



Evolog - Actions and Modularization in Lazy-Grounding Answer Set Programming

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Diplom-Ingenieur

im Rahmen des Studiums

Logic and Computation

eingereicht von

Michael Langowski, BSc.

Matrikelnummer 01426581

an der Fakultät für Informatik

der Technischen Universität Wien

Betreuung: Prof. Dr. Thomas Eiter

Mitwirkung: Dr. Antonius Weinzierl

Wien, 1. Juli 2022

Michael Langowski

Thomas Eiter



Evolog - Actions and Modularization in Lazy-Grounding Answer Set Programming

DIPLOMA THESIS

submitted in partial fulfillment of the requirements for the degree of

Diplom-Ingenieur

in

Logic and Computation

by

Michael Langowski, BSc.

Registration Number 01426581

to the Faculty of Informatics

at the TU Wien

Advisor: Prof. Dr. Thomas Eiter

Assistance: Dr. Antonius Weinzierl

Vienna, 1st July, 2022

Michael Langowski

Thomas Eiter

Erklärung zur Verfassung der Arbeit

Michael Langowski, BSc.

Hiermit erkläre ich, dass ich diese Arbeit selbständig verfasst habe, dass ich die verwendeten Quellen und Hilfsmittel vollständig angegeben habe und dass ich die Stellen der Arbeit – einschließlich Tabellen, Karten und Abbildungen –, die anderen Werken oder dem Internet im Wortlaut oder dem Sinn nach entnommen sind, auf jeden Fall unter Angabe der Quelle als Entlehnung kenntlich gemacht habe.

Wien, 1. Juli 2022

Michael Langowski

Danksagung

Ihr Text hier.

Acknowledgements

Enter your text here.

Kurzfassung

Ihr Text hier.

Abstract

Enter your text here.

Contents

Kurzfassung	xi
Abstract	xiii
Contents	xv
1 Introduction	1
2 Preliminaries	3
3 The Evolog Language	5
3.1 Actions in Evolog	5
List of Figures	9
List of Tables	11
List of Algorithms	13
Bibliography	15

CHAPTER 1



Introduction

Intro here

CHAPTER 2

Preliminaries

The Evolog Language

The Evolog language extends (non-disjunctive) ASP as defined in the ASP-Core2 standard [CFG⁺20] with facilities to communicate with and influence the "outside world" (e.g. read and write files, capture user input, etc.) as well as program modularization and reusability features, namely *actions* and *modules*.

3.1 Actions in Evolog

Actions allow for an ASP program to encode operations with *side-effects* while maintaining fully declarative semantics. Actions are modelled in a functional style loosely based on the concept of monads as used in Haskell . Intuitively, to maintain declarative semantics, actions need to behave as pure functions, meaning the result of executing an action (i.e. evaluating the respective function) must be reproducible for each input value across all executions. On first glance, this seems to contradict the nature of IO operations, which inherently depend on some state, e.g. the result of evaluating a function *getFileHandle(f)* for a file *f* will be different depending on whether *f* exists, is readable, etc. However, at any given point in time - in other words, in a given state of the world - the operation will have exactly one result (i.e. a file handle or an error will be returned). A possible solution to making state-dependent operations behave as functions is therefore to make the state of the world at the time of evaluation part of the function's input. A function *f(x)* is then turned into *f'(s, x)* where *s* represents a specific world state. The rest of this section deals with formalizing this notion of actions.

cite something here!

3.1.1 Syntax

Definition 3.1.1 (Action Rule, Action Program). An *action rule* *R* is of form

$$a_H : @t_{act} = act_{res} \leftarrow l_1, \dots, l_n.$$

where

Define non-disjunctive ASP-Core2 in detail in preliminaires. Give detailed definition of all "standard ASP" elements referenced here!

- a_H is an atom called *head atom*,
- t_{act} is a functional term called *action term*,
- act_{res} is a term called *(action-)result term*
- and l_1, \dots, l_n are literals constituting the *body* of R .

An *action program* P is a set of (classic ASP-)rules and action rules.

3.1.2 Semantics

To properly define the semantics of an action program according to the intuition outlined at the start of this section, we first need to formalize our view of the "outside world" which action rules interact with. We call the world in which we execute a program a *frame* - formally, action programs are always evaluated *with respect to a given frame*. The behavior of actions is specified in terms of *action functions*. The semantics (i.e. interpretations) of action functions in a program are defined by the respective frame.

Action Rule Expansion

To get from the practical-minded action syntax from Definition 3.1.1 to the formal representation of an action as a function of some state and an input, we use the helper construct of an action rule's *expansion* to bridge the gap. Intuitively, the expansion of an action rule is a syntactic transformation that results in a more verbose version of the original rule called *application rule* and a second rule only dependent on the application rule called *projection rule*. A (ground) application rule's head atom uniquely identifies the ground instance of the rule that derived it. As one such atom corresponds to one action executed, we call a ground instance of an application rule head in an answer set an *action witness*.

Definition 3.1.2 (Action Rule Expansion). Given a non-ground action rule R with head atom a_H , action term $f_{act}(i_1, \dots, i_n)$ and body B consisting of literals l_1, \dots, l_m , the expansion of R is a pair of rules consisting of an *application rule* R_{app} and *projection rule* R_{proj} . R_{app} is defined as

$$a_{res}(f_{act}, S, I, f_{act}(S, I)) \leftarrow l_1, \dots, l_n.$$

where S and I and function terms called *state-* and *input-*terms, respectively. An action rule's state term has the function symbol *state* and terms $fn(l_1), \dots, fn(l_m)$, with the expression $fn(l)$ for a literal l denoting a function term representing l . The (function-)term representation of a literal $p(t_1, \dots, t_n)$ with predicate symbol p and terms t_1, \dots, t_n uses p as function symbol. For a negated literal *not* $p(t_1, \dots, t_n)$, the representing function term is *not*($p(t_1, \dots, p_n)$). The action input term is a "wrapped" version of all arguments of the action term, i.e. for action term $f_{act}(t_1, \dots, t_n)$, the corresponding input term is

define (classic ASP) grounding and substitutions in preliminaries

$input(t_1, \dots, t_n)$. The term $f_{act}(S, I)$ is called *action application term*. The projection rule R_{proj} is defined as

$$a_H \leftarrow a_{res}(f_{act}, S, I, v_{res}).$$

where a_H is the head atom of the initial action rule R and the (sole) body atom is the action witness derived by R_{app} , with the application term $f_{act}(S, I)$ replaced by a variable v_{res} called *action result variable*.

Looking at the head of an action application rule of format $a_{res}(f_{act}, S, I, t_{app})$ with action f_{act} , state term S , input term I and application term t_{app} , the intuitive reading of this atom is "The result of action function f_{act} applied to state S and input I is t_{app} ", i.e. the action application term t_{app} is not a regular (uninterpreted) function term as in regular ASP, but an actual function call which is resolved using an interpretation function provided by a *frame* during grounding.

Grounding of Action Rules

Definition 3.1.3 (Frame). Given an action program P containing action application terms $A = \{a_1, \dots, a_n\}$, a frame F is an interpretation function such that, for each application term $f_{act}(S, I) \in A$ where $S \in H_U(P)^*$ and $I \in H_U(P)^*$, $F(f_{act}) : H_U(P)^* \times H_U(P)^* \mapsto H_U(P)$.

Example 3.1.1 demonstrates the expansion of an action rule as well as a compatible example frame for the respective action.

Definition 3.1.4 (Grounding of Action Rules). Blabla - Not sure if this is actually needed.

Example 3.1.1 (Expansion and Frame). Consider following Evolog Program P which contains an action rule with action a :

$$\begin{aligned} & p(a). \ q(b). \ r(c). \\ & h(X, R) : @a(X, Z) = R \leftarrow p(X), q(Y), r(Z). \end{aligned}$$

The expansion of R is:

$$\begin{aligned} & a_{res}(a, state(p(X), q(Y), r(Z)), input(X, Z), a(state(p(X), q(Y), r(Z)), input(X, Z))) \leftarrow \\ & \qquad \qquad \qquad p(X), q(Y), r(Z). \\ & h(X, R) \leftarrow a_{res}(a, state(p(X), q(Y), r(Z)), input(X, Z), R). \end{aligned}$$

Furthermore, consider following frame F :

$$F(a) = \{a(state(p(a), q(b), r(c)), input(a, c)) \mapsto success(a, c)\}$$

which assigns the result $success(a, c)$ to the action application term (i.e. function call $a(state(p(a), q(b), r(c)), input(a, c))$).

Then, the ground program P_{grnd} after action rule expansion is

$$\begin{aligned} & p(a). q(b). r(c). \\ a_{res}(a, state(p(a), q(b), r(c)), input(a, c), success(a, c)) & \leftarrow p(a). q(b). r(c). \\ h(a, success(a, c)) & \leftarrow a_{res}(a, state(p(a), q(b), r(c)), input(a, c), success(a, c)). \end{aligned}$$

The sole model of P with respect to frame F is

$$\begin{aligned} M = \{ & p(a), q(b), r(c), \\ & a_{res}(a, state(p(a), q(b), r(c)), input(a, c), success(a, c)) \\ & h(a, success(a, c)) \} \end{aligned}$$

according to
semantics? r
ence LFP he

List of Figures

List of Tables

List of Algorithms

Bibliography

- [CFG⁺20] Francesco Calimeri, Wolfgang Faber, Martin Gebser, Giovambattista Ianni, Roland Kaminski, Thomas Krennwallner, Nicola Leone, Marco Maratea, Francesco Ricca, and Torsten Schaub. Asp-core-2 input language format. *Theory and Practice of Logic Programming*, 20(2):294–309, 2020.