FUZZY OBJECT-ORIENTED DYNAMIC NETWORKS. I

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Abstract. The concepts of fuzzy objects and their classes are described that make it possible to structurally represent knowledge about fuzzy and partially-defined objects and their classes. Operations over such objects and classes are also proposed that make it possible to obtain sets and new classes of fuzzy objects and also to model variations in object structures under the influence of external factors.

Keywords: fuzzy object, fuzzy class of objects.

INTRODUCTION

At present, one of main problems facing scientists in the field of artificial intelligence (AI) is the development of intelligent information systems (IIS) to solve problems arising in different AI fields. The solution of such a problem is often reduced to heuristic programming that can yield good results, but, in this case, the complex solution of the problem is not provided. Systems based on knowledge representation models (KRM s) belong to largest classes of IISs. To date, the following models are well-known and actively used: semantic networks, conceptual graphs, frames, scripts, logical and production models, ontologies, etc. But, despite the use of some KRM or other as the base for an IIS, an implemented system consists of at least two levels, namely, the KRM level and level of its practical implementation. An implementation of a KRM often creates definite problems and complexities connected with interacting different levels of the system. In this connection, an object-oriented knowledge representation model was proposed in [1], which can be integrated into object-oriented programming languages and thereby to unite the KRM itself and the language used for its implementation. This approach will allow one to get rid of some levels of abstraction and to partly simplify the structure of the system being developed and, hence, the development process itself.

The present article describes main ideas that form the basis for constructing fuzzy object-oriented dynamic networks, in particular, fuzzy objects and classes that allow one to structurally represent knowledge about objects that are unfuzzily specified, are fuzzy, or are incompletely defined and, at the same time, to classify them. Operations over fuzzy objects and classes of fuzzy objects are also considered with the help of which sets and new classes of fuzzy objects can be constructed and, thereby, new knowledge can be obtained.

FUZZY OBJECTS AND CLASSES

Objects can be considered to be both arbitrary things from our real life and results of using our imagination. In other words, an object is every thing that can be perceived in some way or other, i.e., can be sensed or imagined. It is obvious that each object (irrespective of its nature) has definite properties that are characteristic for it. For example, let us consider a natural number. It is obvious that it must be integer and larger than zero. It is these characteristic properties of natural numbers that allow one to distinguish them from other objects. In fact, in order to reveal whether the numbers $-1, 4.67, and 5$
are natural, it is necessary to check their properties, in particular, to check whether these numbers possess the same
properties as natural numbers. As a result of verification, it becomes obvious that –1 and 4.67 are not natural numbers. From
this it is possible to draw the conclusion that a natural number is a crisply defined object. But, in addition to crisp objects,
there also are other objects such as fuzzy and approximately or incompletely described objects. They arise in trying to
recollect something, in describing our desires or fancies, in searching for something about which we know very little, etc.
They mentally arise when we want to formalize some intuitive guess whose whole nature is fuzzy from the viewpoint of
logic or mathematics. L. A. Zadeh was the first to propose a formalistic approach to the description of such objects [2]. With
time, this approach was transformed into a theory, and many results were obtained within the framework of this theory, in
particular, in the field of constructing information systems that operate with fuzzy concepts. Taking into account the
flexibility and efficiency of the approach proposed by L. Zadeh, we use here some of his ideas for formal definition of fuzzy
objects.

In addition to the aforesaid concerning objects and their properties, we will pay attention to the following important
point: properties of an object and the object itself are closely interconnected and cannot exist separately. Properties do not
exist in themselves without an object since some object is their manifestation, and properties cannot be seen, understood, and
even described without it. In turn, an object cannot exist without properties since their absence makes the construction or
even a representation of the object impossible. It is obvious that this takes place for both crisp and fuzzy objects. Therefore,
a formal definition of the concept of an object cannot be formulated if its properties are not formally defined and vice versa,
it is impossible to define properties without knowing an object. In this connection, we first define properties of an object and
then the object itself with allowance made for their interrelations.

Before considering properties of an object, note that they are subdivided into quantitative and qualitative ones.

Definition 1. A fuzzy quantitative property of an object \( A \) is a tuple of the form \( p(A) = \langle V(p(A)), u(p(A)) \rangle \), where
\( V(p(A)) = \{v_1 / \mu(v_1), \ldots, v_n / \mu(v_n)\} \) is a fuzzy set describing the quantitative value of the property \( p(A) \) and \( u(p(A)) \) are its
measurement units.

Example 1. Let us consider an object, for example, an apple; one of its properties is its mass. After weighing it, we
obtain its exact mass, and this will determine the value of its crisp quantitative property described in [1]. But if it is
impossible to approximately or exactly weigh an apple and thereby determine its mass, then we can represent it using a fuzzy
set \( p_m(A) = \langle V(p_m(A)), u(p_m(A)) \rangle \). If we take an apple and, based on our sensation, reveal that its mass is about 100 g,
then this mass can be represented in the form

\[
p_m(A) = \{95/0.8, 100/0.9, 105/1, 110/0.9, 115/0.8\}, \text{ g}.\]

Let us define the equivalence of two fuzzy quantitative properties of objects to provide the possibility of comparing them.

Definition 2. Two fuzzy quantitative properties \( p(A) \) and \( p(B) \) are equivalent, i.e., \( Eq(p(A), p(B)) = 1 \), if and only if
the following conditions are fulfilled:

1. \( u(p(A)) = u(p(B)) \);
2. \( \mu(v_i) - \mu(v_j) = 0 \), \( i = \overline{1,n} \), \( j = \overline{1,m} \);
3. \( v_{k+1} - v_k = v_{w+1} - v_w \), \( k = \overline{1,n-1} \), \( w = \overline{1,m-1} \).

Definition 3. A fuzzy qualitative property of an object \( A \) is a verification function \( v_f(A) \); \( p(A) \rightarrow [0,1] \) that reflects
the degree (measure) of truth (presence) of a property \( p(A) \) for the object \( A \).

Example 2. Let us consider an object such as a water-melon and its property such as its (geometrical) form. The form
of a water-melon can be described in different ways, but it is necessary to proceed from the fact that its form resembles
a sphere. It is obvious that each concrete water-melon will have a unique form of a flat sphere. But an advantage of this
approach is that a sphere is a crisply defined geometric object and, hence, the geometrical form of a water-melon, namely,
the degree of its sphericity, can be represented as a function of verification of its sphericity, i.e., \( v_{f_S}(W) ; p_S(W) \rightarrow [0,1] \).

Let us define the equivalence of two fuzzy qualitative properties of objects to provide the possibility of comparing them.

Definition 4. Two fuzzy qualitative properties \( v_{f_1}(A) \) and \( v_{f_2}(B) \) are equivalent, i.e., \( Eq(v_{f_1}(A), v_{f_2}(B)) = 1 \), if and
only if the following condition is fulfilled: \( (v_{f_1}(A) = v_{f_2}(A)) \land (v_{f_2}(B) = v_{f_2}(B)) \).

Since one object can have several properties that are quantitative and qualitative, it makes sense to define the concept of a fuzzy object specification.