Scientific Report

regarding the implementation of the project
PN-II-ID-PCE-2011-3-0439
from October 2013 to November 2014

The implementation of the project during the period October 2013 - November 2014 was performed within the three objectives specified in the project proposal:

I. Foundations of structured specifications;

II. Universal approach to the formal verification; and

III. Institution theoretic approach to logic combination.

1 Foundations of structured specifications

The research under this objective has focused on the study of the translations of structured specifications within institution theory. This issue occurs in the heterogeneous specification paradigm [16, 20, 24] that has recently witnessed an important development. The results obtained are the subject of the work [15]. The main contributions are as follows:

1. Within the theory of \textit{abstractly} structured institutions [11] we have introduced a semantic concept of normal form that subsumes the existing syntactic one in the literature [21, 23]. Also, we have shown that this semantic concept of normal form is significantly broader than the syntactic one.

2. We have developed a general existence theorem on translating structured specifications based on a set of general conditions with a rather broad applicability. The translations of structured specifications are formalized as comorphisms between abstractly structured institutions (see [8]).

2 Universal approach to formal verification

Under this objective, research has focused on the study of a new approach to abstract logic programming and on implementation and evaluation of the developed theory for the classical
paradigm of logic programming and for service-oriented computation. The results obtained are
the subject of the works [28, 29] and were presented at the The 22nd International Workshop
on algebraic Development Techniques (WADT 2014) [30, 27] and at the 22nd meeting of the
group IFIP WG1.3 [31]. The main contributions are as follows:

1. The introduction of the concepts of substitution system and substitutions generalised substi-
tution system (see [28]); they extend the notion of institution through constructions
allowing the capture of (explicit) variables and substitutions – fundamental elements for
defining the operational semantics of logic programming.

2. The study of quantified sentences within the abstract framework of generalised substi-
tution systems and highlight the role of the model amalgamation property in ensuring
the invariance of their satisfaction relative to the change of signature – the link between
these two concepts has been investigated since 1985 within the context of the theory of
formal specifications (see, for example [4, 21, 10] and also more recent works [25, 5]
devoted to the study of heterogeneous specifications).

3. Generalization of Herbrand theorems of [9] to logical systems in which variables can not
be described by morphisms of signatures – the main exponent in this case being the logic
of asynchronous relational networks logic (which is the base paradigm of service-oriented
computing) described in [26].

4. Definition of a mathematical concept of logic programming language and of an abstract
form of resolution (as a rule of inference) that generalizes both the classical resolution
(specific to relational logic programming) and paramodulation and narrowing (specific
to equational logic programming). These enable the introduction of a general procedure
for solving a logic programming problem. We have showed the soundness of the general
procedure and have identified sufficient conditions for its completeness also.

5. The study of problem solving in logic programming (using the procedure discussed above)
when structuring logic programs (see [30]). This includes investigation of the preservation
of solutions over the morphisms of logic programs (imports) and the possibility of
reducing the context (set of clauses) against which one tries solving a problem.

6. The application of the general theory of logic programming for calculation oriented
services. In the work [29] the concept of orchestration scheme is introduced; this alge-
braic structure allows the study of models of dynamic calculations specific to the
service-oriented computing paradigm (involving both local computing and communi-
cation phases between software components, as well as global reconfiguration steps)
independently of the local computational model involved – which may for example be
based upon Hoare calculus introduced in [19] or the asynchronous relational networks
discussed in [18].

7. The definition of a fully operational semantics of services (see [27]) by characterizing
the execution of an activity (which is assumed to be dynamic, in the sense of accepting
possible reconfigurations of activity) as trace of a dedicated transition system. This re-
fines the operational semantics proposed in [26] (based on logic programming concepts)
by making explicit the local computation and communication steps of asynchronous
relational networks activities; in addition, by the derivation of transition systems equivalent (from the operational semantics perspective) to asynchronous relational networks it is facilitated the application of model checking techniques for formal verification of activities.

3 Institution-independent approach to logic combination

Under this objective we have developed a synthesis of important contributions of the theory of formal specification to universal logic. This was the subject of the work [12] (paper invited to International Colloquium on Theoretical Aspects of Computing 2014) and developed a algebraic theory of Squares of Opposition (published in [?]). The contributions discussed in [12] are:

1. Morphism of signatures versus language extensions.
2. Local approach on logical variables and on quantifications. The concept of quantification space.

The main contributions of [14] are:

2. Definition of a concept of many-valued consequence by weakening the concept of graded consequence of [6, 7, 17, 13].
3. The generation of non-Boolean opposition squares via many-valued consequences.
4. The generation of many-valued consequences by many-valued abstract semantics of a similar kind of institution theory (in a generalised many-valued sense).

References


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