CPE/EE 322
Engineering Design VI
Lesson 7: Synthesis

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Outline

1. Synthesis in engineering design
2. Barriers to synthesis
3. Design by serendipity
4. Creativity stimulation techniques
5. Morphological analysis

Objectives

G. Voland, Engineering by Design, Chapter 7

- Discuss the role that synthesis plays in design as entities are combined in appropriate ways to create an engineered product or system
- Identify the barriers or conceptual blocks to creative thinking
- Explain why one must be prepared to transform accidents into design solutions
- Apply such strategies as brainstorming, bionics, synectics, adaptation, and inversion to stimulate creativity in engineering problem solving
- Use morphological charts to perform synthesis by joining preliminary ideas or subsolutions to form total design concepts

Lab 7 — ThingSpeak and Google Sheets

- Study the GitHub repository Lesson 7
- Sign up and log in MathWorks ThingSpeak
- Run thingspeak_cpu_loop.py or thinkspeak_feed.py in a demo folder
- Install gspread and oauth2client
- Log in the Google Cloud Platform Identity and Access Management, create a project cpudata, enable both Drive API and Sheets API, create and download service account JSON key file
- Start a new Google sheet cpudata, share it with the client email in the JSON file, delete Rows 2 to 1000, and edit the header cells
- Run cpu_spreadsheet.py with the JSON key file in a demo folder

Assignment 7 — Synthesis

Revisit the design goals in Assignment 4 (Solution Development) and develop a morphological chart to combine ideas for achieving desired goals or functions of the proposed design

Program Outcome 2: (Design)
2.5 (Technical design) Students will be able to develop the design for a project using a hierarchical approach (top-down) and to apply successive refinement to their design, incorporating new information and insights into your design while adjusting the overall design for necessary changes.

Synthesis in Engineering Design

- Synthesis in engineering design requires creative thinking to combine ideas and things into new, meaningful, and practical forms
- Synthesis generally follows careful preparation and laborious execution
- Engineers must be creative within the design specifications or boundaries of the problem to be solved
- A synthesis may suddenly occur in the designer's mind with definite awareness of assured suitability for a particular new development

Synthesis From a Flash of Insight

Pablo Picasso welded a bicycle seat and handlebars together for Bull's Head in 1942

Barriers to Synthesis

1. Knowledge	Lack of scientific knowledge base to draw ideas
2. Perceptual	Stereotyping elements in a proposed solution or in the problem itself
	Delimiting the problem by imagining additional constraints beyond the actual design specifications
	Information overload can prevent one from developing an accurate understanding of the goals
3. Emotional	Fear of failure and the need for approval
	A need to follow prescribed paths and methodologies
	A tendency to accept the status quo in problem formulation and solution
	Impatience
4. Cultural	The company culture may discourage new ways of performing routine tasks
5. Expressive	One can not communicate effectively with oneself and with others

Bloom's Taxonomy

Bloom's taxonomy named after Benjamin Bloom 1913—1999 is a set of three hierarchical models used to classify educational learning objectives into levels of complexity and specificity

- The cognitive domain (knowledge-based)
  - 1956: knowledge, comprehension, application, analysis, synthesis, and evaluation
  - 2001: remember, understand, apply, analyze, evaluate, and create
- The affective domain (emotion-based)
  - 1964: receiving, responding, valuing, organizing, and characterizing
- The psychomotor domain (action-based)
  - 1966 by Elizabeth Jane Simpson, University of Illinois: perception, set, guided response, mechanism, and complex overt response, plus adapting and originating

Knowledge Dimensions

Tacit knowledge can be distinguished from explicit knowledge in three major areas:

- Codifiability and mechanism of transferring knowledge
- Main methods for the acquisition and accumulation
- Potential of aggregation and modes of appropriation

The SECI model of knowledge dimensions is a model of knowledge creation explaining how tacit and explicit knowledge are converted into organizational knowledge, originally developed by Ikujiro Nonaka in 1990 and refined by Hirotaka Takeuchi, coauthor of their 1986 paper that introduced scrum

The SECI model distinguishes four knowledge dimensions:

- Socialization (tacit to tacit)
- Externalization (tacit to explicit)
- Combination (explicit to explicit)
- Internalization (explicit to tacit)

Tacit

S   **E**

Tacit   Explicit

I   **C**

Explicit
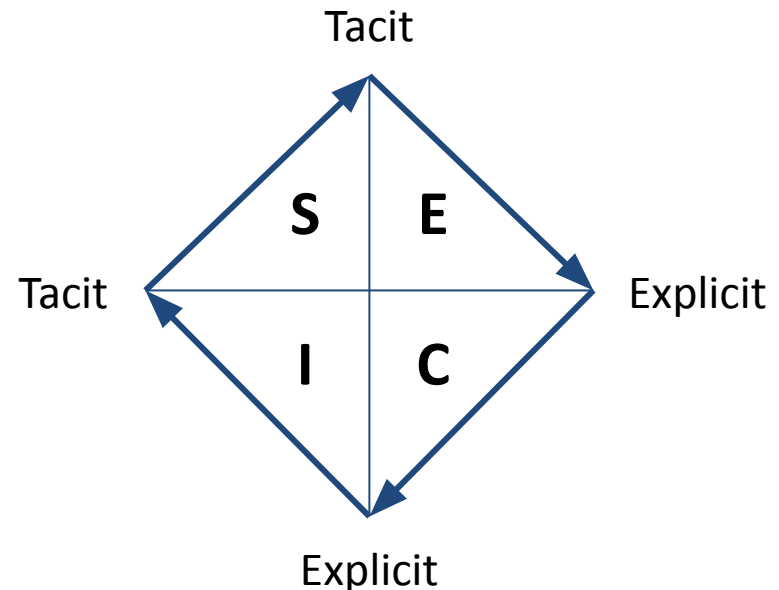
Design by Serendipity

- Engineers can not depend on unplanned, accidental occurrences to provide solutions to technical problems
- Still, one must be prepared to take advantage of a serendipity and transform it into a serendipitous discovery, e.g.,
    - Newton's law of universal gravitation by Isaac Newton 1643—1727
    - Lysozyme and benzylpenicillin by Alexander Fleming 1881—1955
    - Microwave oven by Percy Spencer 1894—1970 of Raytheon
    - Teflon or polytetrafluoroethylene (PTFE), 1938
    - Velcro, 1941
    - Slinky, 1943
    - Post-it, 1968 and 1974
    - Gore-Tex (expanded PTFE), 1969
    - EnChroma color blind glasses, 2015
- Such preparation requires an extensive knowledge of science, mathematics, and engineering fundamentals together with curiosity, analytical skills, and imagination
- Pasteurization was named after Louis Pasteur 1822—1895, "In the fields of observation, chance favors only the prepared mind."

Solution Without a Problem
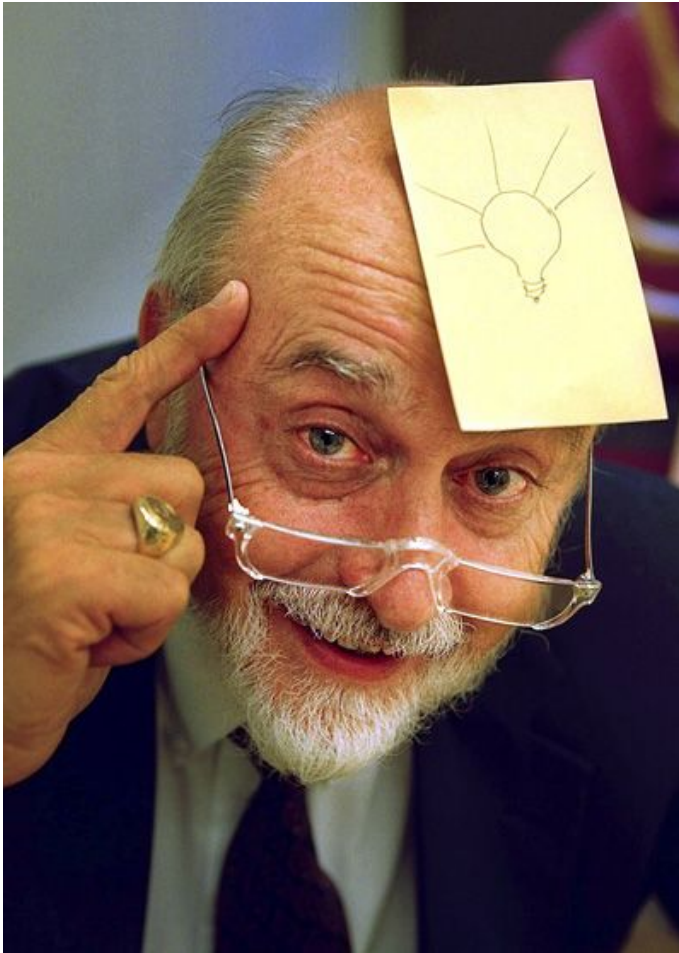
- In 1968, Spencer Silver 1941—2021 at 3M in the US attempting to develop a super-strong adhesive accidentally created a "low-tack," reusable, pressure-sensitive adhesive
- In 1974, Art Fry who had attended one of Silver's seminars came up with the idea of using the adhesive to anchor his bookmark in his hymn book, whereas Alan Amron has claimed to disclose his 1973 invention to 3M
- The original Post-it notes' yellow color was chosen by accident, as the lab next-door to the Post-it team had only yellow scrap paper
- In 1979, the rollout of Post-it began
- Although the patent expired in 1997, "Post-it" and the original notes' distinctive yellow color remain registered trademarks of 3M

Reimagination

- Alfred W. Fielding 1917—1994 and Marc A. Chavannes 1896—1994 were attempting to create a three-dimensional plastic wallpaper but no one seemed interested in their idea
- They decided to use it as insulation in greenhouses to keep the plants warm but that idea wasn't successful either
- In 1957, they found what they made could be used as packing material
- Sealed Air was founded in 1960 based on this invention of Bubble Wrap (US3,142,599)

Creativity Stimulation Techniques

1. [Brainstorming](#)
2. [Brainwriting](#)
3. Biologically inspired engineering
   - [Biomimetics](#) coined by [Otto Schmitt](#) 1913—1998
   - [Bionics](#), a portmanteau from biology and electronics, coined by [Jack E. Steele](#) 1924—2009
   - [Biomimicry](#) popularized by [Janine Benyus](#)
4. [Checklisting](#) trigger questions and words
5. [Synectics](#) stimulates thought processes by joining different and apparently irrelevant elements, developed in the 1950s by [George M. Prince](#) 1918—2009 and [William J.J. Gordon](#) 1919—2003 at the [Arthur D. Little](#) Invention Design Unit
6. Analogies, adaptation, and duplicated design
7. Fresh perspective
8. Inversion of less effective ways, e.g., a hacksaw cuts the wood held still vs. the wood moves against a table saw
9. Idea diagrams such as [mind map](#) or [concept map](#)

Examples of Trigger Questions

- What is wrong with it?
- What is similar to it?
- Why is it necessary?
- What can be eliminated?
- What materials could be used?
- How can its assembly be improved?
- Can any components be eliminated?
- Is it unsafe?

- What does it fail to do?
- In what way is it inefficient?
- In what way is it costly?
- Who will use or operate it?
- Are there any other applications?
- What is it not?
- Can it be misused?

Categories of Trigger Words

Change quantity	Add, assemble, cheapen, combine, condense, converge, deepen, elongate, fasten, fractionate, increase, lessen, lengthen, lighten, lower, reduce, shorten, stretch subtract, thin, widen
Change order	Arrange, interchange, interweave, reverse, stratify
Change time	Endure, quicken, renew, slow, synchronize
Change state	Alter, cool, curve, destroy, dry, energize, harden, heat, liquefy, lubricate, moisten, pulverize, roughen, smooth, soften, solidify, straighten, vaporize
Change relative motion or position	Accelerate, animate, attract, direct, encircle, influence, lift, lower, oscillate, repel, rotate, substitute

Morphological Analysis

- Morph: (1940s) from Greek morphē 'form'
  (1990s) element from metamorphosis, a biological process by which an animal physically develops after birth or hatching
- Morph is a series of clay stop-motion comedy animations, named after the main character initially seen in 1977 interacting with Tony Hart 1925—2009 on several of his British children television programs
- Morphological analysis is a method developed by Fritz Zwicky 1898—1974 for systematically structuring and investigating the total set of relationships contained in a multi-dimensional, non-quantifiable problems where causal modeling and simulation do not work

Morphological Chart

Joining preliminary ideas or subsolutions together to form total design concepts

Desired functions or goals	Table lamp Partial concepts or means to achieve each goal			
Stability	Large base	Weighted base	Tie-down straps	
Adjustable height	Flexible neck	Sectional designs	Adjustable legs	
Lightweight	Use lightweight materials	Use less materials		

Lesson 7 Summary

- Synthesis is the formation of a whole from a set of building blocks or constituent parts, appropriate ways to create a product or system that solves a problem
- There are numerous barriers to creativity, including knowledge, perceptual, emotional, cultural, and expressive barriers
- One must be prepared to transform accidents into design solutions
- Techniques and strategies for stimulating creativity and overcoming barriers to imagination include brainstorming, brainwriting, bionics, checklisting, synectics, analogies, adaptation, fresh perspective, inversion, and idea diagrams
- Use a morphological chart to perform synthesis by joining preliminary ideas or subsolutions together to form total design concepts

Lack of Footwear

[The World Shoe](#)

- More than 1.5 billion people are infected with parasitic diseases transmitted through contaminated soil that could be prevented by wearing proper footwear with an [antimicrobial](#) agent
- There are many diseases contracted and spread due to bare feet and the inability of the poor to obtain shoes
- The most prevalent among them are [soil-transmitted helminth](#) (STH), the most prevalent of neglected tropical diseases and is responsible for significant morbidity and, indirectly, mortality in poor developing countries
  - [Hookworm](#) is an intestinal parasite that is caused by direct contact with soil contaminated with larvae, or by ingestion of the larvae
  - An estimated 576-740 million people in the world are infected with hookworm
- Up to 10% of barefoot populations suffer from [podoconiosis](#), one of the world's most neglected tropical diseases
- With the recent increase in cases and severity of [Ebola](#), walking barefoot could contribute to the spread of this deadly disease

Eco-friendly Expandable Shoes

Kenton Lee founded the nonprofit [Because International](#) to get "The Shoe That Grows" to as many kids as possible who are in desperate need of footwear to protect their feet

[GroFive](#) Expandals are commercial versions of "The Shoe That Grows" five sizes—the small lasts from kindergarten to fourth grade and the large from fifth grade through ninth

Unattended Cooking

HOUSE FIRE STATS

357,000
HOME STRUCTURE FIRES PER YEAR

12,800
INJURIES FROM HOUSE FIRES PER YEAR

#1
cause of house fires is cooking equipment

7
people die in house fires
EVERY DAY

$1.1 BILLION
in property damage per year from cooking equipment resulting in a house fire

EVERY **85** SECONDS
ONE HOUSE FIRE IS REPORTED

Retrofittable Smart Stove Sensor

Inirv React

LED INDICATOR
LED ring indicates device status and motion detection

WI-FI
Allows for status alerts and software updates

GAS DETECTION
Reliable detection of flammable gases

SMOKE DETECTION
Detects smoke and dangerous situations before escalation

ALARM
Signals when a hazard is detected

BLUETOOTH
Efficiently keeps sensor and knob units connected at all times

MOTION DETECTION
Identifies periods of prolonged absence

EASY MOUNTING
No tools necessary for installation

RECHARGEABLE BATTERIES
Easily removable and replaceable batteries

HEAT & CHEMICAL RESISTANT
Made of durable and high quality materials

- The Inirv React sensor unit houses the gas, smoke, and motion detectors that monitor kitchen's environment
- If it senses high levels of smoke or gas, or if the motion sensor recognizes that the stove was left on accidentally, this sensor unit signals the knob units via Bluetooth technology to turn off burners

Retrofittable Smart Stove Knobs

LED INDICATOR
LED quadrants indicate timer setting

TIMER
Communicates with the motion sensor to detect when a stove is left on accidentally

FLEXIBLE DESIGN
Conveniently use as a new knob or attach current knob to unit

BACKLIGHTS
Indicate active burners and device status

WI-FI
Allows for remote temperature control

BLUETOOTH
Efficiently keeps sensor and knob units connected at all times

TOUCH SENSOR
Sleek user interface allows for timer adjustment and cancellation of alarms

UNIVERSAL ADAPTORS
Allow for compatibility with virtually any gas or electric stove

RECHARGEABLE BATTERIES
Easily removable and rechargeable batteries

HEAT & CHEMICAL RESISTANT
Made of durable and high quality materials

- The Inirv React knob units turn burners off when a hazard is detected by the sensor unit
- Attach these units to stove and use them as new knobs, or attach existing knobs back onto these units with the supplied adapter.
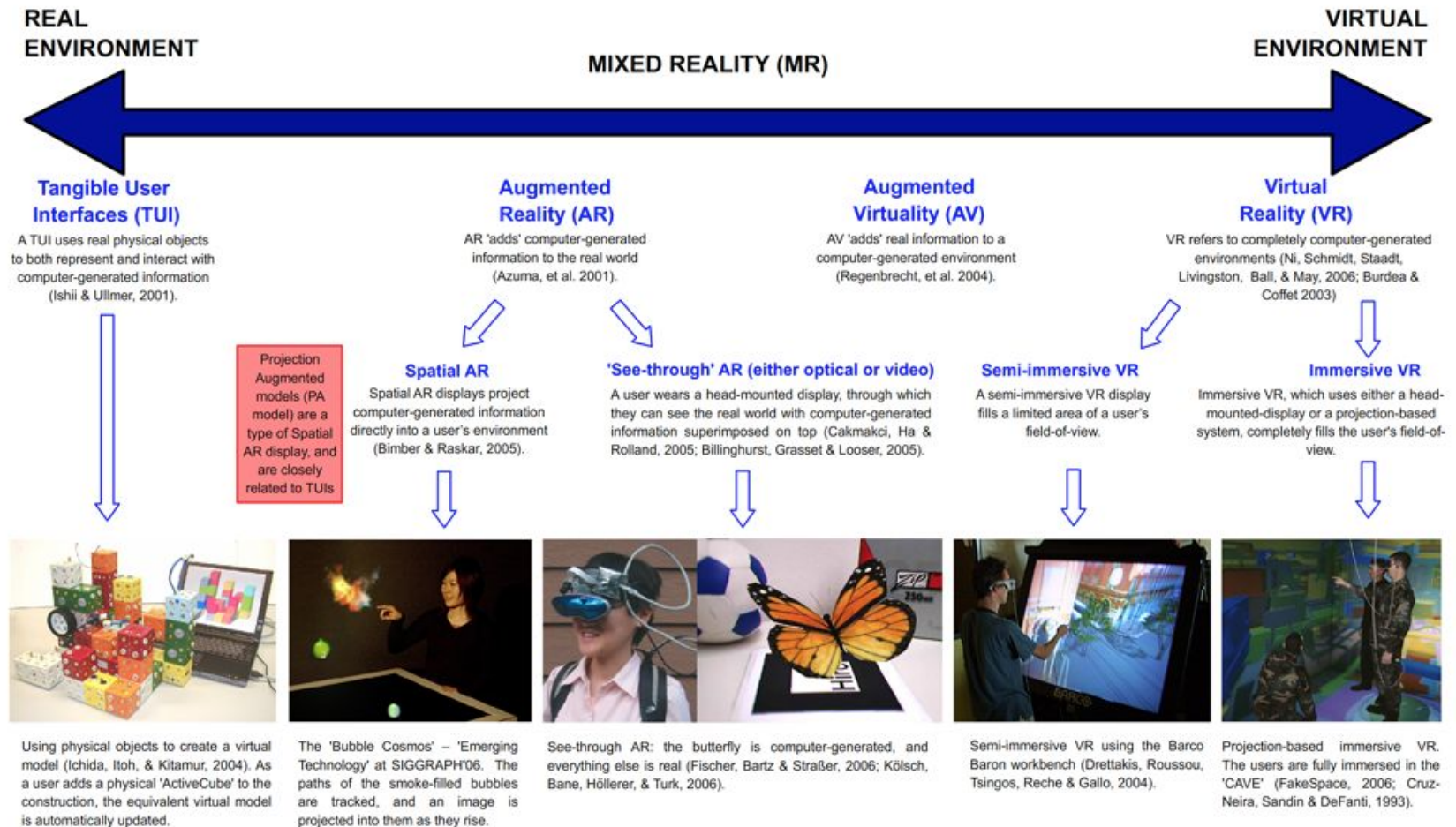
Retrofittable Smart Stove App
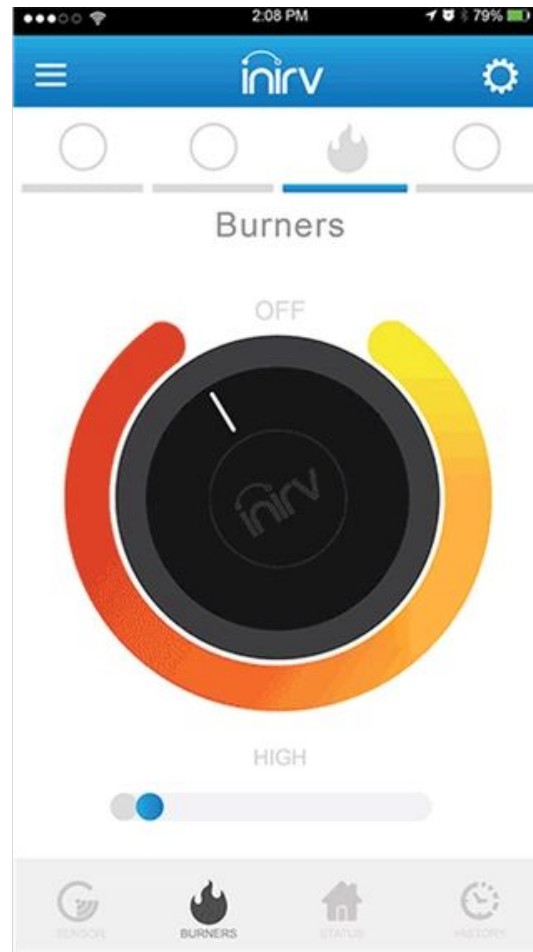
- The smartphone app allows users to easily monitor kitchen environment and status of the stove
- The user receives alerts if a hazard is detected or if the user left the house with the stove on
- The user can turn the stove off or change the temperature right from the phone

Reality-to-Virtuality Continuum

https://upload.wikimedia.org/wikipedia/en/d/d2/Adapted_milgrams_VR-AR_continuum.png

REAL ENVIRONMENT — **VIRTUAL ENVIRONMENT**

MIXED REALITY (MR)

Tangible User Interfaces (TUI)
A TUI uses real physical objects to both represent and interact with computer-generated information (Ishii & Ullmer, 2001).

Augmented Reality (AR)
AR 'adds' computer-generated information to the real world (Azuma, et al. 2001).

Augmented Virtuality (AV)
AV 'adds' real information to a computer-generated environment (Regenbrecht, et al. 2004).

Virtual Reality (VR)
VR refers to completely computer-generated environments (Ni, Schmidt, Staadt, Livingston, Ball, & May, 2006; Burdea & Coffet 2003)

Projection Augmented models (PA model) are a type of Spatial AR display, and are closely related to TUIs

Spatial AR
Spatial AR displays project computer-generated information directly into a user's environment (Bimber & Raskar, 2005).

'See-through' AR (either optical or video)
A user wears a head-mounted display, through which they can see the real world with computer-generated information superimposed on top (Cakmakci, Ha & Rolland, 2005; Billinghurst, Grasset & Looser, 2005).

Semi-immersive VR
A semi-immersive VR display fills a limited area of a user's field-of-view.

Immersive VR
Immersive VR, which uses either a head-mounted-display or a projection-based system, completely fills the user's field-of-view.

Using physical objects to create a virtual model (Ichida, Itoh, & Kitamur, 2004). As a user adds a physical 'ActiveCube' to the construction, the equivalent virtual model is automatically updated.

The 'Bubble Cosmos' – 'Emerging Technology' at SIGGRAPH'06. The paths of the smoke-filled bubbles are tracked, and an image is projected into them as they rise.

See-through AR: the butterfly is computer-generated, and everything else is real (Fischer, Bartz & Straßer, 2006; Kölsch, Bane, Höllerer, & Turk, 2006).

Semi-immersive VR using the Barco Baron workbench (Drettakis, Roussou, Tsingos, Reche & Gallo, 2004).

Projection-based immersive VR. The users are fully immersed in the 'CAVE' (FakeSpace, 2006; Cruz-Neira, Sandin & DeFanti, 1993).

Artificial Intelligence (AI)

Artificial Intelligence (AI) refers to the theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages

- One Hundred Year Study on AI
  https://ai100.stanford.edu
  https://ai100.stanford.edu/2016-report
- Isaac Asimov's Laws of Robotics
  https://www.brookings.edu/opinions/isaac-asimovs-laws-of-robotics-are-wrong
  https://www.technologyreview.com/s/527336/do-we-need-asimovs-laws
- Eight tenets released by Partnership on AI
  http://www.partnershiponai.org
- IEEE global initiative for ethical considerations in artificial intelligence and autonomous systems http://standards.ieee.org/develop/indconn/ec/autonomous_systems.html

Intelligence Augmentation (IA) refers to the effective use of information technology in augmenting human intelligence

- https://www.research.ibm.com/cognitive-computing/ostp/rfi-response.shtml
- https://www.technologyreview.com/s/601678/augmenting-human-intelligence

Cognitive IoT

[Cognitive IoT](#) is the use of cognitive computing technologies in combination with data generated by connected devices and the actions those devices can perform

- Provides capabilities for IoT apps and solutions to have cognition
- Allows IoT apps and solutions to exhibit characteristics such as
  - Deep [natural language](#) understanding
  - Accurate and evidence-based decisions
  - Relating and linguistic analysis
  - Maps [euphemisms](#) or [colloquial terms](#)
  - Deeper understanding of user intrinsic preferences and characteristics
  - Communicating with resonance
  - Knowledge and relationships discovery
  - Continuous learning

Virtual Assistants

		Amazon Alexa	Apple Siri	Google Assistant	Microsoft Cortana
Device	Laptop	✔	✔	✔	✔
	Tablet	✔	✔	✔	✔
	Smart Phone	✔	✔	✔	✔
	Wearable	✔	✔	✔	✔
	Home	✔	✔	✔	✔
	Car	✔	✔	✔	✔
Platform	Amazon	✔			
	Android	✔		✔	✔
	Chrome			✔	
	iOS	✔	✔	✔	
	Windows				✔

Apple Logo

- The single bite out of the [Apple logo](#) created by [Rob Janoff](#) originally served a very practical purpose: scale
- The size of the bite showed that the shape was an apple, not a cherry or any other vaguely round fruit
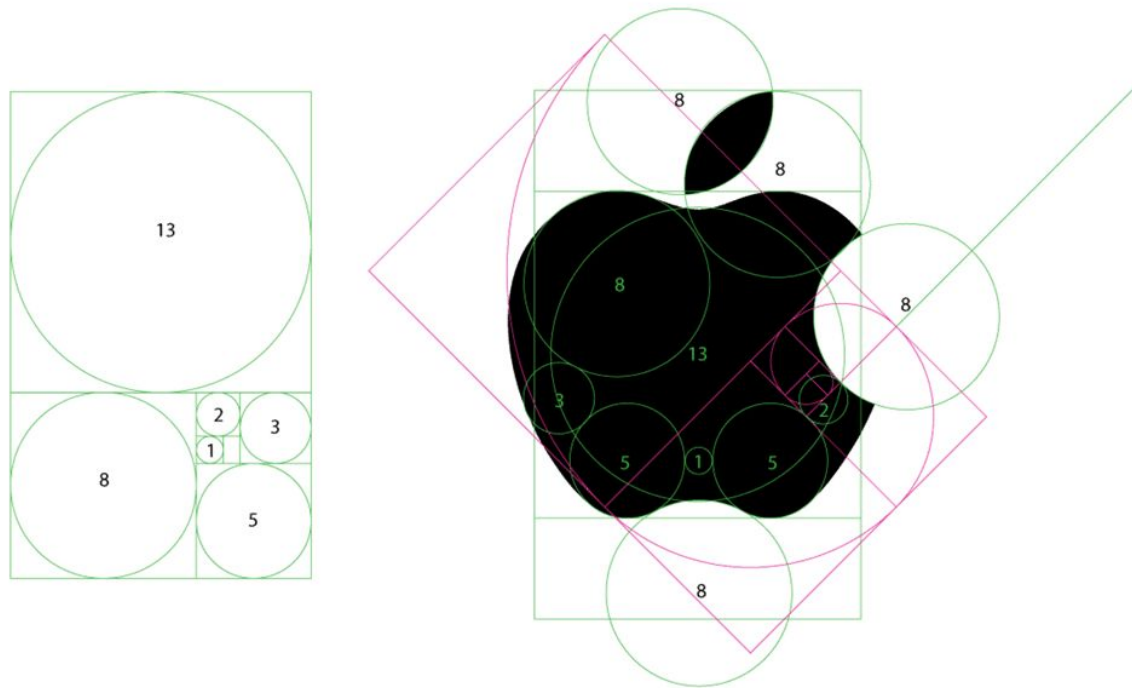
Biomimetics or Biomimicry

The towers of Sagrada Família were inspired by the structure of sedum acre

Hingeless Flapping Devices

The [Flectofin](#) using [fiber-reinforced plastic](#) (FRP) was derived from the kinematics of the valvular pollination mechanism in the [strelitzia](#) or bird-of-paradise flower
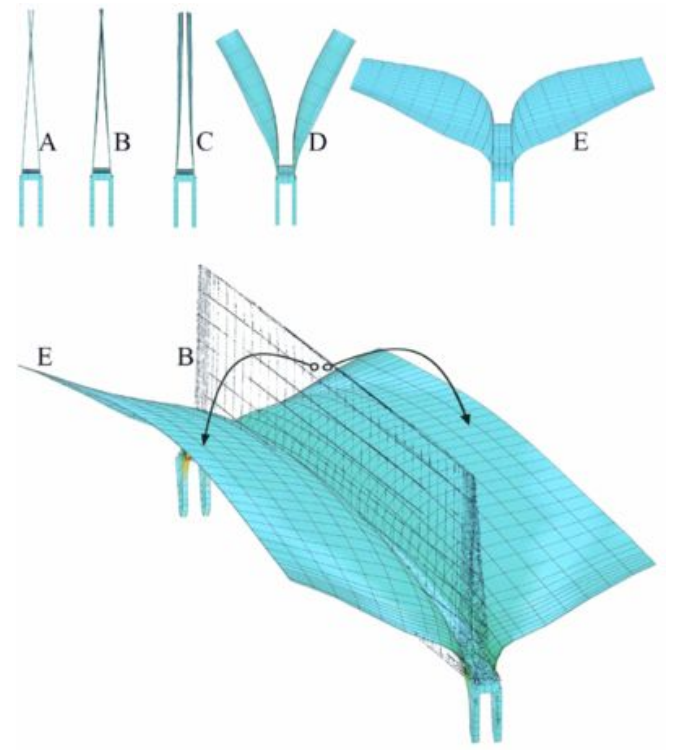
Low-Noise Wind Turbine Blades

The Siemens [DinoTail](#) technology is an aeroacoustic noise augmentation tool patterned after the trailing fringe of an owl's wing during flight

Natural Computing

- [Natural computing](#) encompasses three classes of methods
  - Take inspiration from nature for the development of novel problem-solving techniques
  - Use computers to synthesize natural phenomena
  - Employ natural materials (e.g., molecules) to compute
- The main fields of research are
  - Artificial neural networks
  - Evolutionary algorithms
  - Swarm intelligence
  - Artificial immune systems
  - Fractal geometry
  - Artificial life
  - DNA computing
  - Quantum computing

Evolved Antennas

- An evolved antenna is designed by evolutionary algorithms to automatically find novel antenna designs that are more effective than manual design
- The 2006 NASA Space Technology 5 (ST5) X-band spacecraft antennas such as STS5-3-10 (left) for the best initial gain pattern and STS-33-142-7 (right) for the revised specifications [Source]
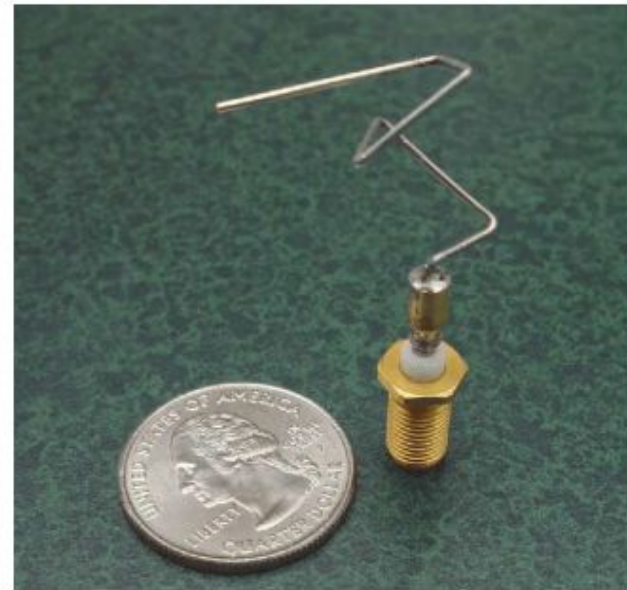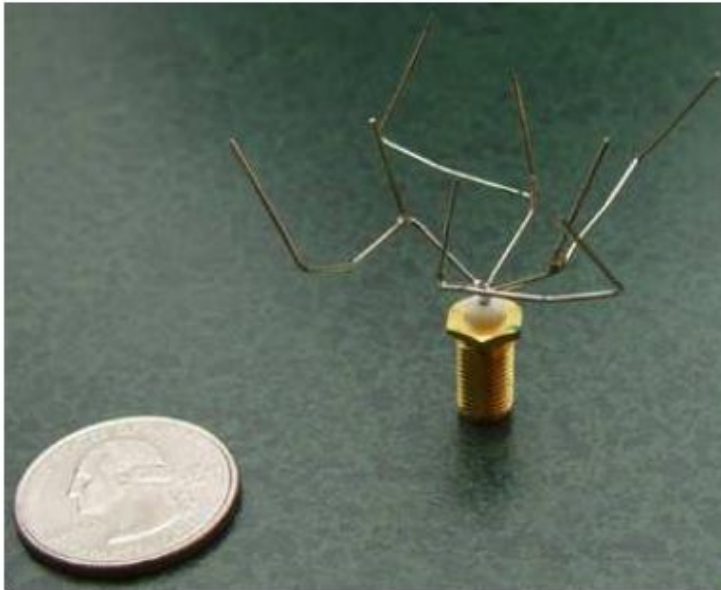
Inverted Umbrella

Reversible umbrella US7484518B2 2009-02-03 was invented by Noah L. Brader, The InBrella Group Ltd.
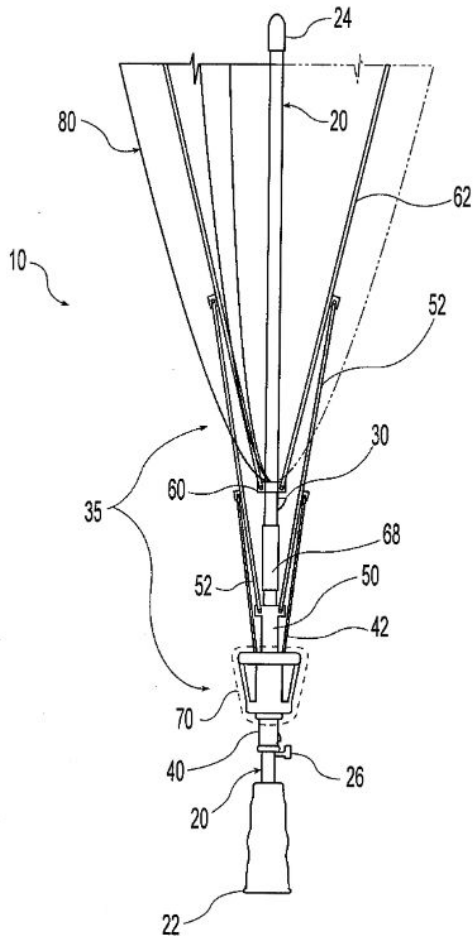
IoT Mind Map
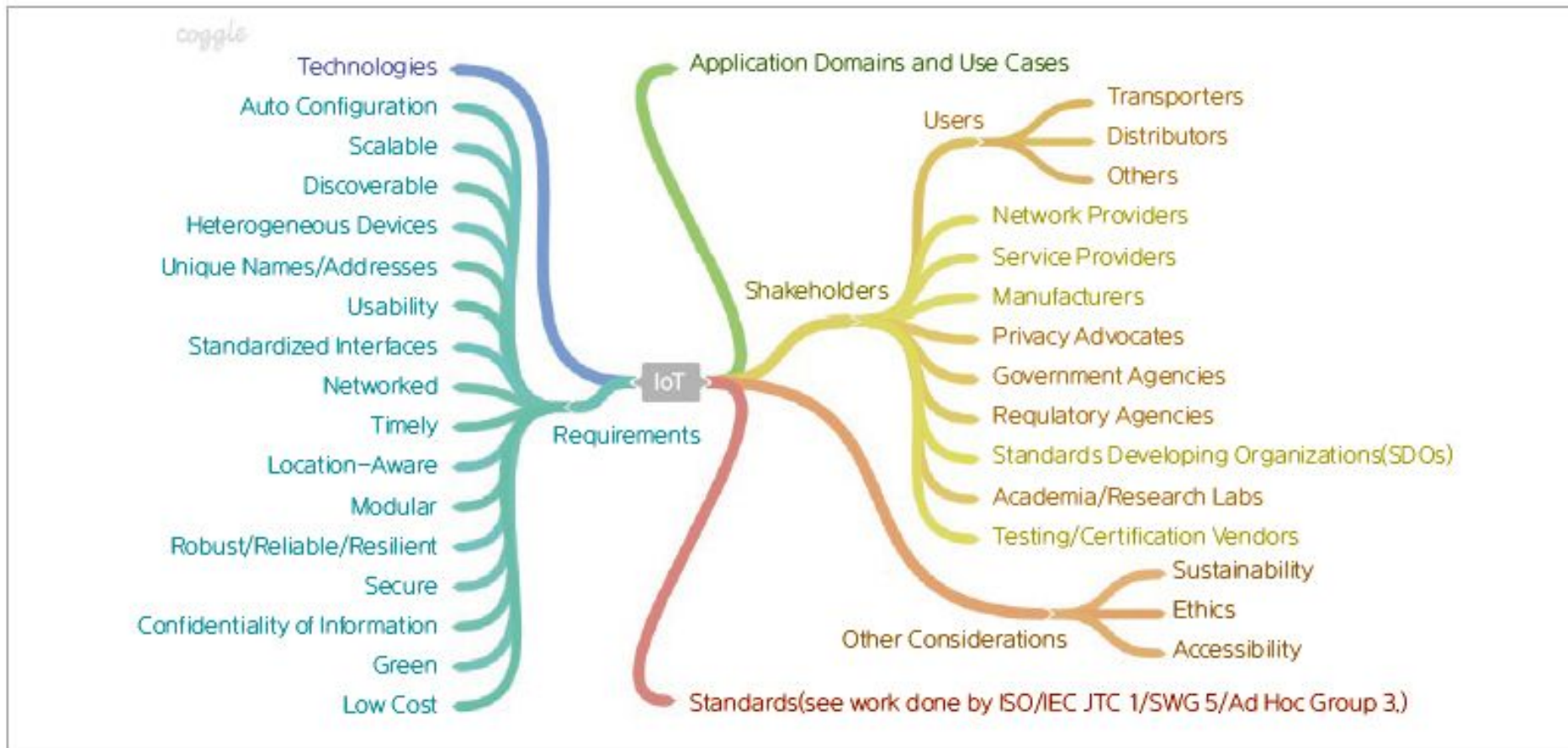
Cloud Computing Services

Cloud Computing

IaaS (**Infrastructure** as a Service) — G2 Crowd Reviews
- Amazon Web Services (AWS) Elastic Compute Cloud (EC2), Simple Storage Service (S3), and Virtual Private Cloud (VPC); Google Compute Engine, Microsoft Azure, DigitalOcean, Green Cloud, Linode, Netrepid, Nimbix, Rackspace
- Software: Apache CloudStack, OpenStack

PaaS (**Platform** as a Service)
- Apiant, ARTIK Cloud (by Samsung), AWS IoT, Ayla Networks, C3 IoT, Cumulocity, EVRYTHNG, GE Predix, Google Cloud IoT, Heroku, InterDigital IoT, Keen IO, Microsoft IoT, OpenSensors, PTC ThingWorx, relayr, RoboMQ (by IBM), Watson IoT (and IBM Bluemix), Xively by LogMeIn
- Free account: Beebotte, Blynk, Carriots, Cayenne (by myDevices), Eclipse IoT, Exosite, Fluxtream, GroveStreams, IFTTT, Instapush, Ionic, PrivateEyePi, Pushbullet, remot3.it, Sparkfun, Stringify, Temboo, ThingSpeak (by ioBridge), WebIOPi, Yeelink (in Chinese), Zapier

SaaS (**Software** as a Service)
- August, Awair, AWS Greengrass, Azumio, Cardiio, Fitbit, Lumo, MyQ (Chamberlain, LiftMaster, Raynor, Sears/Craftsman), Iris (by Lowe's), Nest (by Google), NIU (by NodeOn), Nokia Health (formerly Withings), Particle, Philips Hue, Qardio, Runtastic, Samsara, Schlage Connect, SmartThings (by Samsung), Wemo (by Belkin), Wink

Other Cloud Computing Services
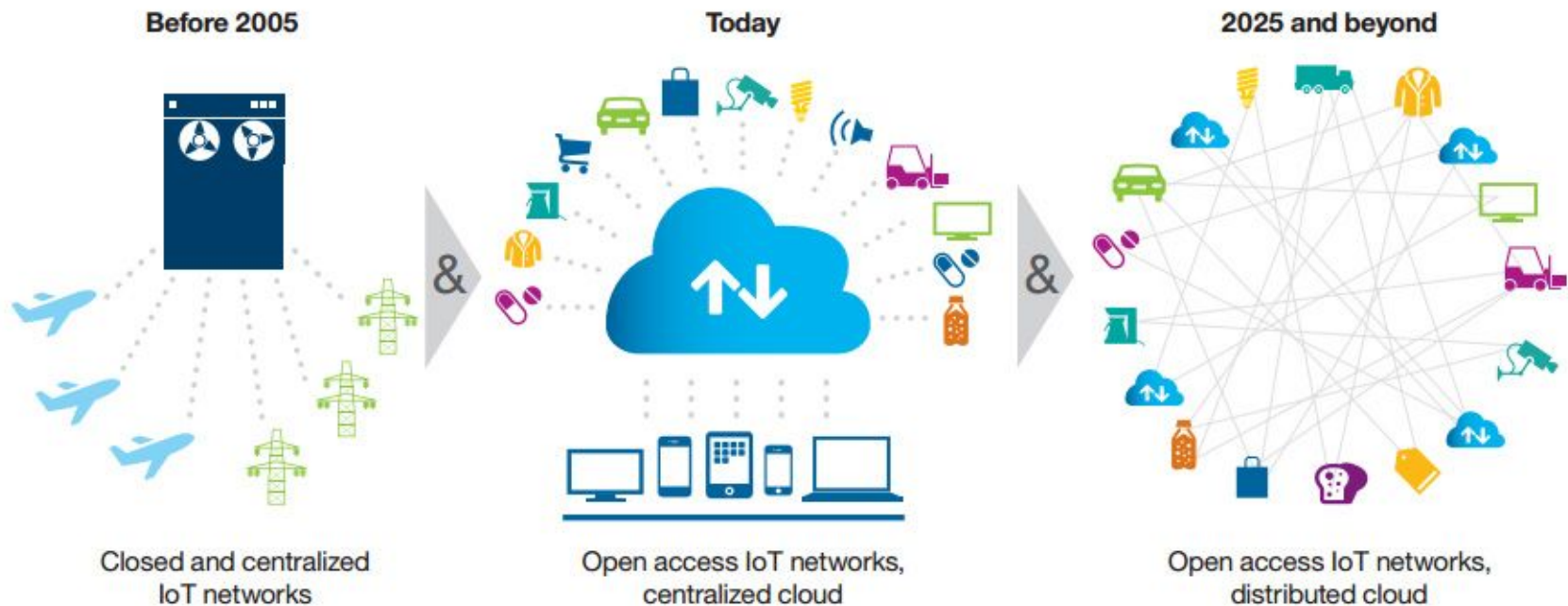
- AaaS (**Acceleration** as a Service) for accessing accelerators such as graphics processing units (GPUs) or field-programmable gate arrays (FPGAs) in the Cloud
- BaaS (**Blockchain** as a Service) to facilitate easy adoption of blockchain technologies for businesses
- CaaS (**Container** as a Service) for managing and deploying containers, applications, and clusters through container-based virtualization
- CaaS (**Content** as a Service) for subscribing contents on demand
- DaaS (**Data** as a Service) for using the data in the Cloud
- DBaaS (**Database** as a Service) for installing and maintaining the database
- FaaS (**Function** as a Service) for serverless microservices
- MaaS (**Machine** as a Service) rather than the sale of the machine hardware itself
- MLaaS (**Machine Learning** as a Service) for using machine learning tools
- SaaS (**Storage** as a Service) for storing the data in the Cloud

Distributed Ledger Technology

- A [distributed ledger](#) technology (DLT) is a consensus of replicated, shared, and synchronized digital data geographically spread across multiple sites, countries, or institutions
- There is no central administrator or centralized data storage
- A peer-to-peer network is required as well as consensus algorithms to ensure replication across nodes is undertaken
  - Could be used to track and verify any kind of digital exchange
  - Provides a way to track the unique history of individual devices, by recording a ledger of data exchanges between it and other devices, web services, and human users
  - Enables smart devices to become independent agents, autonomously conducting a variety of transactions, e.g., an autonomous vehicle that can diagnose, schedule, and pay for its own maintenance
- One form of distributed ledger design is the [blockchain](#) system, which can be either public or private

Blockchains and IoT

http://www.postscapes.com/blockchains-and-the-internet-of-things

Before 2005 — Closed and centralized IoT networks

Today — Open access IoT networks, centralized cloud

2025 and beyond — Open access IoT networks, distributed cloud

Internet Top-Level Domains

https://en.wikipedia.org/wiki/List_of_Internet_top-level_domains

- The Internet Assigned Numbers Authority (IANA) maintains the official list of Top-Level Domains (TLDs)
- Seven original TLDs (.com, .org, .net, .int, .edu, .gov, and .mil) were created in 1985, predating the 1998 creation of the Internet Corporation for Assigned Names and Numbers (ICANN)
- The first registered two-letter country-code TLDs (ccTLDs) were .us, .uk, and .il in 1985
- Country-code TLDs can be restricted to registration by individuals or companies in the countries although some are marketed as global domains for domain hack or URL Shortening

Domain Hacks

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

- .ai Anguilla, a British Overseas Territory (aeva.ai, aeye.ai, ariv.ai, bluehexagon.ai, c3.ai, clearview.ai, comma.ai, deep6.ai, deeplearning.ai, deepsig.ai, doc.ai, fast.ai, graphen.ai, hash.ai, iEngage.ai, khealth.ai, kodiak.ai, krisp.ai, kriya.ai, lunchclub.ai, noodle.ai, nuro.ai, obita.ai, onnx.ai, pennylane.ai, people.ai, pony.ai, reclaim.ai, rosebud.ai, rul.ai, sensity.ai, standard.ai, suki.ai, swim.ai, viz.ai, wavecomp.ai, wit.ai, x.ai, xanadu.ai, xnor.ai)
- .be Belgium (youtu.be)
- .cc Cocos (Keeling) Islands of Australian territory (arduino.cc, seeed.cc)
- .co Colombia (apteo.co, climacell.co, coolers.co, elastic.co, fontpair.co, g.co, mirror.co)
- .cx Christmas Island of Australian territory (mcorp.cx, mothership.cx)
- .me Montenegro (diagnose.me, kano.me, lumen.me, mayku.me, me.me)
- .gl Greenland (deck.gl, kepler.gl, luma.gl, open.gl), .in India (lnkd.in)
- .io The British Indian Ocean Territory (aira.io, atom.io, blynk.io, crossbar.io, mqtt.eclipseprojects.io, freeboard.io, github.io, hackster.io, otonomo.io, particle.io, prototypr.io, pynq.io, tessel.io)
- .it Italy (adafru.it), .ly Libya (bit.ly, plot.ly, visual.ly), .py Paraguay, .se Sweden (curl.se)
- .sh The British Overseas Territory of Saint Helena, Ascension, and Tristan da Cunha (brew.sh)
- .to Tonga (cr.yp.to, dev.to, p.ota.to)

Generic TLDs

https://en.wikipedia.org/wiki/Generic_top-level_domain

- 2011-05-30 and 2012-06-04: ICANN published *Applicant Guidebook* for the New Generic TLD (gTLD) program [FAQs] for a new phase of diversity in languages, participants, and business models on the internet, promoting competition and consumer choice

- 2014-06-02: .xyz became available to the general public from registries such as gen.xyz and CentralNic

- 2015-10-02: Google was reorganized into Alphabet Inc., a holding company that uses abc.xyz as its website

- Other examples: ree.auto, voyage.auto, levels.fyi, coinmint.one, spectral.space, aurora.tech, starship.xyz

- DomainStats.com tracks and analyzes TLD counts, e.g., .com, .net, .org, .info, .xyz, .top, .us, .loan, .biz, .wang (Web in Chinese is pronounced as wǎng), .win, .club, .online, .vip, .mobi, .site, .bid, .tech (aurora.tech), .men