AGI: STRUCTURING THE OBSERVABLE

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This chapter continues the analysis of structuring techniques discussed earlier in the chapters "Structures discovering" and "Time, space, causality, neural networks, and text".Imagine a bicycle with wheel-mounted flashlights or a twin-rotor aircraft with flashlights on propeller blades. When the apparatus moves with the rotation of the wheels or propellers in complete darkness, flashlights moving along complex trajectories will be visible; the observer easily recognizes a pair of rotating elements, and the stability of their mutual position will prompt the existence of an unobservable something that connects these rotating elements:

This means that, despite the impossibility of identifying the observed object and its elements, a person constructs a structured description of the observed: a pair of rotating objects, each of which consists of several smaller ones, are united by some third directly unobservable element; when moving in space, the elements of the structure move relative to each other, nevertheless retaining the detected structure.

As it was found out earlier, the process of such detection is formally reduced to the ***search for invariants*** - the constancy of the invariant function in time means the presence of the observed ***structure***. The ***detected structures, in turn, can be elements of another structure, forming a hierarchical model of the observed scene***. In the hypothetical situation described above, two rotating structures of elements that do not change their relative position are found; they are also elements of a superstructure, which also includes a third unobservable component that connects them into a single whole, the elements of which can change their relative position (rotate), nevertheless forming a stable object.

Of course, the presence of a physical element that connects the components is not necessary: the soldiers marching in formation in the parade and the geese flying in a wedge form structures without physical connections, unlike the wheels of a car or excavator elements that are physically connected; if there is no mechanical connection, there is something else to ensure the stability of the structure.

For structures detection, an intelligent system must have a ***set of possible invariants***. It is essential that the ***possible invariants of such a set reflect the specifics of the environment*** (space-time in the case of the natural environment) and ***not the specifics of objects or the system's mission***. So it is possible to use a ***small set of potential invariants*** to build an ***unlimited number of models of arbitrary complexity*** and apply these invariants to systems for various purposes - in other words, the ***use of a small set of invariants is compatible with the system generality requirement***.

Each previously ***unknown structure is a potential new concept***; structuredness provides a natural way to ***describe such concepts***. The process of forming structures is ***recursive*** - any structure can be used as an element of the next level in the ***hierarchy***.

The most important aspect of forming structures from known elements is that the ***concept grounding problem is solved***: a new concept defined in terms of already known concepts.

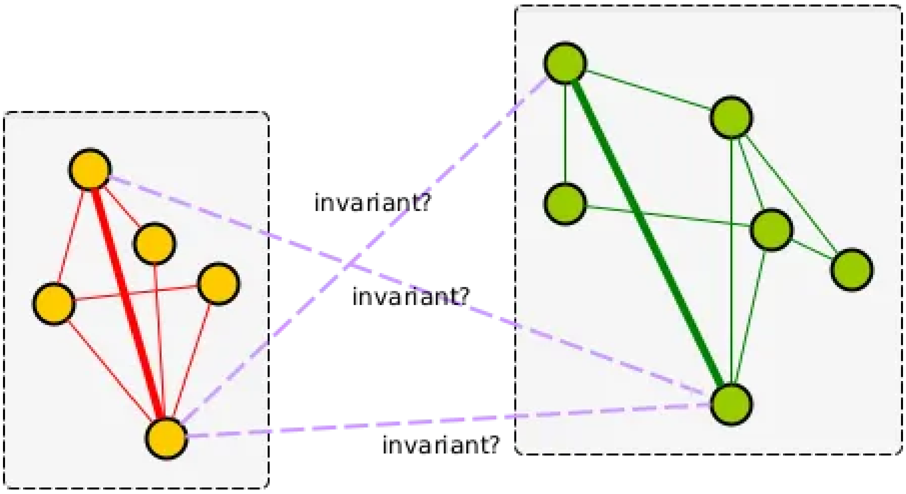
A simplified model of the situation described at the beginning of the chapter is used as a proof-of-the-concept. In a two-dimensional environment, atomic objects are point objects that have coordinates on a plane as attributes. There are three types of invariants:

1. The constancy of the distance between atomic objects in a group of atomic objects.

In the case of two objects, it is simply the distance between them. A group of three or more atomic objects models a rigid body that can move and rotate as a whole, that is, a non-deformable composite object.

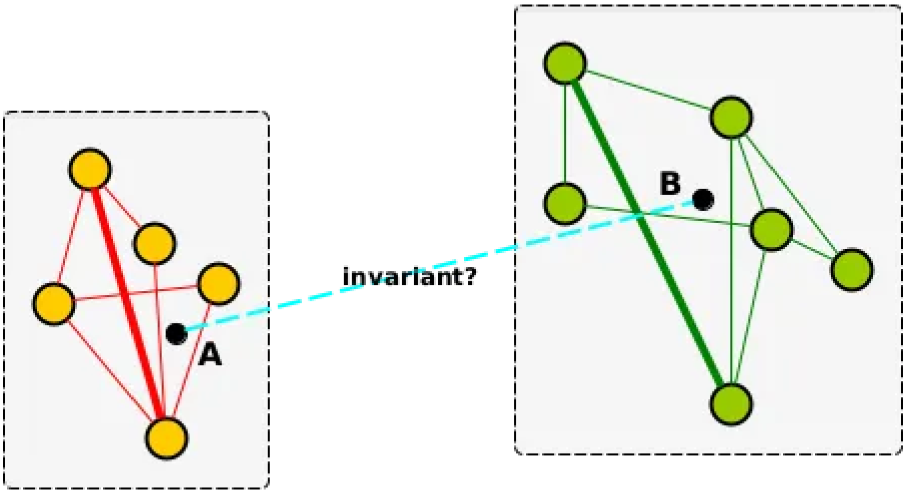
2. The constancy of the mutual position of two non-deformable composite objects.

It boils down to the constancy of mutual distances between a pair of atoms of one object and a pair of atoms of the second (naturally, the constancy of three distances is sufficient). The two most distant atoms of the composite structure were selected as elements of the pair:



3. The constancy of the distance between the deformable objects with the possibility of changing the mutual orientation.

It requires the existence of a pair of points **A, B** (not structure components!), the first of which belong to one composite object and the other to the second object, and the distance between **A** and **B** is invariable. Coordinates of **A** and **B** in the local coordinate system of a composite object are to be determined in the process of searching for an invariant (and become an attribute of the description of the structure along with the distance between them in the case of an invariant):



This invariant corresponds to the arbitrariness of the angular position of the two composite objects relative to the segment **AB**. Detecting an invariant is reduced to ***solving an overdetermined system of second-order equations with four unknown coordinates*** of points **A** and **B** in ***local coordinates*** (accordingly, the absence of a solution means the absence of an invariant).

The set of potential invariants corresponds to the properties of the environment: the ***presence of a metric in space allows the use of distance as an invariant***, and so on; the set of possible invariants is ***dictated by the environment***, not by the system or its mission.

Since we are talking about invariance in time in a ***dynamical system***, the presence of an invariant implies its ***presence over a specific time interval***. It has two consequences: firstly, the result of an attempt to detect the invariant depends on the ***minimum duration*** of the time interval during which the degree of constancy of the potential invariant is estimated; this value is a ***parameter of the detection process***. Second, if the invariant and the corresponding structure are detected, the intelligent system must regularly ***check the structure for integrity***; this becomes an element of detected ***object tracking*** - a process that tracks changes in object parameters (position, orientation, and so on) over time. The ***detection of a structure and its destruction are system events*** processed by the decision-making system.

The essential technical aspects of the described processes are that operations are performed in ***real-time***, so it is necessary to ***represent each value*** (coordinates, distances, and so on) ***as a function of time***. Any values involved in calculating the value of the potential invariant must refer to the exact moment in time: it is impossible to determine the distance between objects if the coordinates of one of them refer to one moment in time, and the coordinates of the other - to another moment. The ***values reported by the sensors refer to discrete moments***, while in practice, it is not possible to ensure the measurement of all used values at the same moments. Therefore, it is required to ***construct a function that approximates the dependence of the value on time***. Accordingly, there are such processes that are performed permanently independently of each other:

- Collection sensor data.
- Updating the approximation functions of the dependence of quantities on time.
- Using these functions for detecting and tracking structured objects.

Approximation techniques are the subject of a separate chapter.

A demo program simulates a two-dimensional environment in real-time. At the initial stage, the system builds two objects in several steps, each moving and rotating as a rigid whole. At the next stage, the system searches for points on these objects, the distance between which does not change during the movement; thus, a ***two-tier model is constructed***. Situations are ***randomly generated***, thus providing a check of the stability of the algorithms. The video clip demonstrates the process of one of the runs (slowed down in order to match the speed of human perception of the situation):

https://gnosiseng.com/vid/struct.mp4

The advantage of the described process of ***constructing dynamic hierarchical models*** of observed objects and the situation as a whole is the absolute ***explainability*** of all stages. A radical difference of the described approach is that there is no need to identify structured objects by comparison with items of a previously prepared set of samples/patterns.

SUMMATION

- *The detection of structures is based on a* ***set of potential invariants that reflect the properties of the environment (space)****.*
- *An invariant is essentially a* ***hypothesis that needs to be tested and confirmed or rejected****.*
- *For the natural environment, the* ***set of invariants reflects the properties of space-time and does not depend on the purpose of the system****.*
- *A* ***fixed set of invariants allows detecting previously unknown structures of arbitrary complexity****.*
- ***Detecting a previously unknown structure is essentially the construction of new concepts****.*
- *The* ***construction of concepts by structuring the description of the situation solves the concept grounding problem****.*
- *The detection of structures requires operating with* ***functions of time, which in turn requires the approximation of discrete data from sensors****.*
- ***Data collection, their representation as time functions by approximation, detection, and tracking of structures are permanent real-time processes****.*
- *The structured description of the situation is* ***dynamic, providing the ability to forecast****.*
- *The* ***discovery of a structure and its disappearance/destruction are events*** *of the intelligent system.*
- *The process of building dynamic hierarchical models is* ***explainable*** *and controlled by the corresponding parameters.*

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