5 Cognitive information systems

It became possible to develop cognitive information systems on the foundation of intelligent information systems whose purpose was not just the simple analysis of data consisting in recording, processing and interpreting it, but primarily an analysis by understanding and reasoning about the semantic contents of the processed data (e.g. images, biometric patterns, economic data etc.).

Every information system which analyses a selected type of patterns and data using certain features characteristic for them keeps in its database some knowledge – indispensable for executing the correct analysis – which forms the basis for generating the system's expectations as to all stages of the interpretation it conducts. As a result of combining certain features found in the analysed type of data with the expectations - generated using this knowledge - about the existing semantic contents of the data or information, cognitive resonance occurs as described previously.

Cognitive information systems use methods which determine semantic/structural reasoning techniques serving to interpret patterns [57]. A system which executes a cognitive data analysis very often analyses not just text information or numerical data, but frequently also image data. In this last case, the structure of the image being analysed is compared during the analysis process to the structure of the image which serves as a type of pattern. This comparison is obviously conducted using strings of derivation rules which enable the pattern to be generated unambiguously. These rules, sometimes referred to as productions, are established in a specially derived grammar, which in turn defines a certain formal language, called an image language. Examples of such languages will be presented in subsequent chapters describing example systems for interpreting selected medical images. An image (or information) thus recognised is assigned to the class to which the pattern that represents it belongs.

Cognitive analysis used in information systems very frequently uses a syntactic approach which employs certain strictly defined functional stages for the meaning analysis and interpretation of the image [13, 17].

The input image first of all undergoes preprocessing, which comprises:

– coding the image with terminal components of the introduced language;
– approximating the shapes of the analysed objects; and also
– filtering and preprocessing the input image.

The completion of these stages represents the image anew in the form of hierarchical structures of a semantic tree and subsequent steps of deriving this representation from the initial symbol of the grammar [17, 37].

At the stage of preprocessing image data, an intelligent cognitive recognition system must (in most cases) segment the image, identify picture primitives and also determine the relations between them. The classification proper, combined with the semantic interpretation, consists in recognising whether the specific representation of the input image belongs to the class of images generated by the
formal language defined by one of the grammars that can be introduced – a sequential, tree or graph grammar – which are used for recognition processes executed during the syntactic analysis performed by the system [17, 37].

The most recent studies of intelligent information systems indicate that only recognising (that is classifying) the analysed image is no longer sufficient, because researchers increasingly frequently propose to employ these systems also for automatic, computer understanding of the image, which means determining its semantics as well.

This applies in particular to image data, which can contain deep layers of meaning.

Such image data certainly includes medical images. This is why pattern interpretation systems have mainly developed in medical patterns in recent years. In order to support machine semantic reasoning for a selected class of patterns, artificial intelligence techniques are used. These techniques, apart from the simple recognition of the image identified for analysing, can also extract significant semantic information which forms its semantic interpretation, and this in turn makes its full understanding possible.

This process applies only to cognitive information systems and is much more complex than just recognition, as the information flow in this case is clearly two-way [53, 57, 61]. In this model, just as in brain structures, the stream of empirical data contained in the subsystem whose job it is to record and analyse the image interferes with the stream of expectations generated. A certain type of interference must occur between the stream of expectations generated by the specified hypothetical meaning of the image and the stream of data obtained by analysing the image currently under consideration. This interference means that some coincidences (of expectations and features found in the image) become more important, while others (both consistent and inconsistent) lose importance. This interference, whose action leads in consequence to achieving cognitive resonance, confirms one of the possible hypotheses (in the case of an image whose contents can be understood), or justifies a statement that there is a non-removable inconsistency between the image currently perceived and all gnostic hypotheses which have an understandable interpretation. The second case means that the attempt to automatically understand the image has failed [49].

So cognitive information systems use cognitive resonance, which is characteristic only for these systems of computer reasoning and distinguishes them from other intelligent information systems. The use of such systems may be varied, as today's science offers them broad possibilities. However, the greatest opportunities for using cognitive information systems are currently found in medicine, as more and more pathological entities occur in disease processes which can affect individual organs of the human body. Such systems may significantly contribute to improving the detectability and recognisability of such entities.

Medical images are among the most varied data and have extremely deep and significant meaning interpretation. Cognitive information systems could certainly also help in many other fields of science and everyday life if an attempt were made to add the process of understanding the analysed information and data to in-