Definition of Information

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Abstract
This definition can be applied to information of every kind, level and complexity. Information is considered as the feature manifesting itself in the relations between certain real world entities. The real world has to be seen in terms of objects, actions, relations and properties..
The defintion is used as the basis of the Theory of Meaningful Information [1] that explains the nature and functionality of information and enables the production of relevant definitions regarding language and knowledge, which remain operative also in the case of non-human languages and knowledge systems.

1. Introduction

According to the standard theory of cosmology, literally everything – matter, space and time – started with the Big Bang. In the beginning, all matter and energy which made up the universe was squeezed into an infinitely hot, dense, unstructured singularity. It then started to expand, became more structured, the fundamental forces were divided, matter formed to atom nuclei, leptons and molecules. The content separated into distinct components, parts of which were more stable than others and so got to preserve their form and size over long periods of time.

So was formed our universe, which we can consider as a super heap consisting of stable objects of different levels of matter organization and their heaps. The process of Universe formation and evolution consists of permanent births, deaths, and changes of all entities of the heap.

A *stable object* here is understood as a three dimensional item with mass, which is reasonably steady, has a location or position in space at any moment, and which can be changed by exerting force. The stable objects of the lower levels of the matter organization are inanimate physical bodies like stars, planets, stones, molecules, atoms and subatomic elements like hadrons, leptons etc. and those of the upper levels are living organisms of various complexity levels starting from unicellular bacteria up to human beings.

Under the influence of force, a stable object changes its speed, movement direction, starts/stops moving if it is exposed to the physical (energetic) influence of another object or process (like one object hitting another object and changing its movement etc.) and is distorted. A body in rest can come into motion if the balance of forces maintaining its immobility is disturbed, e.g. a bridge is stable because its weight is balanced by the counter-pressure of its pillars and thus failing if one pillar is damaged.

A general characteristic of force-induced changes is that the effectual change occurs exclusively because of the energy produced or withdrawn by the causal action (as in the case of the falling bridge).

Stable objects are not really static but rather dynamic combinations of elements. Electrons revolve around atomic nuclei, quarks exchange in hadrons, molecules perform chemical reactions in the body of cosmic objects and cellular organisms. Stated more precisely, stable objects are dynamic systems that are better at adapting to the environmental conditions around them and therefore can retain their form and stability. This ability to adapt means they are able to resist external and internal influences by either ignoring them or changing in order to counteract the influence. Since the ability to resist is limited, a stable object will collapse if the force influencing it exceeds a certain threshold, and it will be changed.

The life of a stable object can last from a fraction of a second to billions of years and during all this time it is constantly moving and/or changing. The sequence of changes and movements of a

stable object is defined in this work as the object's **algorithm** that can be represented with the help of various expression means like pictures, schemes and texts composed in various languages.

The subject to be considered here is the causal relations between the changes of stable objects and their environments. The phenomenon of causality, famously characterized as the cement of the universe by David Hume [HUME 1987/(1777)], includes many miscellaneous causal relationships, but we will limit ourselves to changes occurring in objects under various influences in a Newtonian world.

According to the Random House Unabridged Dictionary [RHUD], the term **causality** denotes "a necessary relationship between one event (called cause) and another event (called *effect*) which is the direct consequence (result) of the first."

The term **change** is defined in the same dictionary as "to make the form, nature, content, future course, etc., of (something) different from what it is or from what it would be if left alone".

 The axiom of this work is that all causal changes in the real world are based on only **four** distinct schemas: ― two primitive causal relations occurring under the influence of physical forces and two complex ones. Changed entities are either complex stable objects including several components or systems thereof.

2. Change I driven by an internal force (internal change)

Changes of this kind are independent from the external environment of a changed object or at least considered to be independent on the level of the analysis of the object. A stable object alters its form, position or structure under the force produced by its internal processes. Such a change is the most frequent case of alterations among living organisms. Growth of living creatures, human mental processes or cellular division can be cited as examples.

Non-living physical entities are also changed in this way, especially those consisting of a dynamically balanced set of physical processes such as cosmic stars. Also stable atoms disintegrate due to spontaneous radioactivity, which can take a very long time. This simplest causal mechanism occurring within a single stable object is designated here as internal change.

Internal change will be represented with the help of a horizontal rectangle that is split along the x-axis into two parts. The upper half refers to the changed entity and the bottom half describes the change to this entity. Because this object changes spontaneously without any apparent external force or influence, there is only one rectangle and no other objects or arrow directions contained in this graphic (Figure 1).
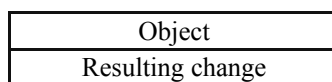
Object
Resulting change

Figure 1. Internal change

3. Change II driven by the external force (forced change)

The second basic kind of causal relation consists of changes that occur as a result of externally working forces. According to Britannica force is "any action that tends to maintain or alter the motion of a body or to distort it" ["Force", in: Britannica 2009].
The mechanism of this change is simple: the influence of a force alters the affected object or its movement: A cosmic body changes its orbit due to the influence of gravity produced by some external entity. A bullet accelerates because of the powder explosion in the cartridge; glass breaks when it falls to the floor etc. This form of causal mechanism is called forced change here.
Forced changes represent the simplest form of a causal relation between two objects, first of which ― a causal action of force ― delivers energy causing the effectual change of a stable object. Forced change is represented as follows (Figure 2):

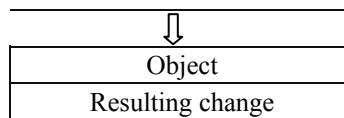| |
| --- |
| Causal change |

| ⇩ |
| Object |
| Resulting change |
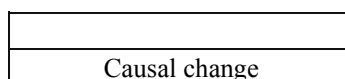
Figure 2. Forced change

The empty part of the upper rectangle illustrates the fact that causal change can have an arbitrary origin. The arrow designates the direction of force. The vertical order of rectangles represents their relationship in time.

4. Change III activated by external force (activated change)

This and the following causal mechanism are based on the sequence of primitive changes described above. The entities being subject to change are complex stable objects with several components and internal energy sources or systems consisting of several components and energy source(s). Furthermore, the changed objects are either organic organisms or inorganic systems of artificial origin. Inorganic objects of natural origin are too primitive for such complex behavior.

The activated change consists of changing a stable object (system) by external non-forceful influence. A changed object (system) has to possess (or have access to) an energy source and an externally controlled lock (switch), which opens and closes the energy flow produced/delivered by the energy source.

A typical example of this kind is an electric light activated by an electrical button or lever when someone (something) switches it on and the electrical bulb lights up. The sequence of actions includes following four activities:

- external force presses the button;
- the button closes the electrical circuit thereby unlocking the energy source;
- electricity flows to the bulb;
- bulb lights up.

The general graphical schema of this change is as follows (Figure 3):

| |
| Causal change |
| ⇩ |
| Object.Switch |
| Unlocking energy source |

| Object.energy_source |
| Forcing energy flow |
| ⇩ |
| Object |
| Resulting change |
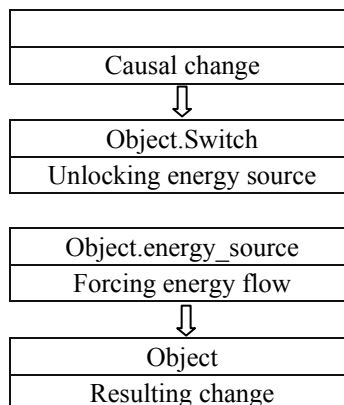
Figure 3. Activated change

The difference between change II and change III are the addition of the two externally activated steps two and three. The lack of an arrow between them shows the missing energetic influence between the respective changes. This change is thus a sort of combination between change I and change II with the internal change being triggered by an external force.

The thing activating an internal change by external influence is referred to in this work as an activating switch or an activator.

Examples among biological objects are unicellular organisms registering the change of the environment by their sensors and changing in response the process of their metabolism.

Components built on the principle of activated changes are integral parts of any technical system like electronic circuits.

A more elaborate example would be a traffic light at a pedestrian crossing (crosswalk). A person approaches a crosswalk, pushes a button, the traffic light changes to red and the crosswalk sign flashes green. The only work a person has to do is push a button and the rest is done by the internal component(s) and energy source(s).

The specifics of this type of causal relation is the energetic independence between the activating action and the resulting change which allows various activation-result pairs with the same internal mechanism. The energetic independence radically increases the survival chances and adaptability of systems implementing it.

Suppose, there is a sea lagoon fed by an intermittent river. Some microorganisms, whose nutrition is delivered by the river's water, have been able to adapt to the changeable conditions by slowing its metabolism after the level of oxygen in the water drops below a critical point. The internal mechanism by registering the level of oxygen is the typical activator changing the behavior pattern of these microorganisms in result of the alternation of the external environment.

If some species of this microorganism are carried by currents into the open sea, they encounter another changeable food source consisting of unsteady sea currents of very salty water. Surviving in these conditions requires another activator, which would regulate the microorganism's metabolism by reacting to the change in water salinity, while activator-controlled basic structures can be left unchanged.

From the viewpoint of evolution it is a much more efficient way of development than the development of a completely new microorganism, which would be necessary if the activating switches were not involved in the evolutional process.

5. Change IV communicated by external force (communicated change)

The mechanism of activated change provides an essential part of flexibility relative to primitive causal mechanisms I and II, but on the other side it also has its restrictions convincingly demonstrated by the traffic light example. In the form delineated above, these traffic lights are hardly usable on a busy street, because many pedestrians who want to cross the street will actually block the traffic by persistently pushing the crosswalk button.

In order to solve this problem our traffic light needs to be able to define the switching moment on its own, i.e. by changing the cause-effect direction. Assume that a person doesn't push the button, but the button will be periodically (e.g. once every 3 minutes) pushed against the finger of a person presumably pressing the button. If the finger blocks the button, the crosswalk lights switches to green for the pedestrians and red for cars. Otherwise the color of the traffic light remains the same.

Certainly this is not a very convenient schema for traffic lights and it doesn't give pedestrians utter satisfaction either. A more efficient solution to this problem consists of augmenting the switching schema by adding one more element – a passive mediator object (in this case a button together with associated components), which can be pressed by a pedestrian and queried periodically by a traffic light. By pushing such a button, the pedestrian only switches the button to another state which can be ascertained by the traffic light during the querying process. If the button is set, the traffic light unsets it and then switches the crosswalk light to green for the pedestrians.

This example demonstrates the work of ***information***, which is a state of some passive object set by some actor and queried by some reactor in order to produce some resulting action. An actor has to set at least one state and a reactor has to distinguish between at least two states (the absolute minimum is a dichotomous variable – the state set by an actor and the lack thereof).

The following definitions will be used throughout this work:
- The mediating object is a ***variable***. Wherefrom follows a yet even shorter definition of information being conceived as a value of a variable used in an algorithm

- ***Communication*** is the process of interaction between an actor setting a variable's value and a reactor identifying it and performing these or other actions as the result.
- An actor is designated as an ***I***nformation ***S***etting ***E***ntity (***ISE***) and a reactor as an ***I***nformation ***D***riven ***E***ntity (***IDE***).
- The resulting change constitutes the ***semantics*** of information.

Relative to the activated change, this kind of causal relation has been enhanced by the addition of three new steps inserted after the causal change.

```
┌─────────────────────────┐
│                         │
├─────────────────────────┤
│      Causal change      │
└─────────────────────────┘
            ⇓
┌─────────────────────────┐
│        Variable         │
├─────────────────────────┤
│         Setting         │
└─────────────────────────┘

┌─────────────────────────┐
│         Object          │
├─────────────────────────┤
│     Inquire variable    │
└─────────────────────────┘
            ⇓
┌─────────────────────────┐
│        Variable         │
├─────────────────────────┤
│        Answering        │
└─────────────────────────┘
            ⇓
┌─────────────────────────┐
│      Object.Switch      │
├─────────────────────────┤
│ Unlocking energy source │
└─────────────────────────┘

┌─────────────────────────┐
│   Object.energy_source  │
├─────────────────────────┤
│    Forcing energy flow  │
└─────────────────────────┘
            ⇓
┌─────────────────────────┐
│         Object          │
├─────────────────────────┤
│     Resulting change    │
└─────────────────────────┘
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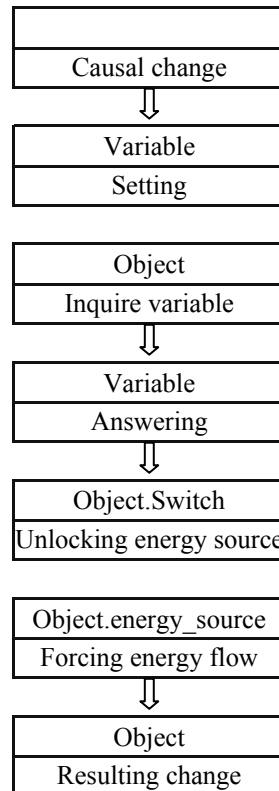
Figure 4. Communicated change

In this work, a variable is not considered a mathematical construction, but an object in the discernable world. Since the features of communicators and communications can differ, the structure of the variable can differ too. Thus, in implementation where the crosswalk light directly differentiates between pressed and non-pressed buttons, the variable consists of the complete button mechanism. In alternative implementations where the button mechanism is connected to the input port of the traffic light's internal processor the mediated variable is the input computer port and the button mechanism is an auxiliary appliance used by a pedestrian for setting this variable.

It is not required that a variable can be switched unlimitedly between its states. A variable is considered to be constant if it can get the only value during its life span as a printed letter, which is essentially a picture painted on some surface. Another special case are variables that can be changed only once, e.g., a undamaged pencil can be used as one sign and a broken pencil as another sign.
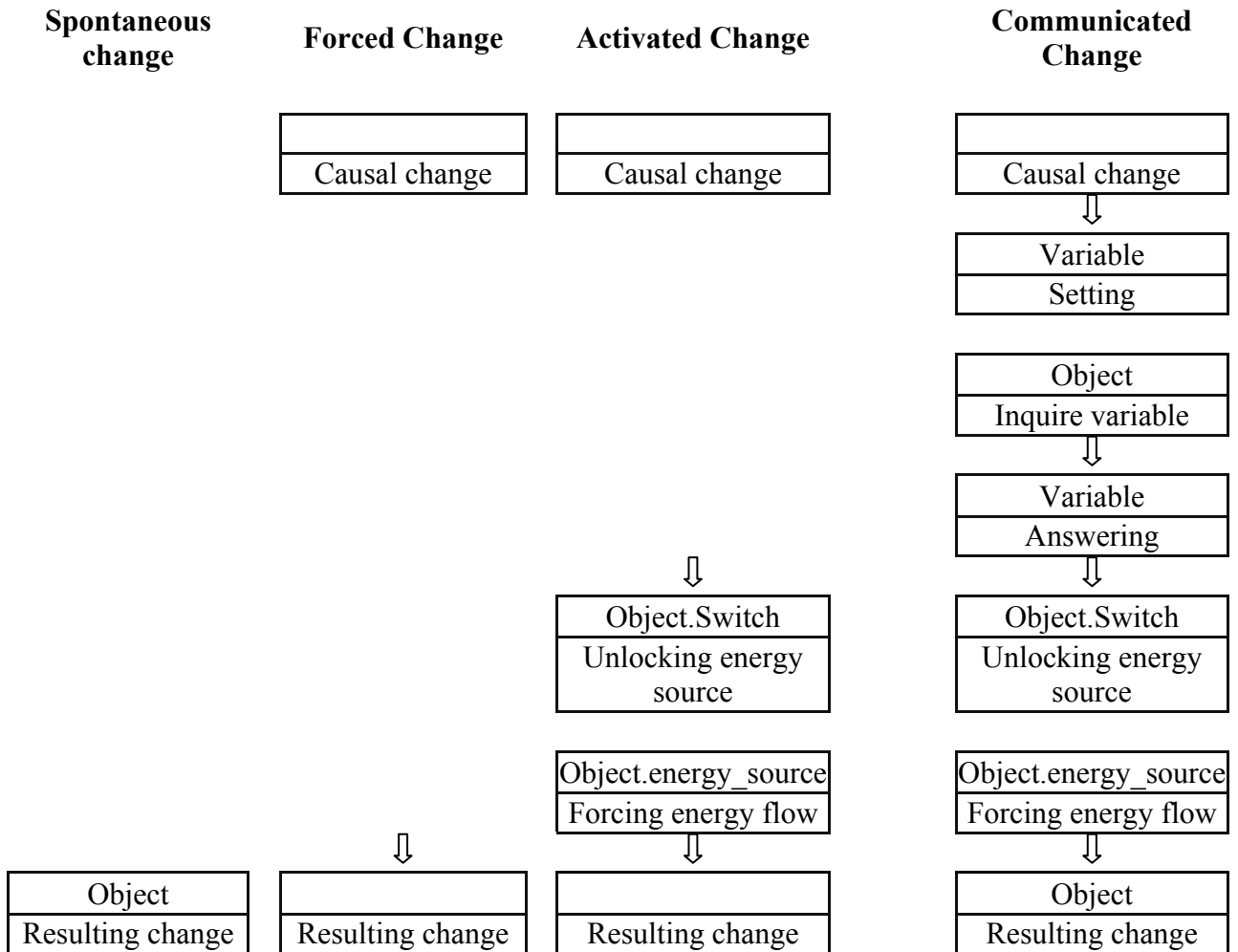
This understanding of information complies with the one actually applied in programming. The variables in programming are restricted to bits or bit sequences and the only two fundamental operations with variables are set and query, whereas all others are based on these two operations.

Another restriction when programming is that the actor and the reactor are usually the same, so the communication occurs not between different objects but between different states of the same computer.

6. Summary of causal relations

All four types of changes are given in Table 1. Each rectangle contains the stable object (if present) and its change. The order from top to bottom represents the timely flow. The arrows represent a force being exerted.

Table 1. Summary of causal relations

Spontaneous change	Forced Change	Activated Change	Communicated Change
	Causal change	Causal change	Causal change
			⇓ Variable / Setting
			Object / Inquire variable
			⇓ Variable / Answering
		⇓ Object.Switch / Unlocking energy source	⇓ Object.Switch / Unlocking energy source
		Object.energy_source / Forcing energy flow	Object.energy_source / Forcing energy flow
Object / Resulting change	⇓ Resulting change	⇓ Resulting change	⇓ Object / Resulting change

Bibliography

1. Theory of Meaningful Information www.GeneralInformationTheory.com