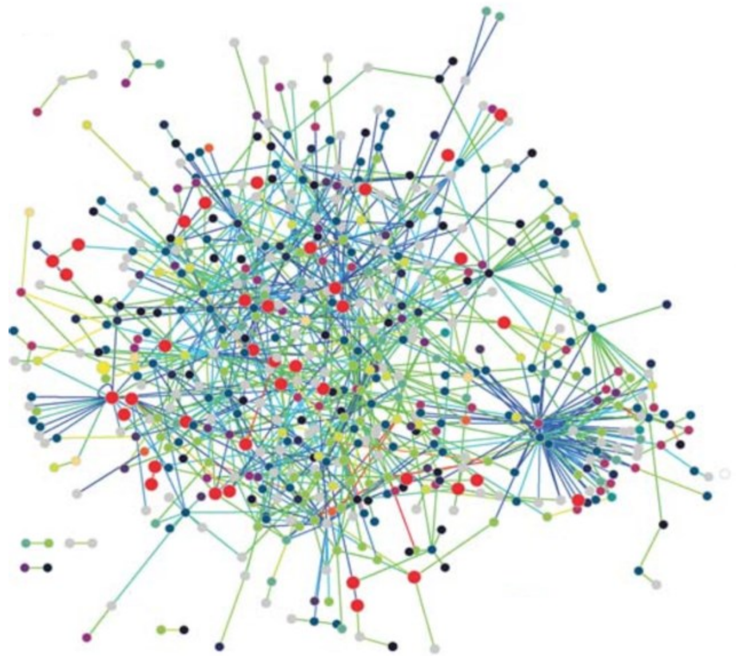
Molecular interaction networks based on DS

- BME: Tens of thousands of three-dimensional protein structures are determined by X-ray Crystallography and protein Nuclear Magnetic Resonance (NMR) spectroscopy.
- Bioinformatics: Protein–protein interaction identifies, predicts, and catalog physical interactions between pairs or groups of proteins.



https://en.wikipedia.org/wiki/Bioinformatics

Network analysis



- Study of relationships within biological networks
  - metabolic or
  - protein–protein interaction networks.
- Biological networks can be constructed from
  - a single type of molecule or entity (such as genes),
  - many different data types, such as proteins, small molecules, gene expression data.
- Abbreviation recognition – identify the long-form and abbreviation of biological terms
- Named entity recognition – recognizing biological terms such as gene names
- Protein–protein interaction – identify which proteins interact with which proteins from text

Systems biology

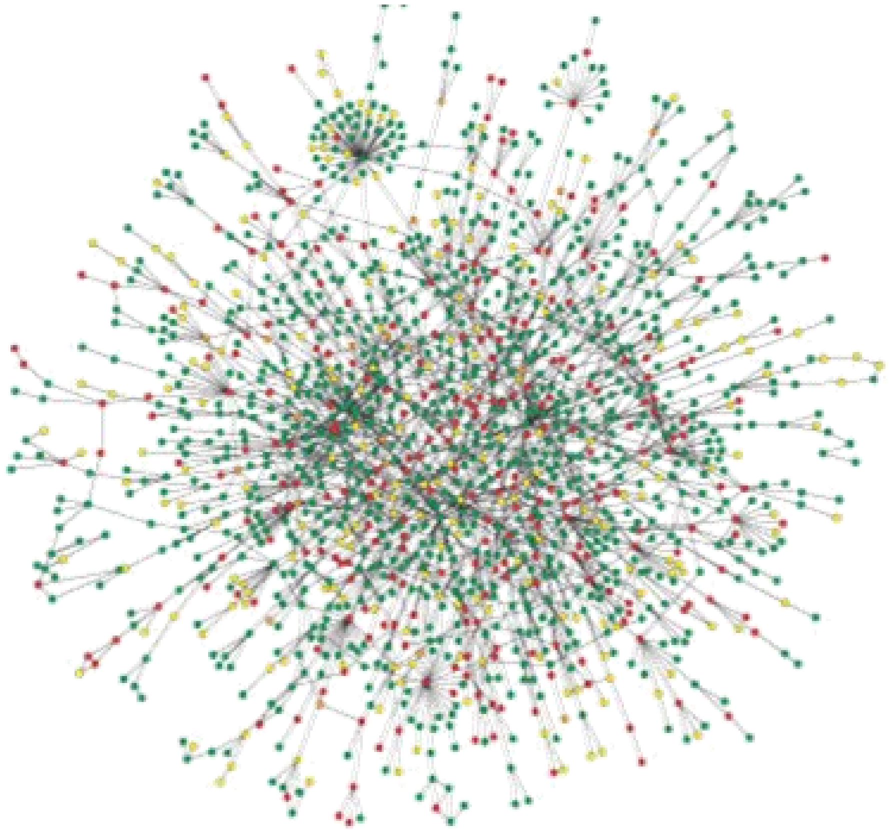
- It involves the use of computer simulations of cellular subsystems such as the networks of metabolites and enzymes that comprise metabolism.
- Signal Transduction Pathways and Gene Regulatory Networks to both analyze and visualize the complex connections of these cellular processes.
- **Artificial** life or virtual evolution attempts to understand evolutionary processes via the **computer simulation of simple (artificial) life forms**.

Bio Interactions

- Protein-Protein Interaction
- DNA-Protein interactions
- GeneNet (Gene networks)
- Biomolecular Interaction
- Molecular interactions
- Protein and Biochemical Interactions

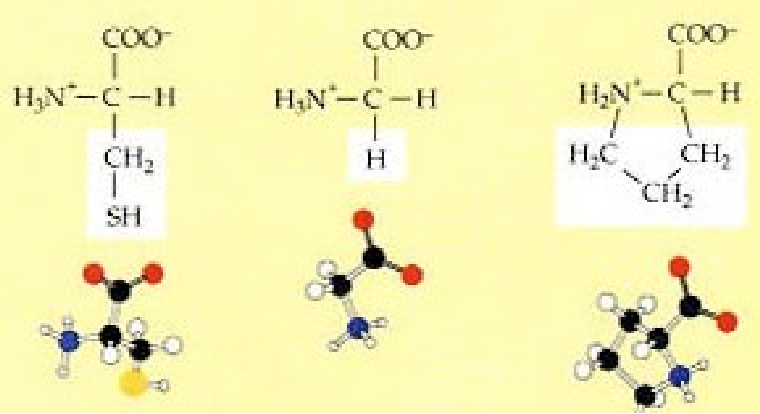
Nodes: proteins

Links: physical interactions (binding)



Bioinformatics Visualization

- Amino Acid to Graph



- Human Hemoglobin

>gi|14456711|ref|NM_000558.3| **Homo sapiens hemoglobin, alpha** 1 (HBA1), mRNA

```
ACTCTTCTGGTCCCCACAGACTCAGAGAGAACCCACCATGGTGCTGTCT
CCTGCCGACAAGACCAACGTCAAGGCCGCCTGGGGTAAGGTCGGCGCGC
ACGCTGGCGAGTATGGTGCGGAGGCCCTGGAGAGGATGTTCCTGTCCTT
CCCCACCACCAAGACCTACTTCCCGCACTTCGACCTGAGCCACGGCTCT
GCCCAGGTTAAGGGCCACGGCAAGAAGGTGGCCGACGCGCTGACCAACG
CCGTGGCGCACGTGGACGACATGCCCAACGCGCTGTCCGCCCTGAGCGA
CCTGCACGCGCACAAGCTTCGGGTGGACCCGGTCAACTTCAAGCTCCTA
AGCCACTGCCTGCTGGTGACCCTGGCCGCCCACCTCCCCGCCGAGTTCA
CCCCTGCGGTGCACGCCTCCCTGGACAAGTTCCTGGCTTCTGTGAGCAC
CGTGCTGACCTCCAAATACCGTTAAGCTGGAGCCTCGGTGGCCATGCTT
CTTGCCCCTTGGGCCTCCCCCCAGCCCCTCCTCCCCTTCCTGCACCCGT
ACCCCCGTGGTCTTTGAATAAAGTCTGAGTGGGCGGC
```

Bio-Informatics Databases

- KEGG (Kyoto Encyclopedia of Genes and Genomes)
  - http://www.genome.ad.jp/kegg/
  - Institute for Chemical Research, Kyoto University
- PathDB
  - http://www.ncgr.org/pathdb/index.html
  - National Center for Genomic Resources
- SPAD: Signaling PAthway Database
  - Graduate School of Genetic Resources Technology. Kyushu University.
- Cytokine Signaling Pathway DB.
  - Dept. of Biochemistry. Kumamoto Univ.
- EcoCyc and MetaCyc
  - Stanford Research Institute
- BIND (Biomolecular Interaction Network Database)
  - UBC, Univ. of Toronto

Natural Language Processing

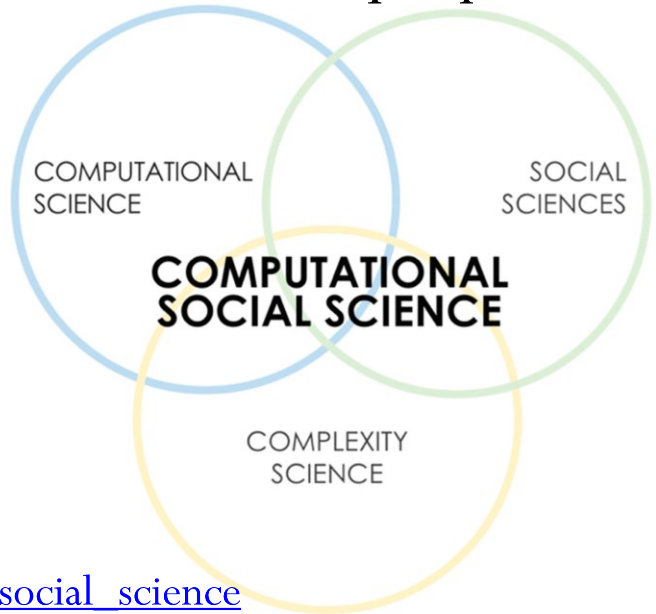
- Text mining or analytics is the process of analyzing quality information from text; by automatically discovering and extracting unknown information from text resources.
  - Regular Expressions (Regex), Text Pattern matching

- Sentiment analysis involve analysis of labeled or unlabeled natural language based affectivity of words and concepts made from WordNet and ConceptNet.
  - Positive, Negative, and Neutral Sentiments

https://en.wikipedia.org/wiki/Text_mining

Interdisciplinary Examples

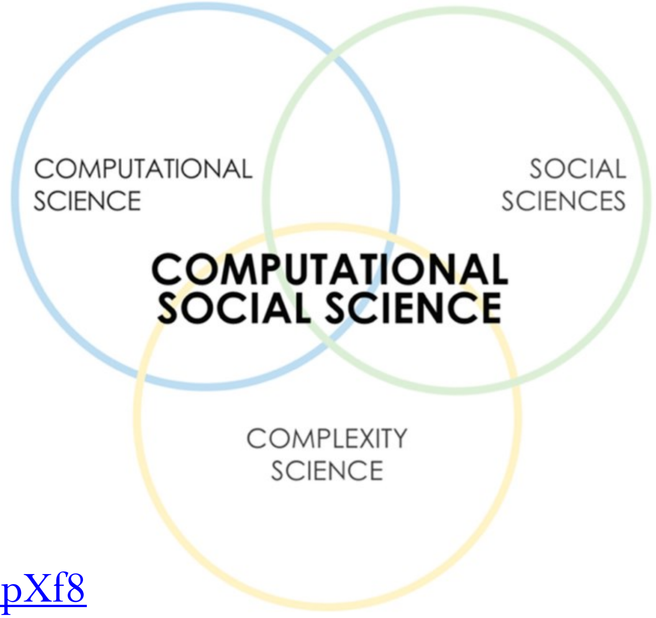
- Computational social science is sub-disciplines concerned with computational approaches to the social sciences.
  - Sub-field, Natural Language processing
- Human–Computer Interaction (HCI) studies the design and use of computer technology, focused on the interfaces between people (users) and computers.
  - SixthSense



https://en.wikipedia.org/wiki/Computational_social_science
https://en.wikipedia.org/wiki/Human%E2%80%93computer_interaction

Sixth Sense

- Gesture-based wearable computer system developed at MIT Media Lab by
  - Steve Mann in 1994 and 1997 (headworn gestural interface),
  - 1998 (neckworn version), and
  - Pranav Mistry (also at MIT Media Lab), in 2009, developed both hardware and software for headworn and neckworn versions of it.



https://www.youtube.com/watch?v=E8GU-dGpXf8
https://en.wikipedia.org/wiki/SixthSense

Synergy and AI

Synergy

- Synergy is two or more things functioning together to produce a result not independently obtainable.
- This may give both positive and negative effects.
- In systems engineering, Synergy describes how system behavior emerges from the interaction between elements or components or entities.
- Synergy is closely related to Emergence.
- An interaction or cooperation giving rise to a whole that is greater than the simple sum of its parts.
- Term comes from the Attic Greek, meaning "working together".

https://www.sebokwiki.org/wiki/Synergy_(glossary)
https://en.wikipedia.org/wiki/Synergy

Synergy

- In an organization synergy is the ability of a group to outperform even its best individual member. (Buchanan and Huczynski,1997).
- A construct or collection of different elements working together to produce results not obtainable by any of the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, documents: all things required to produce system-level results. (Blanchard 2004).

https://www.sebokwiki.org/wiki/Synergy_(glossary)
https://en.wikipedia.org/wiki/Synergy

Biological and Artifical Neural Network synergy

- Biology and AI synergy: Artificial Neural Network
- In medicine synergy is used to describe combinations of drugs which interact in ways that enhance or magnify one or more effects, or side-effects, of those drugs.
- Pest synergy occur in a biological host organism population.
  - parasite A cause 10% fatalities, and parasite B also cause 10% loss. When both parasites are present, the parasites in combination have a synergistic effect.
- Drug synergy: involved in the development of synergistic effects of drugs
  - two different antibiotics can improve the effect

https://www.sebokwiki.org/wiki/Synergy_(glossary)
https://en.wikipedia.org/wiki/Synergy

Human and Machine Learning synergy

- Supervised and Semi-supervised learning where Human help to do labeling.
- Human synergy relates to human interaction and teamwork.
  - Person A is too short to reach an apple and person B is also too short. When person B sits on the shoulders of person A, they are tall enough to reach the apple.
  - If each politician gather 1 million votes, but together two politician appeals to get 2.5 million voters, their synergy produced 500,000 more votes.
  - Taking more than one musical part and putting them together to create a song.

https://en.wikipedia.org/wiki/Synergy

Decision science and Corporate synergy

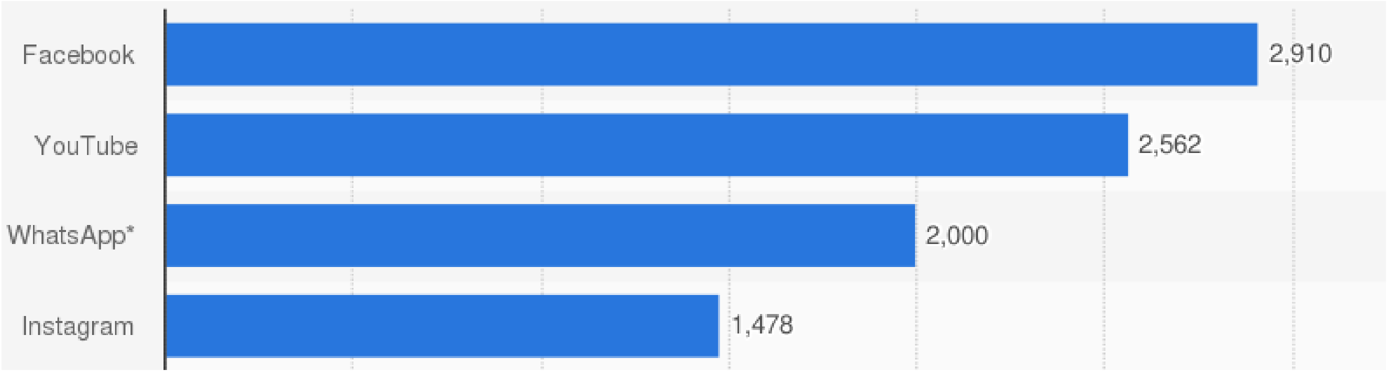
- Financial decision making using data mining and data analytics.
- Used in business or other human activity systems to describe outcomes which can only be achieved by encouraging people or organizations to work together.
- Financial benefit of a corporation expects to realize when it merges with or acquires another corporation.
  - If company A sells product X, company B sells product Y, and company A **decides** to buy company B, thereby increasing the revenue to sell products X and Y together.

https://www.sebokwiki.org/wiki/Synergy_(glossary)
https://en.wikipedia.org/wiki/Synergy

Computer-Human Synergy

- Synergy between Computational Social Science and Social Media
- The combination of human strengths and computer strengths.
- Computers can process data much more quickly than humans, but lack heuristics i.e., the ability to respond meaningfully to arbitrary stimuli.

Social Media size



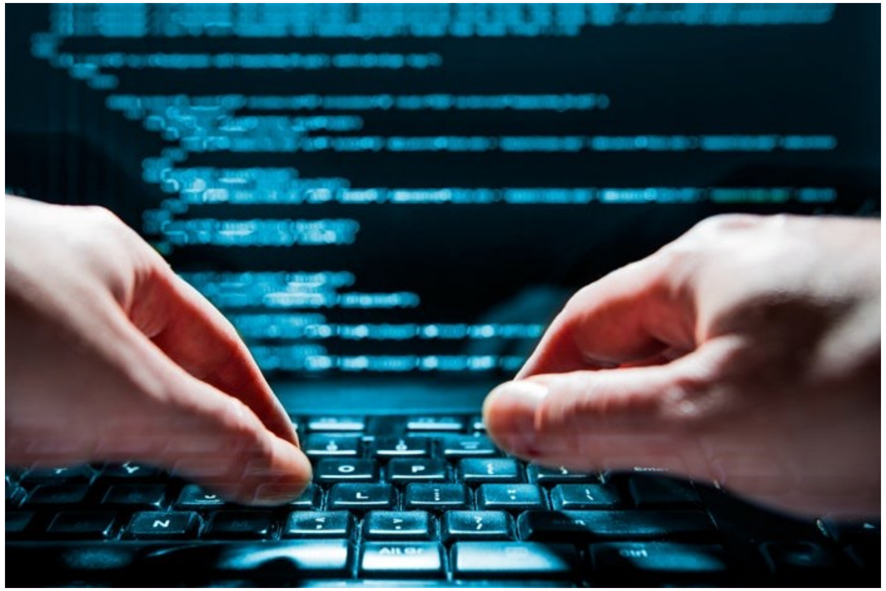
https://www.sebokwiki.org/wiki/Synergy_(glossary)
https://en.wikipedia.org/wiki/Synergy

Animated-AI and Cartoon Synergy

- Walt Disney did synergistic marketing techniques in the 1930s by granting dozens of firms the right to use his Mickey Mouse character in products and ads.
- Spider-Man films earned from
  - toys of webshooters (device that can shoot thin strands of a special "web fluid“) and
  - spiderman posters, and
  - spiderman games.

https://en.wikipedia.org/wiki/Synergy

Software engineering and AI



- Digital computers appeared in the early 1940s
  - “Stored program architecture"
  - Von Neumann architecture
  - division between "hardware" and "software"
- Programming languages started to appear in the early 1950s
  - Fortran, ALGOL, PL/I, and COBOL
- Systematic application of engineering approaches to the development of software.
- “Software Engineering” 1965 issue of COMPUTERS and AUTOMATION magazine
- Margaret Hamilton coined the term
  - "software engineering"
  - during the Apollo missions
- Communities: ICSE, FSE, ICSME, ASE, SANER

https://en.wikipedia.org/wiki/Software_engineering

Software Engineering and AI synergy

- AI employed to assist or automate activities in software engineering. Example
  - constraint solving and search heuristics used in test generation.
  - machine learning used in debugging.
  - natural language processing used in specification inference.
  - knowledge engineering used in various software-engineering tasks.
- Human-assisted computing and Human-centric computing can help realize the synergy of human and artificial intelligence.
  - Test generation: to automatically generate test inputs that can satisfy testing requirements
  - Specification generation: to write specifications based on recommendation
  - Debugging: to automatically isolate failure-inducing inputs and fix faulty code
  - Programming: to automatically synthesize programs for implementing some functionalities

Xie, Tao. "The synergy of human and artificial intelligence in software engineering." 2013 2nd International Workshop on Realizing Artificial Intelligence Synergies in Software Engineering (RAISE). IEEE, 2013. http://taoxie.cs.illinois.edu/publications/raise13-keynote.pdf

Software Engineering and AI synergy

- Intelligent Software Engineering
  - Instilling intelligence in solutions for software engineering problems.
  - Providing software engineering solutions for intelligent software.
- AI and Software Engineering
  - search-based software engineering;
  - recommender systems;
  - autonomous and self-adapting systems;
  - AI for SE;
  - SE for AI.
- Software Analytics
  - mining software repositories;
  - apps and app store analysis.

Xie, Tao. "Intelligent software engineering: Synergy between AI and software engineering." International symposium on dependable software engineering: Theories, tools, and applications. Springer, Cham, 2018. https://taoxie.cs.illinois.edu/publications/isec18-ise.pdf
https://conf.researchr.org/track/ase-2023/ase-2023-papers

Humans and AI Synergy

- To reduce human efforts and burden on human intelligence in these activities, Artificial Intelligence (AI) techniques, which aim to create software systems that exhibit some form of human intelligence.
- Human's domain knowledge can serve as starting points for designing AI techniques.
- AI techniques are often interpreted or verified by human users. Feedback could be incorporated to further improve the AI techniques, forming a continuous feedback loop.
- Human-human cooperation is often in the form of crowdsourcing.
- Human Aspects of Software Engineering
  - program comprehension; systematic reviews, code inspection;
  - human-computer interface; software visualization;
  - crowd-based software engineering; distributed and collaborative software engineering.

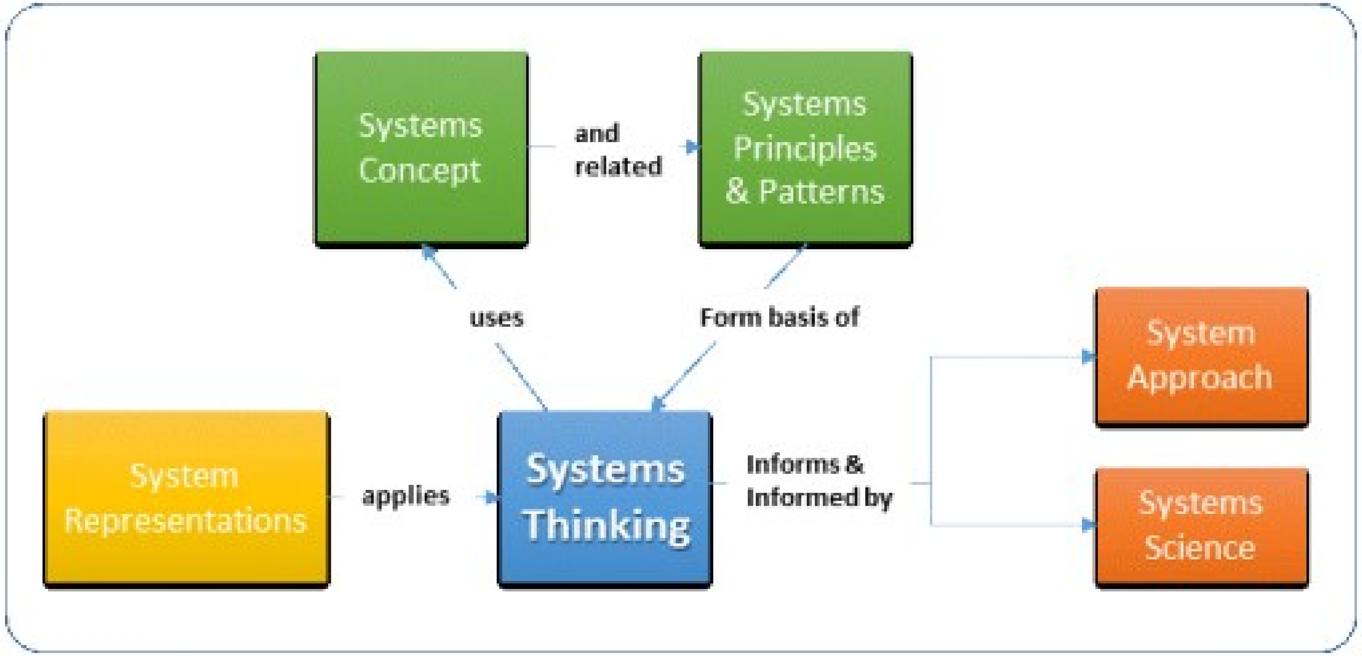
Xie, Tao. "The synergy of human and artificial intelligence in software engineering." 2013 2nd International Workshop on Realizing Artificial Intelligence Synergies in Software Engineering (RAISE). IEEE, 2013.

https://conf.researchr.org/track/ase-2023/ase-2023-papers

Systems Thinking ≈ Systems Intelligence

Systems Thinking

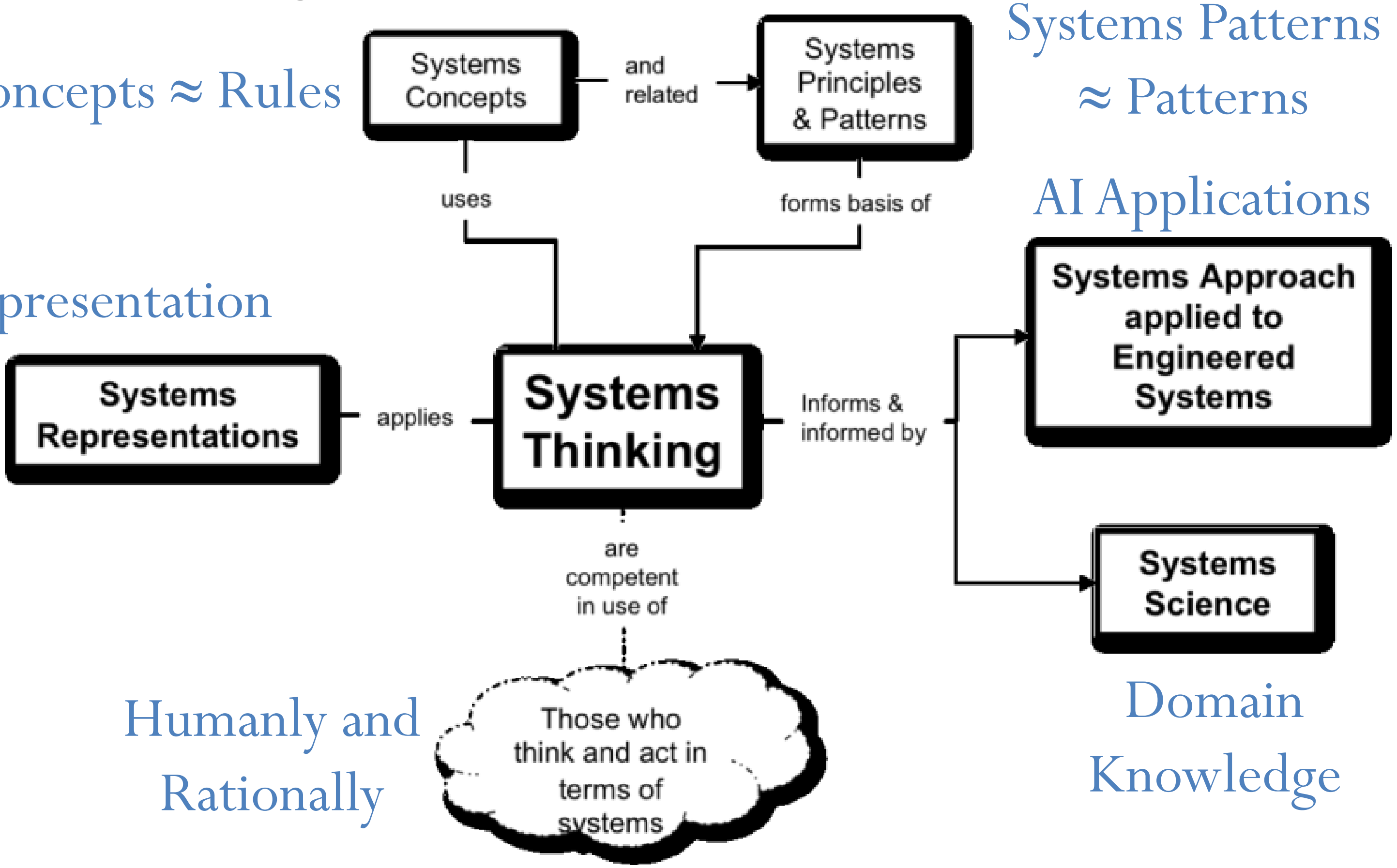
- Focuses and emphasizes on
  - behavior of the whole rather than the individual parts.
  - the interfaces between/among the subsystems.
- Ability to think about interactions between components of a system and their effect on functionalities.
- Understanding or Intervening in problem situations, based on the principles and concepts of the systems paradigm.



[8] "Systems Engineering Jr. Handbook", *INCOSE LA Chapter and The Creativita Institute*.

Systems Thinking and Artificial Intelligence

- Relationship between the System Thinking with other concepts of Systems Engineering.



Systems Concepts ≈ Rules

Systems Patterns ≈ Patterns

AI Applications

Systems Representation ≈ Knowledge Representation

Humanly and Rationally

Domain Knowledge

[9] Cloutier, R. J. "The Guide to the Systems Engineering Body of Knowledge (SEBoK); v. 2.2." *INCOSE and The Trustees of the Stevens Institute of Technology: Hoboken, NJ, USA* (2016).

Data Science for Complexity, Chaos, Regularity

- **Self-adaptive systems:** Process of attention and **adaptation** to ensure appropriately identified boundaries, dependencies, and relationships.
- **Community detection:** Components has **cohesion**, or "**togetherness**"
- **Machine learning** or **Data mining** to calculate complexity, chaos, managing interdependency, and understanding choice.
  - More complex and chaotic because of inadequate concepts to explain.
  - Understanding reduce chaotic or complex.
- **Automation** for Similarities and Differences. E.g. Github code differencing
- **Machine learning** or **Data mining** to find Regularity
  - Regularity is a uniformity or similarity that exists in multiple entities or at multiple times.
  - Regularity in both natural systems and engineered systems.

[9] Cloutier, R. J. "The Guide to the Systems Engineering Body of Knowledge (SEBoK); v. 2.2." *INCOSE and The Trustees of the Stevens Institute of Technology: Hoboken, NJ, USA* (2016).

Systems attributes & environment

- Any quality or property of a system element is called an **attribute**.
- Attributes are used for **Data Analytics: Machine learning** and **Data mining**.
  - The state of a system is a set of system attributes at a given time.
  - A system event describes any change to the environment of a system, and hence its state:
- Type of system based on attributes
  - Static - A single state exists with no events.
  - Dynamic - Multiple possible stable states exist.
  - Homeostatic - System is static but its elements are dynamic. The system maintains its state by internal adjustments.

[9] Cloutier, R. J. "The Guide to the Systems Engineering Body of Knowledge (SEBoK); v. 2.2." *INCOSE and The Trustees of the Stevens Institute of Technology: Hoboken, NJ, USA* (2016).

State Variables, Stability, and Determinism

- **Data Analytics** to study state variables, stability, and determinism of a system state
  - A stable state is one in which a system will remain until another event occurs.
  - State can be monitored using state variables, values of attributes which indicate the system state.
  - The set of possible values of state variables over time is called the "state space".
  - State variables are generally continuous but can be modeled using a finite state model (or "state machine").
  - A system can react, respond, or act.
  - A stable system is one which has one or more stable states within an environment for a range of possible events.
  - Deterministic systems have a one-to-one mapping of state variables to state space, allowing future states to be predicted from past states.
  - Non-Deterministic systems have a many-to-many mapping of state variables; future states cannot be reliably predicted

[9] Cloutier, R. J. "The Guide to the Systems Engineering Body of Knowledge (SEBoK); v. 2.2." *INCOSE and The Trustees of the Stevens Institute of Technology: Hoboken, NJ, USA* (2016).

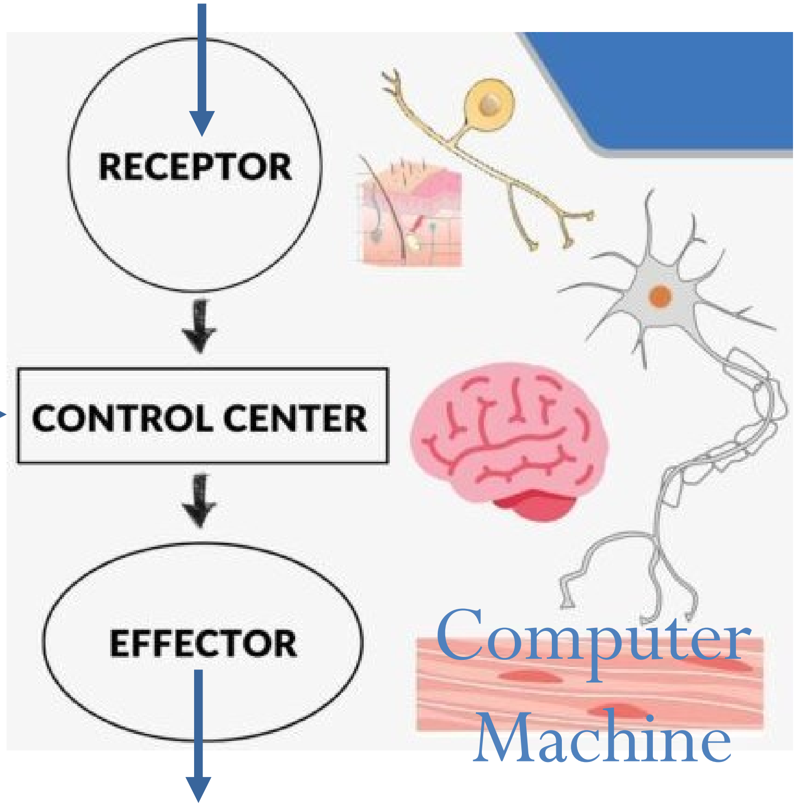
Survival Behaviour and Goal Seeking Behaviour

- **Automation** to make Survival Behavior
  - Systems often behave in a manner that allows them to sustain themselves in one or more alternative viable states.
  - Many natural or social systems have this goal, either consciously or as a "self organizing" system, arising from the interaction between elements.
  - Entropy is the tendency of systems to move towards disorder or disorganization.
- **Automation** to make Goal Seeking Behaviour
  - Some systems have reasons for existence beyond simple survival.
  - Goal seeking is one of the defining characteristics of engineered systems:
  - A goal is a specific outcome which a system can achieve in a specified time.
  - An objective is a longer-term outcome which can be achieved through a series of goals.
  - An ideal is an objective which cannot be achieved with any certainty, but for which progress towards the objective has value.

[9] Cloutier, R. J. "The Guide to the Systems Engineering Body of Knowledge (SEBoK); v. 2.2." *INCOSE and The Trustees of the Stevens Institute of Technology: Hoboken, NJ, USA* (2016).

Control Behaviour using AI

- **Cybernetics**, the science of control, defines two basic control mechanisms:
  - Negative feedback,
  - Positive feedback,
- **Control behavior** is a trade between:
  - Specialization, the focus of system behavior to exploit particular features of its environment, and
  - Flexibility, the ability of a system to adapt quickly to environmental change.



[9] Cloutier, R. J. "The Guide to the Systems Engineering Body of Knowledge (SEBoK); v. 2.2." *INCOSE and The Trustees of the Stevens Institute of Technology: Hoboken, NJ, USA* (2016).

References

[1] Goode, Harry H.; Robert E. Machol (1957). "System Engineering: An Introduction to the Design of Large-scale Systems". *McGraw-Hill*. p. 8. LCCN 56011714.

[2] Chestnut, Harold (1965). "Systems Engineering Tools". *Wiley*. ISBN 978-0-471-15448-8.

[3] "NASA Systems Engineering Handbook". *NASA*. 1995. SP-610S.

[4] "Systems Engineering Fundamentals". *Defense Acquisition University Press*, 2001.

[5] "Systems Engineering Handbook", *version 2a. INCOSE*. 2004.

[6] "Conquering Complexity: lessons in Defence systems acquisition", *The Defence Engineering Group. University College London*. 2005.

[7] "International Space Station Basics", *National Aeronautics and Space Administration (NASA)*.

[8] Choi BC, Pak AW. "Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness". *Clin Invest Med*. 2006 Dec; 29(6):351-64. PMID: 17330451.

[8] "Systems Engineering Jr. Handbook", *INCOSE LA Chapter and The Creativita Institute*.

[9] Cloutier, R. J. "The Guide to the Systems Engineering Body of Knowledge (SEBoK); v. 2.2." *The Trustees of the Stevens Institute of Technology: Hoboken, NJ, USA* (2016).

ขอบคุณ
Thai

Grazie
Italian

תודה רבה
Hebrew

धन्यवादः
Sanskrit

ಧನ್ಯವಾದಗಳು
Kannada

Ευχαριστώ
Greek

Thank You
English

Gracias
Spanish

Спасибо
Russian

Obrigado
Portuguese

شكراً
Arabic

https://sites.google.com/site/animeshchaturvedi07

Merci
French

多謝
Traditional Chinese

धन्यवाद
Hindi

Danke
German

多谢
Simplified Chinese

நன்றி
Tamil

Tamil

ありがとうございました
Japanese

감사합니다
Korean