Black box

In science, computing, and engineering, a **black box** is a device, system or object which can be viewed in terms of its inputs and outputs (or transfer characteristics), without any knowledge of its internal workings. Its implementation is "opaque" (black). Almost anything might be referred to as a black box: a transistor, an algorithm, or the human brain.

To analyse something modeled as an open system, with a typical "black box approach", only the behavior of the stimulus/response will be accounted for, to infer the (unknown) *box*. The usual representation of this *black box system* is a data flow diagram centered in the box.

The opposite of a black box is a system where the inner components or logic are available for inspection, which is most commonly referred to as a white box (sometimes also known as a "clear box" or a "glass box"[1]).

Black box systems

System

Black box · Oracle machine

Methods and techniques

Black-box testing · Blackboxing

Related techniques

Feed forward · Obfuscation
Pattern recognition · White box · White-box testing
System identification

Fundamentals

A priori information · Controls(identify system)|Open systems · Operations research
Thermodynamic systems

Contents

History

The modern meaning of the term "black box" seems to have entered the English language around 1945. In electronic circuit theory the process of network synthesis from transfer functions, which led to electronic circuits being regarded as "black boxes" characterized by their response to signals applied to their ports, can be traced to Wilhelm Cauer who published his ideas in their most developed form in 1941.[2] Although Cauer did not himself use the term, others who followed him certainly did describe the method as black-box analysis.[3] Vitold Belevitch[4] puts the concept of black-boxes even earlier, attributing the explicit use of two-port networks as black boxes to Franz Breisig in 1921 and argues that 2-terminal components were implicitly treated as black-boxes before that.

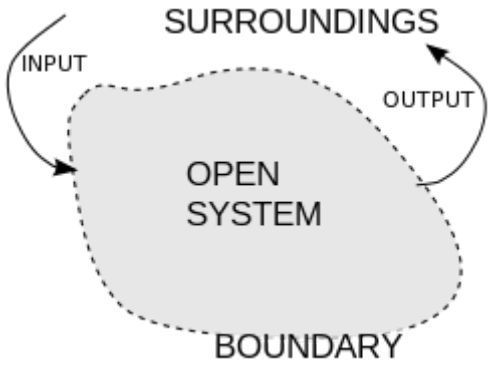
In cybernetics, a full treatment was given by Ross Ashby in 1956.[5] A black box was described by Norbert Wiener in 1961 as an unknown system that was to be identified using the techniques of system identification.[6] He saw the first step in self-organization as being to be able to copy the output behavior of a black box. Many other engineers, scientists and epistemologists, such as Mario Bunge,[7] used and perfected the black box theory in the 1960s.

A black box model can be used to describe the outputs of systems

System theory

In systems theory, the *black box* is an abstraction representing a class of concrete open system which can be viewed solely in terms of its *stimuli inputs* and *output reactions*:

> The constitution and structure of the box are altogether irrelevant to the approach under consideration, which is purely external or phenomenological. In other words, only the behavior of the system will be accounted for.
>
> — Mario Bunge[7]



The *open system theory* is the foundation of *black box theory*. Both have focus on input and output flows, representing exchanges with the surroundings.

The understanding of a *black box* is based on the "explanatory principle", the hypothesis of a causal relation between the *input* and the *output*. This principle states that *input* and *output* are distinct, that the system has observable (and relatable) inputs and outputs and that the system is black to the observer (non-openable).[8]

Recording of observed states

An observer makes observations over time. All observations of inputs and outputs of a *black box* can be written in a table, in which, at each of a sequence of times, the states of the *box*'s various parts, input and output, are recorded. Thus, using an example from Ashby, examining a box that has fallen from a flying saucer might lead to this protocol:[5]

Time	States of input and output
11:18	I did nothing—the Box emitted a steady hum at 240 Hz.
11:19	I pushed over the switch marked K: the note rose to 480 Hz and remained steady.
11:20	I accidentally pushed the button marked "!"—the Box increased in temperature by 20 °C.
11:21	Etc.

Thus every system, fundamentally, is investigated by the collection of a long protocol, drawn out in time, showing the sequence of input and output states. From this there follows the fundamental deduction that all knowledge obtainable from a Black Box (of given input and output) is such as can be obtained by re-coding the protocol (the *observation table*); all that, and nothing more.[5]

If the observer also controls input, the investigation turns into an experiment (illustration), and hypotheses about cause and effect can be tested directly.

When the experimenter is also motivated to control the box, there is an active feedback in the box/observer relation, promoting what in control theory is called a feed forward architecture.

Modeling

The *modeling process* is the construction of a predictive mathematical model, using existing historic data (observation table).

Testing the black box model

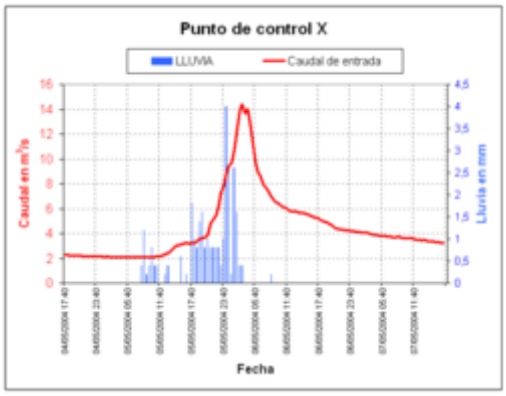
A developed *black box model* is a validated model when *black-box testing* methods[9] ensures that it is, based solely on observable elements.

With backtesting, inputs for past events (not used in the "modeling effort") are entered into the model to see how well the output matches the known results.

Other theories

Black box theories are things defined only in terms of their function.[10][11] The term *black box theory* is applied to any field, philosophy and science or otherwise where some inquiry or definition is made into the relations between the appearance of something (exterior/outside), i.e. here specifically the thing's black box state, related to its characteristics and behaviour within (interior/inner).[12][13]

Specifically, the inquiry is focused upon a thing that has no immediately apparent characteristics and therefore has only factors for consideration held within itself hidden from immediate observation. The observer is assumed ignorant in the first instance as the majority of available data is held in an inner situation away from facile investigations. The *black box* element of the definition is shown as being characterised by a system where observable elements enter a perhaps imaginary box with a set of different outputs emerging which are also observable.[14]



The observed hydrograph is a graphic of the response of a watershed (a blackbox) with its runoff (red) to an input of rainfall (blue).

Adoption in humanities

In humanities disciplines such as philosophy of mind and behaviorism, one of the uses of black box theory is to describe and understand psychological factors in fields such as marketing when applied to an analysis of consumer behaviour.[15][16][17]

The *black box theory of consciousness* states that the mind is fully understood once the inputs and outputs are well-defined.[18]

Black box theory

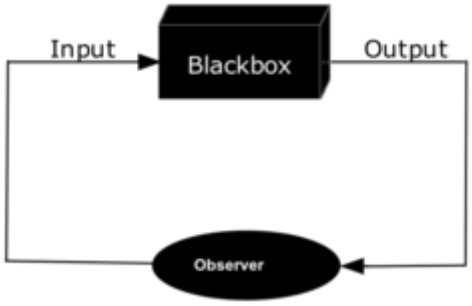
Black Box theory is even wider in application than professional studies:

> The child who tries to open a door has to manipulate the handle (the input) so as to produce the desired movement at the latch (the output); and he has to learn how to control the one by the other without being able to see the internal mechanism that links them. In our daily lives we are confronted at every turn with systems whose internal mechanisms are not fully open to inspection, and which must be treated by the methods appropriate to the Black Box.
>
> — Ashby[5]

> (...) This simple rule proved very effective and is an illustration of how the Black Box principle in cybernetics can be used to control situations that, if gone into deeply, may seem very complex.
> A further example of the Black Box principle is the treatment of mental patients. The human brain is certainly a Black Box, and while a great deal of neurological research is going on to understand the mechanism of the brain, progress in treatment is also being made by observing patients' responses to stimuli.
>
> — Duckworth, Gear and Lockett[19]

Applications

Computing and mathematics



When the observer (an agent) can also do some stimulus (input), the relation with the black box is not only an observation, but an experiment.

- In computer programming and software engineering, *black box testing* is used to check that the output of a program is as expected, given certain inputs.[20] The term "black box" is used because the actual program being executed is not examined.
- In computing in general, a *black box program* is one where the user cannot see the inner workings (perhaps because it is a closed source program) or one which has no side effects and the function of which need not be examined, a routine suitable for re-use.
- Also in computing, a black box refers to a piece of equipment provided by a vendor, for the purpose of using that vendor's product. It is often the case that the vendor maintains and supports this equipment, and the company receiving the black box typically is hands-off.
- In mathematical modeling, a limiting case.

Science and technology

- In neural networking or heuristic algorithms (computer terms generally used to describe 'learning' computers or 'AI simulations'), a black box is used to describe the constantly changing section of the program environment which cannot easily be tested by the programmers. This is also called a white box in the context that the program code can be seen, but the code is so complex that it is functionally equivalent to a black box.
- In physics, a black box is a system whose internal structure is unknown, or need not be considered for a particular purpose.
- In cryptography to capture the notion of knowledge obtained by an algorithm through the execution of a cryptographic protocol such as a zero-knowledge proof protocol. If the output of an algorithm when interacting with the protocol matches that of a simulator given some inputs, it 'need not know' anything more than those inputs.

Other applications

- In philosophy and psychology, the school of behaviorism sees the human mind as a black box;[21] see *other theories*.

- In neorealist international relations theory, the sovereign state is generally considered a black box: states are assumed to be unitary, rational, self-interested actors, and the actual decision-making processes of the state are disregarded as being largely irrelevant. Liberal and constructivist theorists often criticize neorealism for the "black box" model, and refer to much of their work on how states arrive at decisions as "breaking open the black box".

See also

- Black box group
- Blackboxing
- Flight recorder
- Grey box model
- Hysteresis
- *Open system*:
  - in (general) Systems theory
  - in Thermodynamics
  - in Control theory
- Multi-agent system
- Oracle machine
- Pattern recognition
- Prediction/Retrodiction
- System identification
- Systems theory
- Stimulus–response model

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