A

Abstraction

Fields of Study: Computer science; Data management; Data analytics

ABSTRACT

Abstraction is a strategy for managing the complex details of computer systems. It involves simplifying the instructions that a user gives to a computer system in such a way that different systems, provided they have the proper underlying programming, can "fill in the blanks" by supplying the levels of complexity that are missing from the instructions.

KEY CONCEPTS

algorithm: a "recipe" of programming code instructions designed to manipulate and interpret input data to extract meaning for a specific purpose

binary code: a system of coding in which 0 and 1 (the only digits of binary, or base-2, counting) are implemented to send high- and low-voltage signals through the processing system of a computer in accord with Boolean arithmetical logic

Boolean logic: essentially the logic of combinations of identical and opposite values, such as on and off, typically represented as AND , OR, and NOT. For example, for any two input values x and y, the output can be determined as the Boolean sum of x AND y, x OR y, NOT-x AND y, or x AND NOT-y

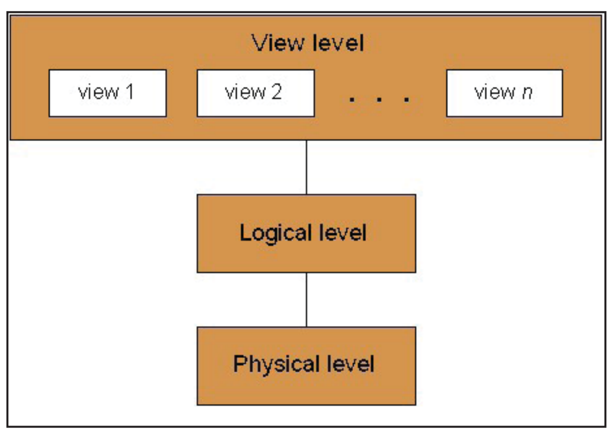
debugging: the identification and correction of points of failure in a computer program's code

SUMMARY

In computer science, abstraction is a strategy for managing the complex details of computer systems. Broadly speaking, it involves simplifying the instructions that a user gives to a computer system in such a way that different systems, provided they have the proper underlying programming, can "fill in the blanks" by supplying the levels of complexity that are missing from the instructions. For example, most modern cultures use a decimal (base 10) positional numeral system, while digital computers read numerals in binary (base 2) format. Rather than requiring users to input binary numbers, in most cases a computer system will have a layer of abstraction that allows it to translate decimal numbers into binary format.

There are several different types of abstraction in computer science. Data abstraction is applied to data structures in order to manipulate bits of data efficiently and meaningfully. Control abstraction is similarly applied to actions via control flows and subprograms. Language abstraction, which develops separate classes of languages for different purposes—modeling languages for planning assistance, for instance, or programming languages for writing software, with many different types of programming languages at different levels of abstraction—is one of the fundamental examples of abstraction in modern computer science.

The core concept of abstraction is that it ideally conceals the complex details of the underlying system, much like the desktop of a computer or the graphic menu of a smartphone conceals the complexity involved in organizing and accessing the



Data abstraction levels of a database system. Image via Wikimedia Commons. [Public domain.]

many programs and files contained therein. Even the simplest controls of a car—the brakes, gas pedal, and steering wheel—in a sense abstract the more complex elements involved in converting the mechanical energy applied to them into the electrical signals and mechanical actions that govern the motions of the car.

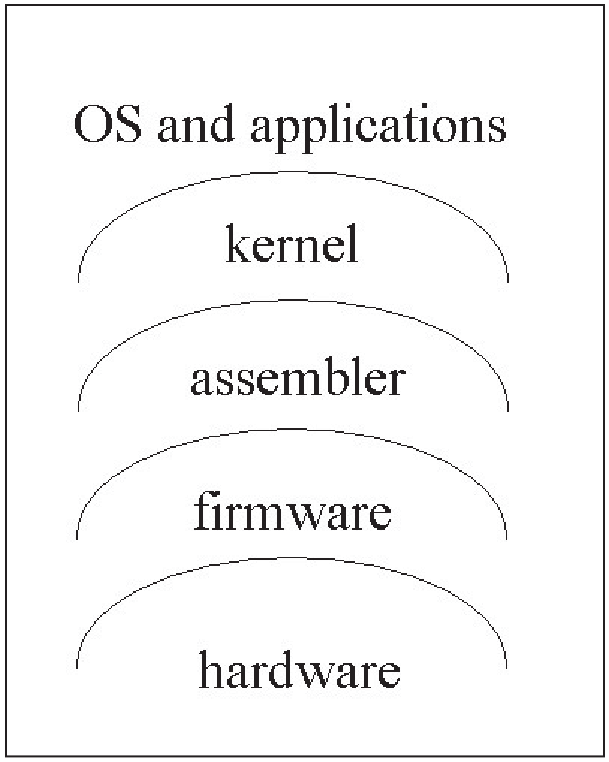
BACKGROUND

Even before the modern computing age, mechanical computers such as the abacus and the slide rule abstracted, to some degree, the workings of basic and advanced mathematical calculations. Language abstraction has developed alongside computer science as a whole; it has been a necessary part of the field from the beginning, as the essence of computer programming involves translating natural-language commands such as "add two quantities" into a series of computer operations. Any involvement of software at all in this process inherently indicates some degree of abstraction.

The levels of abstraction involved in computer programming can be best demonstrated by an exploration of programming languages, which are grouped into generations according to degree of abstraction. First-generation languages are machine languages, so called because instructions in these languages can be directly executed by a computer's central processing unit (CPU), and are written in binary numerical code. Originally, machine-language instructions were entered into computers directly by setting switches on the machine. Second-generation languages are called assembly languages, designed as shorthand to abstract machine-language instructions into mnemonics in order to make coding and debugging easier.

Third-generation languages, also called high-level programming languages, were first designed in the 1950s. This category includes older, now-obscure and little-used languages such as COBOL and FORTRAN as well as newer, more commonplace languages such as C/C++ and Java. While different assembly languages are specific to different types of computers, high-level languages were designed to be machine independent, so that a program would not need to be rewritten for every type of computer on the market.

In the late 1970s, the idea was advanced of developing a fourth generation of languages, further



A typical vision of a computer architecture as a series of abstraction layers: hardware, firmware, assembler, kernel, operating system, and applications. Image via Wikimedia Commons. [Public domain.]

abstracted from the machine itself. Some people classify Python and Ruby as fourth-generation rather than third-generation languages. However, third-generation languages have themselves become extremely diverse, blurring this distinction. The category encompasses not just general-purpose programming languages, such as C++, but also domain-specific and scripting languages such as JavaScript.

Computer languages are also used for purposes beyond programming. Modeling languages are used in computing, not to write software, but for planning and design purposes. Object-role modeling, for instance, is an approach to data modeling that combines text and graphical symbols in diagrams that model semantics; it is commonly used in data warehouses, the design of web forms, requirements engineering, and the modeling of business rules. A simpler and more universally familiar form of modeling language is the flowchart, a diagram that abstracts an algorithm or process.

Further Reading

Compagna, Diego, and Stephanie Steinhart. *Monsters, Monstrosities, and the Monstrous in Culture and Society.* Vernon Art and Science Incorporated, 2020.

Esomba, Steve. *Moving Cameras and Living Movies.* Lulu.com, 2013.

Hall, Richard A. *Robots in Popular Culture: Androids and Cyborgs in the American Imagination.* ABC-CLIO, 2021.

Plaitano, Greta, Paolo Villa, and Simone Venturini. *Moving Pictures, Living machines: Automation, Animation, and the Imitation of Life in Cinema and Media.* Mimesis International, 2020.

Smith, Alvy Ray. *A Biography of the Pixel.* MIT Press, 2021.

See also: Artificial Intelligence (AI); Augmented Reality; Avatars and Simulation; Biomechanics; Computer Simulation; Cybernetics; Deepfake; Graphics Technologies; Kinematics; Motion; Proportionality; Robotics; Video Game Design and Programming

Artificial Intelligence and Robotics in Gaming

Fields of Study: Computer science; Computer animation; Biomechanics

ABSTRACT

In many games created for video gaming consoles and computers, artificial intelligence (AI) and robotics are essential components of the creation process, the continuity of the gameplay, and as character roles.

KEY CONCEPTS

android: an autonomous robot that is humanoid in appearance and endowed with artificial intelligence (AI)

animation variables (avars): defined variables used in computer animation to control the movement of an animated figure or object

anthropomorphic: resembling a human in shape or behavior; from the Greek words anthropos (human) and morphe (form)

artificial intelligence (AI): the intelligence exhibited by machines or computers, in contrast to human, organic, or animal intelligence

avatar: a token image, either still or animated, designed to represent a particular user or character within a virtual environment

biomimetics: the concept of constructing robots and computer programs to function in the manner of living beings

computer graphic imaging (CGI): a process whereby living beings and location scenes are animated with a high degree of realism for inclusion in movies

humanoid: resembling a human

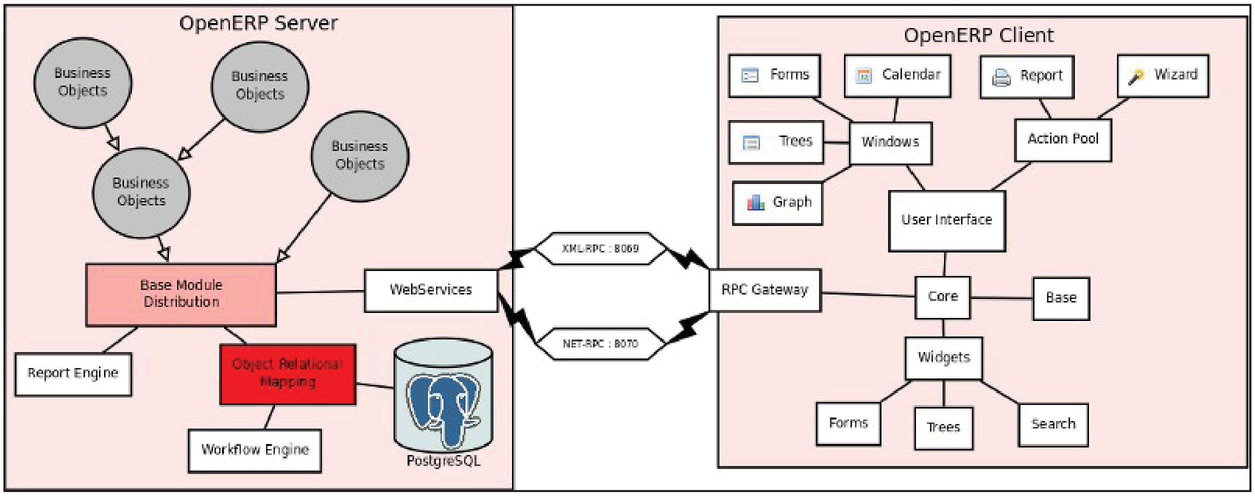
ray tracing: a means of displaying lighting effects according to the geometric relationship between a light source and the desired shape of the object the light's rays are striking

virtual reality: the use of technology to create a simulated world into which a user may be immersed through visual and auditory input

CASE STUDY: HORIZON

In many games created for video gaming consoles and computers, artificial intelligence (AI) and robotics are essential components not only of the game creation process, but also of the viability of the gameplay and as characters in their own right. A number of such games are based on, and essentially mimic, the storylines of the corresponding cinematic releases, aka the movies. However, there are many more that use AI and robotics as central and supporting characters in the actual gameplay. AI is used to generate dialogue and images as computer graphic imaging (CGI) animations, and an AI component built into the basic programming of a game acts to maintain the smooth rollout of scenes and dialogues such that the graphics and the storyline flow as they should.

Photo via iStock/tolgart. [Used under license.]



Software architecture of OpenERP. Image by Nicos interests at en.wikipedia, via Wikimedia Commons.

as a central hub. However, a server can only communicate with so many computers at once. If the server is overloaded with connections, the connections will slow down or stop. This means that computers in the network will lose access to the server. Additionally, each computer in the network has just one path to communicate with the server. This path is limited by bandwidth, which is how much data can be transferred along the connection at one time. The limited bandwidth of a single connection causes a hard limit to how quickly files can be transferred between a central server and a computer.

Servers enable clients to do a particular task and are dedicated to complete only one specific task. (Multiprocessing operating systems, however, can complete multiple tasks at once, referring services as needed.) Because of this, several types of servers exist. File servers manage disk drives and store files. Most users on a network can access and save files to a file server. Print servers allow clients to print to one or several printers. Network servers manage traffic, or activity, on the network. Database servers process information on the database to quickly locate requests. A database is an organized collection of information and data.

A server can manage several clients at the same time, and a client can connect to several servers simultaneously to access different services.

An example of client-server architecture is the internet: A web server provides clients with web pages. For example, when a person accesses his or her bank account from a computer, a client program sends a request to the server at the bank. This request is forwarded on until the correct banking information is retrieved from a database. The bank account information requested is then sent back to the person's client program and is displayed on the computer to the person.

PEER-TO-PEER (P2P) ARCHITECTURE

Peer-to-peer (P2P) architecture is another type of network architecture used to share files across computers. A P2P network is an alternative to client-server architecture.

In a P2P network, there is no central server. Instead, every computer in a network uses specialized software to connect itself to every other computer in the network at the same time. The P2P network software breaks files into tiny data packets. These packets are sent through the network to the computer asking for the file and then are reassembled into a copy of the original file.

P2P networks are most useful when more than one computer in the network contains a file. In this circumstance, multiple computers will send packets of data to the computer asking for the file over their own connections, providing an extremely fast download rate. The process of providing a file for download over a P2P network is called seeding, while the process of downloading a file over a P2P network is called leeching.

In a client-server architecture relationship, if a central server fails, the entire network is taken offline until the server can be repaired. The files on

Graphene

Fields of Study: Chemical engineering; Computer engineering

ABSTRACT

Graphene is a fundamental stable form of carbon. Harnessing graphene has led to major advances in electronics and biotechnology. The value of graphene is in its transparency, elasticity, density, flexibility, hardness, resistance, and electric and thermal conductivity. Graphene is a chemical element existing in a physical two-dimensional (2D) state of the atomic scale as a layer of carbon atoms bonded together in a honeycomb lattice. The graphene molecular structure is one atom thick, but one hundred to three hundred times more tensile strength than steel. It conducts heat, electricity and light efficiently and is a major factor in spintronics, affecting the spin of electrons, magnetic movements, and electronic charge, in solid-state devices.

KEY CONCEPTS

carbon: the twelfth element of the periodic table of elements, consisting of atoms having six protons and six neutrons in a nucleus surrounded by six electrons

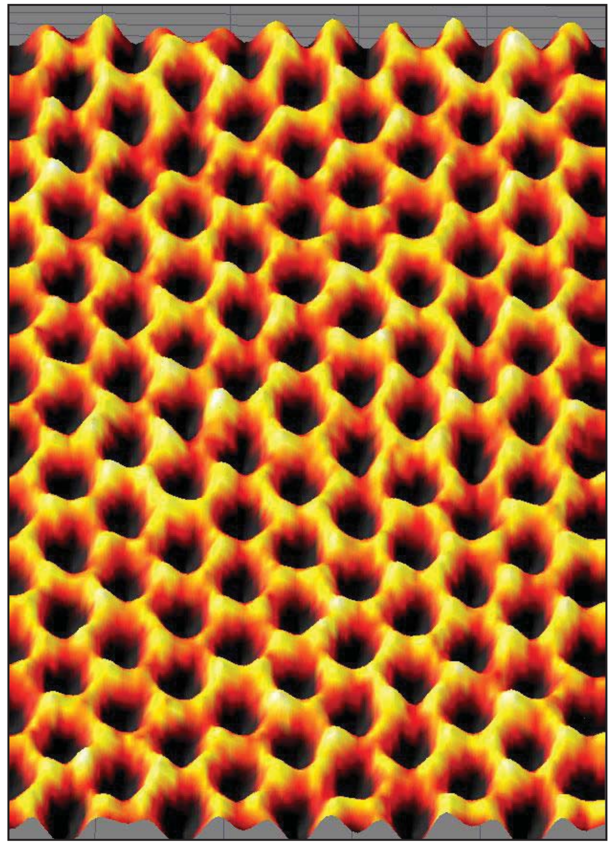
chemical element: a material consisting of and identified by one and only one kind of atom

graphite: a type of coal composed of one-atom-thick layers of graphene

transistor: a structure in which a semiconducting material, typically silicon doped with germanium or phosphorus, can be made to act as a switch to control current flow and voltage; computer "chips" are designed with millions of transistors that are etched onto the surface of the semiconductor base

SUMMARY

Graphene is a fundamental stable form of carbon. Harnessing graphene has led to major advances in electronics and biotechnology. The value of graphene is in its transparency, elasticity, density, flexibility, hardness, resistance, and electric and thermal conductivity. Graphene is a chemical element existing in a physical two-dimensional (2D) state of the atomic scale as a layer of carbon atoms bonded together in a honeycomb lattice. Graphene is the thinnest compound scientists have uncovered. It is one atom thick, one hundred to three hundred times stronger than steel with massive tensile stiffness. It conducts heat and electricity more efficiently than other chemical elements. It conducts light and is a major factor in spintronics, that is, affecting the spin of electrons, magnetic movements, and electronic charge, in solid-state devices. Graphene promotes chemical reactions with other substances, and scientists believe graphene has potential for advancing the technology revolution.



Graphene. Image by U.S. Army Materiel Command, via Wikimedia Commons.

BACKGROUND

Graphite, a mineral occurring naturally on earth, is the most stable form of carbon. Southeastern Europeans were using graphite 3000 years BCE in decorative ceramic paints for pottery. People discovered wider uses for graphite such as making lead pencils, leading scientists to speculate there must be another undiscovered element to graphite. In 1859, Benjamin Brodie studied the structure of graphite. His work was followed up with scientific progress between 1918 and 1925 by other physicists. P. R.

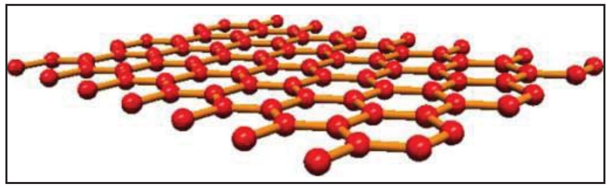
Wallace's study of the theory of graphene in 1947 opened a new field of inquiry that theoretical physicists and chemists continued pursuing for another half-century, setting aside the awareness that graphene was discovered in lab analyses on nickel and silicon carbide.

Andre Geim, a Soviet Union-born University of Manchester professor, discovered graphene from graphite in lab experiments by examining under an electron microscope the tiniest atomic-size particles from graphite grindings. Geim isolated the first 2D material ever discovered. It was a layer of carbon an atom thick with structure and properties about which the physicists had been theorizing. Geim has dedicated most of the rest of his professional career to studying graphene. He and his students uncovered graphene's field effect, allowing scientists to control the conductivity of graphene. This capability is one of the defining characteristics of silicon that advanced the entire world of computer chips and computers. Graphene is the thinnest material known in the universe. In the 1970s, chemists figured a way to place carbon monolayers onto other materials. One of the first US patents for graphene production was granted in 2006. Small amounts Geim produced in his lab were not going to satisfy demand. New processes were discovered to produce graphene in large quantities. Geim and his associate were awarded the Nobel Prize in Physics in 2010 for their groundbreaking experiments on graphene, not for discovering it.

Further study found ways graphene is used in electrical engineering, medicine, and chemistry. Between 2011 and 2013, graphene-related patents issued by the UK Intellectual Property Office rose from 3,018 to 8,416 for products like long-life batteries, computer screens, and desalinization of water.

GRAPHENE TODAY

New research into graphene is making great strides into finding ways to increase the power density of batteries. Scientists have hopes for graphene to produce ultra-long-life batteries that have less weight, are quicker to charge, and are thinner and less expensive to produce than lithium batteries. Korean-based company Samsung has been awarded the most patents in graphene. Samsung funds research on graphene at a Korean university. Chinese universities are second and third in the number of patents for graphene discoveries, and Rice University in the United States has filed a number of patent applications since 2014.



A molecular model of the structure of graphene. Image by Mohammad Javad Kiani, Fauzan Khairi Che Harun, Mohammad Taghi Ahmadi, Meisam Rahmani, Mahdi Saeidmanesh, and Moslem Zare, via Wikimedia Commons.

Professor James Tour, a synthetic organic chemist at Rice University, is among the leaders, researching graphene and looking into its possible commercial applications. His lab sold its patents for graphene-infused paint; its conductivity makes it easier to remove ice from helicopter blades; mixed with fluids, graphene increases oil drill efficiency; and graphene is used in materials to make airplane emergency slides and life rafts lighter and safer for passengers. Thus it is expected to save millions of dollars in fuel costs for airlines.

Tour's associates are experimenting with graphene for help for people with spinal cord injuries. Graphene oxide bonds with radioactive elements, thus the importance of early discoveries in bonding graphene to other substrates. Experiments are attempting to turn the mix into sludge to be scooped away for effective environmental cleanup following radioactive disasters. Improving the mobility of electronic information to flow over graphene surfaces from one point to another will mean increasing the speed of communication a hundred fold or more. In addition to work on graphene by physicists and chemists, biologists are also looking to use graphene nanomaterials. Biologists are working on bonding graphene with chemical groups that might improve therapies and have an effect on cancer and neuronal cells and immune systems. Graphene is being studied for its relation to and interactions with boron nitride, molybdenum sulphate, tungsten, and silicene, all 2D materials as small as atoms. If means of bonding with graphene are discovered, entirely new material properties may be found.

In June 2016, the University of Exeter announced that their research engineers and physicists discovered a lightweight graphene-adapted material for conducting electricity that substantially improves

H

Holographic Technology

Fields of Study: Computer science; Computer engineering; Electronics engineering

ABSTRACT

Holographic technology employs beams of light to record information and then rebuilds that information so that the reconstruction appears three-dimensional (3D). Unlike photography, which traditionally produces fixed two-dimensional (2D) images, holography re-creates the lighting from the original scene and results in a hologram that can be viewed from different angles and perspectives as if the observer were seeing the original scene. The technology, which was greatly improved with the invention of the laser, is used in various fields such as product packaging, consumer electronics, medical imaging, security, architecture, geology, and cosmology.

KEY CONCEPTS

analog signal: a continuous signal whose values or quantities vary continuously over time

hologram: an image recorded as the interference pattern of light reflected from an object such that the image appears to have three-dimensional (3D) depth when viewed

holography: a technique for producing images that are seen as refracted light interference patterns by using laser light to generate the interference pattern from an object and to re-create the object as a 3D image from that recorded interference pattern

interferometry: a technique for studying biochemical and other substances by superimposing light waves, typically one reflected from the substance and one reflected from a reference point, and analyzing the interference

DEFINITION AND BASIC PRINCIPLES

Holography is a technique that uses interference and diffraction of light to record a likeness and then rebuild and illuminate that likeness. Holograms use coherent light, which consists of waves that are aligned with one another. Beams of coherent light interfere with one another as the image is recorded and stored, thus producing interference patterns. When the image is re-illuminated, diffracted light allows the resulting hologram to appear three-dimensional (3D). Unlike photography, which produces a fixed two-dimensional (2D) image, holography re-creates the light of the original scene and yields a hologram, which can be viewed from different

Two photographs of a single hologram taken from different viewpoints. Photo via Wikimedia Commons. [Public domain.]

Robotics

Fields of Study: Mechanical engineering; Robotics; Electrical engineering; Programming

ABSTRACT

Robotics is an interdisciplinary field concerned with the design, development, operation, and assessment of electromechanical devices used to perform tasks that would otherwise require human action. Robotics applications can be found in almost every arena of modern life. Among the most promising robot technologies are those that draw on biological models to solve problems, such as robots whose limbs and joints are designed to mimic those of insects and other animals.

KEY CONCEPTS

actuator: a motor designed to control the movement of a device or machine by transforming potential energy into kinetic energy

algorithm: a set of step-by-step instructions for performing computations

artificial intelligence: the intelligence exhibited by machines or computers, in contrast to human, organic, or animal intelligence

automaton: a machine that mimics a human but is generally considered to be unthinking

autonomous: able to operate independently, without external or conscious control

biomimetics: the concept of constructing robots and computer programs to function in the manner of living beings

bionics: the use of biologically based concepts and techniques to solve mechanical and technological problems

dynamic balance: the ability to maintain balance while in motion

parcour: an athletic activity that involves elements of running, jumping, and gymnastics

SUMMARY

Robotics is an interdisciplinary field concerned with the design, development, operation, and assessment of electromechanical devices used to perform tasks that would otherwise require human action. Robotics applications can be found in almost every arena of modern life. Robots, for example, are widely used in industrial assembly lines to perform repetitive tasks. They have also been developed to help physicians perform difficult surgeries and are essential to the operation of many advanced military vehicles. Among the most promising robot technologies are those that draw on biological models to solve problems, such as robots whose limbs and joints are designed to mimic those of insects and other animals.

DEFINITION AND BASIC PRINCIPLES

Robotics is the science of robots—machines that can be programmed to carry out a variety of tasks independently, without direct human intervention. Although robots in science fiction tend to be androids or humanoids (robots with recognizable human forms), most real-life robots, especially those designed for industrial use, do not resemble humans physically. Robots typically consist of at least three

The Shadow robot hand system. Photo by Richard Greenhill and Hugo Elias/Shadow Robot Company, via Wikimedia Commons.

Soft Robotics

Fields of Study: Robotics; Biomimetics; Biophysics

ABSTRACT

Soft robotics is the development of robots composed of soft components. Traditional robotic components are rigid links in a mechanical chain, but soft robotics may comprise both soft and rigid components, with the ability to conform to their environment and adapt to situations they encounter.

KEY CONCEPTS

algorithm: a description in precise but natural language plus mathematical notation of how a problem is solved

anthropomorphic: resembling a human in shape or behavior; from the Greek words anthropos (human) and morphe (form)

autonomic components: self-contained software or hardware modules with an embedded capacity for self-management, connected via input/outputs to other components in the system

autonomous: able to operate independently, without external or conscious control

autonomous agent: a system that acts on behalf of another entity without being directly controlled by that entity

biomimetics: the concept of constructing robots and computer programs to function in the manner of living beings

dynamic balance: the ability to maintain balance while in motion

BACKGROUND

Although clockwork automatons have been around since at least the Middle Ages, robotics developed primarily to serve industry. George Devol designed the first programmable robot in 1954. He and Joseph Engelberger produced the prototype, Unimate #001, in 1959. They focused on creating a robotic arm that would perform tasks that put human workers at risk. The prototype was installed in a General Motors die-casting plant in Trenton, New Jersey. Unimate took heated die-castings from machines and performed welds. Industrial robots became common in the auto industry and other manufacturing industries within a short time and grew increasingly complex with the advancement of computer chips. The US space program developed robotic rovers, robotic arms, and experimental robotic astronauts. Other applications include search-and-rescue robots and consumer products such as vacuum cleaners, personal assistant devices, and toys such as robotic animals and building kits.

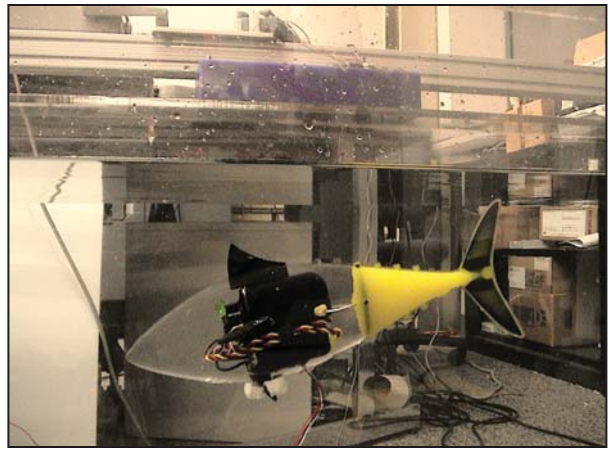
An inflatable robotic arm. Photo by Z22, via Wikimedia Commons.

Traditional robots, with hard components, are not suitable for all applications, however. While industrial robots can pick up hard objects, they are less capable of handling delicate items or items that are not uniform shapes and sizes. They must have multiple controllable joints and force sensing components to handle such items. Robots meant to interact with humans and other living things may have difficulty with some tasks. Their ability to adapt is limited by their rigid components.

Soft robotics is the development of robots composed of soft components. In nature, soft body parts are adaptable; the same reasoning applies to robotics. Whereas traditional robotic components are rigid links in a mechanical chain and move in mathematically predictable ways, soft robotics may be soft materials that contain some rigid components, or may even be made entirely of soft components. They can conform themselves to their environment and adapt to different situations. Soft robotics also describes the variable resistance of the control systems of the robots.

Development of soft robotics began around 2006. Applications potentially include the biomedical field, the service industry, manufacturing of delicate materials, and surgical procedures.

Twenty-first-century soft robotics developers responded with a variety of approaches. Researchers at Harvard University developed a series of soft robots using pneumatic actuation, meaning they use pistons inside of hollow cylinders. Pressure moves the piston along its axis, creating linear force, and a spring-back force on the opposite side returns the piston to its original position. Harvard's silicone-based soft robots use a pneumatic network, which inflates and deflates various parts of the soft body to create movement. These and other soft robots were often inspired by living creatures, including caterpillars, starfish, and octopuses. An octobot developed at Harvard University has no batteries, circuit boards, or other rigid components at all—it is entirely soft.



A soft under-actuated-robot that mimics a tuna fish. Photo by Pablo Valdivia y Alvarado, via Wikimedia Commons.

TOPIC TODAY

Soft robotics is developing in two primary areas. One approach involves robots built with rigid links, like traditional robots, with control systems for the interaction with the robot's environment, such as gripping abilities. In simple terms, these robots have rigid skeletal structures and soft exteriors. The other approach involves robots primarily or entirely made of soft materials, which experience vast shape changes in operation. Many of these soft-bodied robots are made of materials that can adjust to various degrees of stiffness.

One development in gripping technology uses soft components to handle the objects, while much of the robot is composed of solid components. A soft sack made of elastic or another material, for example, can be filled with sand. Sand is granular, and when close together, the grains jam together. The sack of sand is connected to a pneumatic component, which allows a gas such as air into the sand. The robot lowers the sack onto the object to be gripped and vacuums the gas out of the sand. The granular jamming envelops the object; to release it, the robot puts the gas back into the sack of sand, which unjams the grains, and the sack no longer conforms to the object. In addition to gripping objects of inconsistent size and shape, such granular jamming components can also pick up multiple items at once and place them, in the same configuration, in another location.

Flexible, soft components can be constructed to move in many ways. They can expand, contract, bend, and twist with adjustments to pressurized fluid or gas. For example, a tube can be constructed with a smooth side and a reinforced ribbed side. When unpressurized, the tube is straight; under pressure, the ribbed side expands, forcing the smooth side into a curve. The degree of curvature is determined by the amount of pressure.

Soft robotics development has been aided by polymer science and in particular three-dimensional (3D) printing. Some 3D printers can create items out of soft, polymer-based materials. This enables roboticists to design and create any shape using soft materials, including silicone, that were previously impossible to build. The Harvard octobot is one example of this use. The team individually 3D-printed each component needed inside the soft robot body, including fuel storage and power components. Hydrogen peroxide is used as liquid fuel. A reaction using platinum inside the octobot creates gas, which inflates the eight arms. A microfluidic logic circuit controls the movement.

Soft robotics offers a wide range of possibilities in many fields. Some researchers are working on rubbery robots that can be used to perform surgery. These devices would operate more gently around soft tissues and organs, reducing risk of injuries such as punctured arteries and organs that have occurred using traditional rigid robotic systems. Researchers are also exploring the possibility of developing a device that would surround a damaged or malfunctioning heart and rhythmically contract to mechanically aid the organ in pumping blood. Other potential uses of soft robotics include robotic gloves to help patients recovering from strokes to grip