In-source Testing in Answer Set Programming
Setup

```
$ mkdir decl24
$ cd decl24
$ python -m venv .env
$ source .env/bin/activate
$ git clone git@github.com:ejgroene/declarative2024.git
$ cd declarative2024
$ pip install .
```

type

or

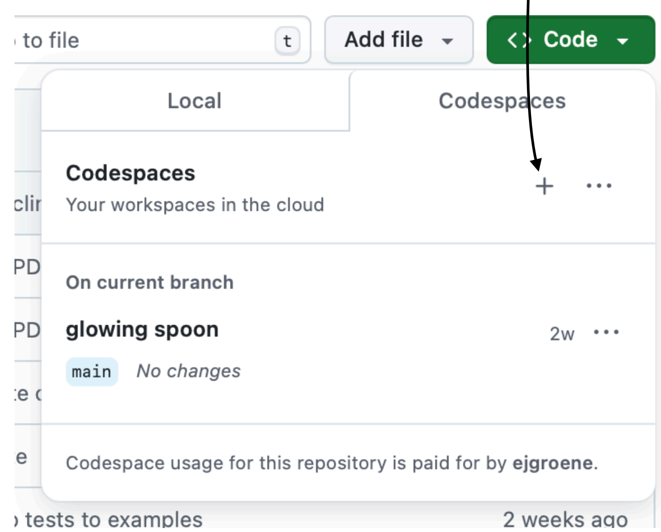
click

Instructions at:

https://github.com/ejgroene/declarative2024

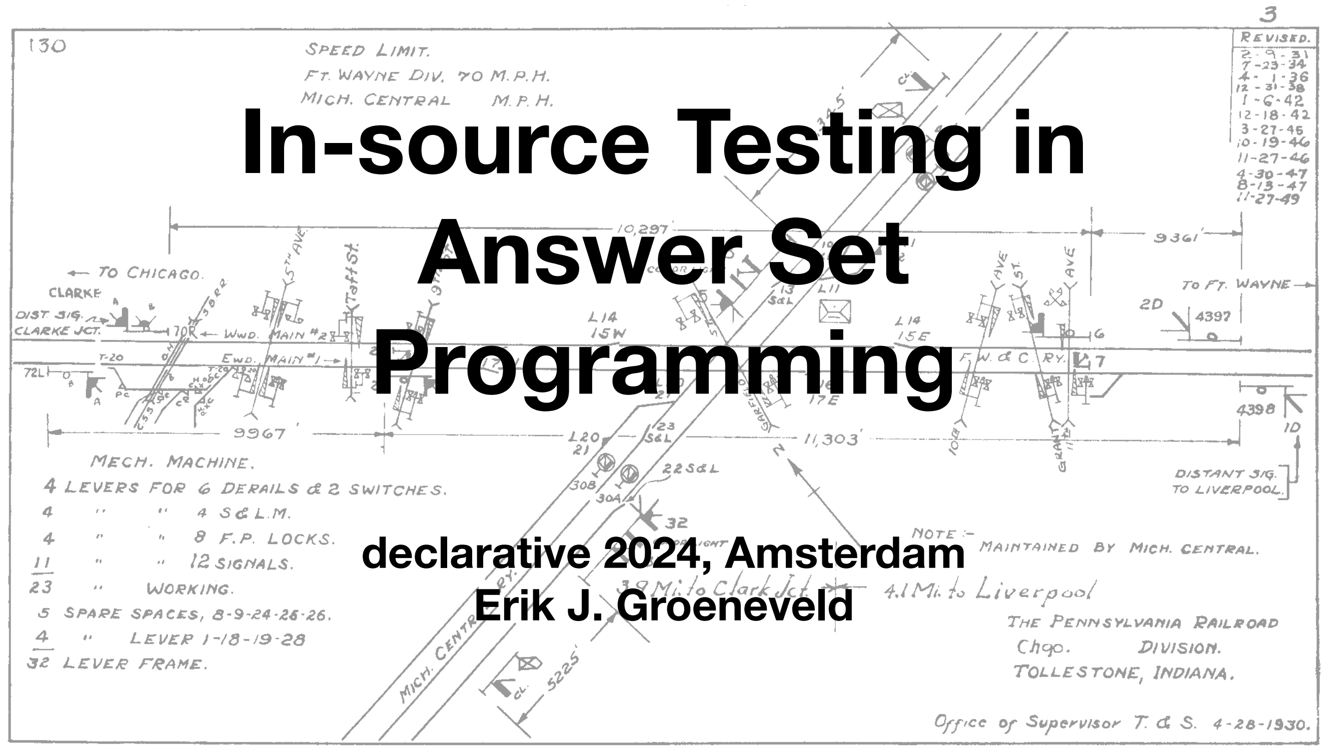
or via:

https://declarative.amsterdam/program



Instructions als via link on program, follow link, README.md.
All examples, challenges and code snippets are there.

In-source Testing in Answer Set Programming



declarative 2024, Amsterdam

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Welcome

Contents

- Setup code environment
- Who am I?
- What is In-source Testing
- How to test ASP programs
- Potassco, clingo
- Hands-on
- Questions

ASP Introduction as we go

Code samples in repo
Invite to join with code.

I love programming

- 1996: Baan R&D (research engineer)
- 1999: Software Engineering Research Centre (SERC)
- 2001: Owner of Seecr (search with Lucene)
- 2024: Independent (finally)

- Programming Languages
  - (GW-)Basic
  - Pascal
  - C/C++
  - Python
  - Clojure
  - Answer Set Programming

- Metaprogramming
  - Efficiency
  - Size reduction
  - Patterns & idioms
  - Metaclasses
  - Integration
  - Extreme Programming
  - Push boundaries

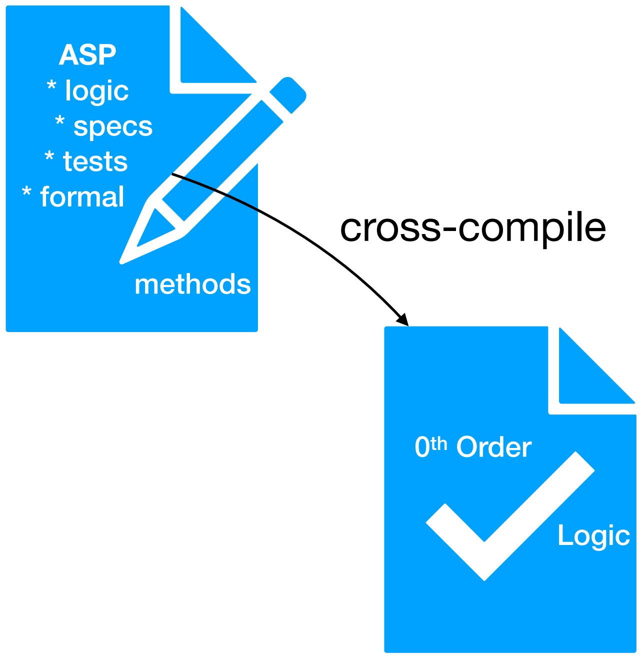
Seecr did Python before it became popular.

How it started…

- Railway Interlocking
- 0^{th} Order Logic

- Design Automation

- Formal Specification
- **Unit Testing**
- Formal Methods
- => Higher Order Logic



Higher order logic

```
normaal_voorwaarde_h(T, Rijweg)  :-
    rijweg_ingesteld(T, Rijweg),
    bgz(T, Rijweg),
    sectie_vrij(T, Rijweg, Sectie)    : rijweg_sectie(Rijweg, Sectie);
    sts_passage(T, Rijweg, Wissel)    : flankzonebewaking(Rijweg, Wissel);
    virtueel_h(T, Rijweg)             : vierdraadsAPB(Rijweg);
    virtueel_d(T, Rijweg)             : rijrichtingskering_zonder_bloksein(Rijweg).
```

variables

sets
(such-that)

cross-compile

```
BOOL 190-192-H = (190-192-BGZ * 190-GZ-CS * 190-TP * 191-TP)
BOOL 192-188-H = (189-TP * 190-TP * 191-TP * 192-188-BGZ *
                  192-GZ-CS * 192-TP * A178-TP)
BOOL 192-190-H = (174C-TP * 190-TP * 191-TP * 192-190-BGZ
                  192-GZ-CS * 192-TP)
```

ASP: rule, head, body, conjunction/and

0-orde: straight forward logic, top to bottom, no choice, implicit time

1-orde: variables

2-orde: sets (such-that)

Look at rule: clearly we need tests: 4 conditions, no less!

What is In-Source Testing?

- Put your test right **between** your code.
  - Same language/file/class/function/compilation unit
  - Runs on **every** import

real Python code

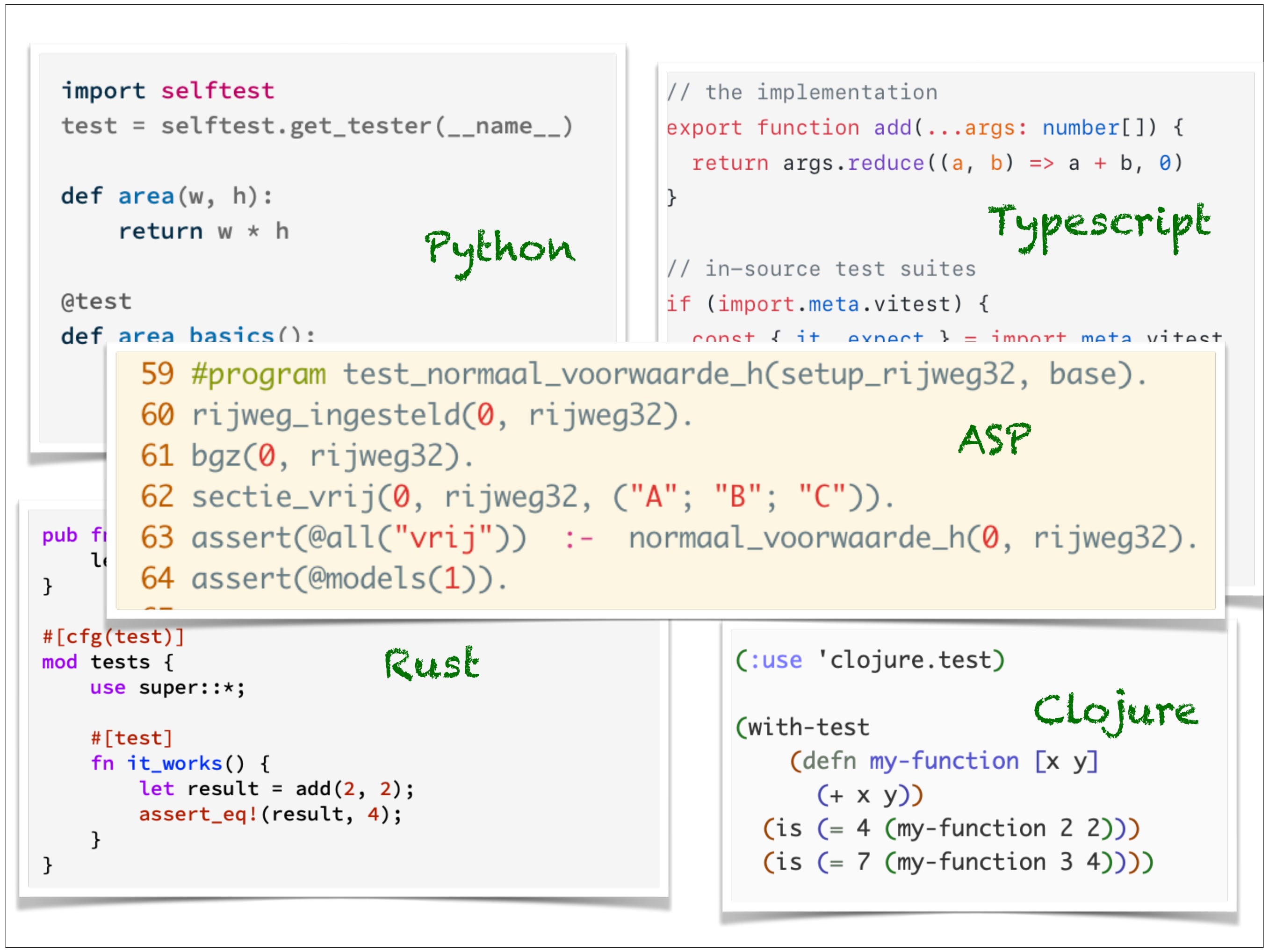
```python

def sym2ids(body):
    """ Create a set of id's for each free symbol in the body """
    return {mk_id(h, t) for h, t in (get_time(s) for s in body.free_symbols)}


@test
def ids_for_symbols():
    test.eq({'a(0)'}, sym2ids(sym('a')))   # simple symbol
    test.eq({'a(0)', 'b(0)'}, sym2ids(sympy.And(sym('a'), sym('b'))))  # compound symbol

```

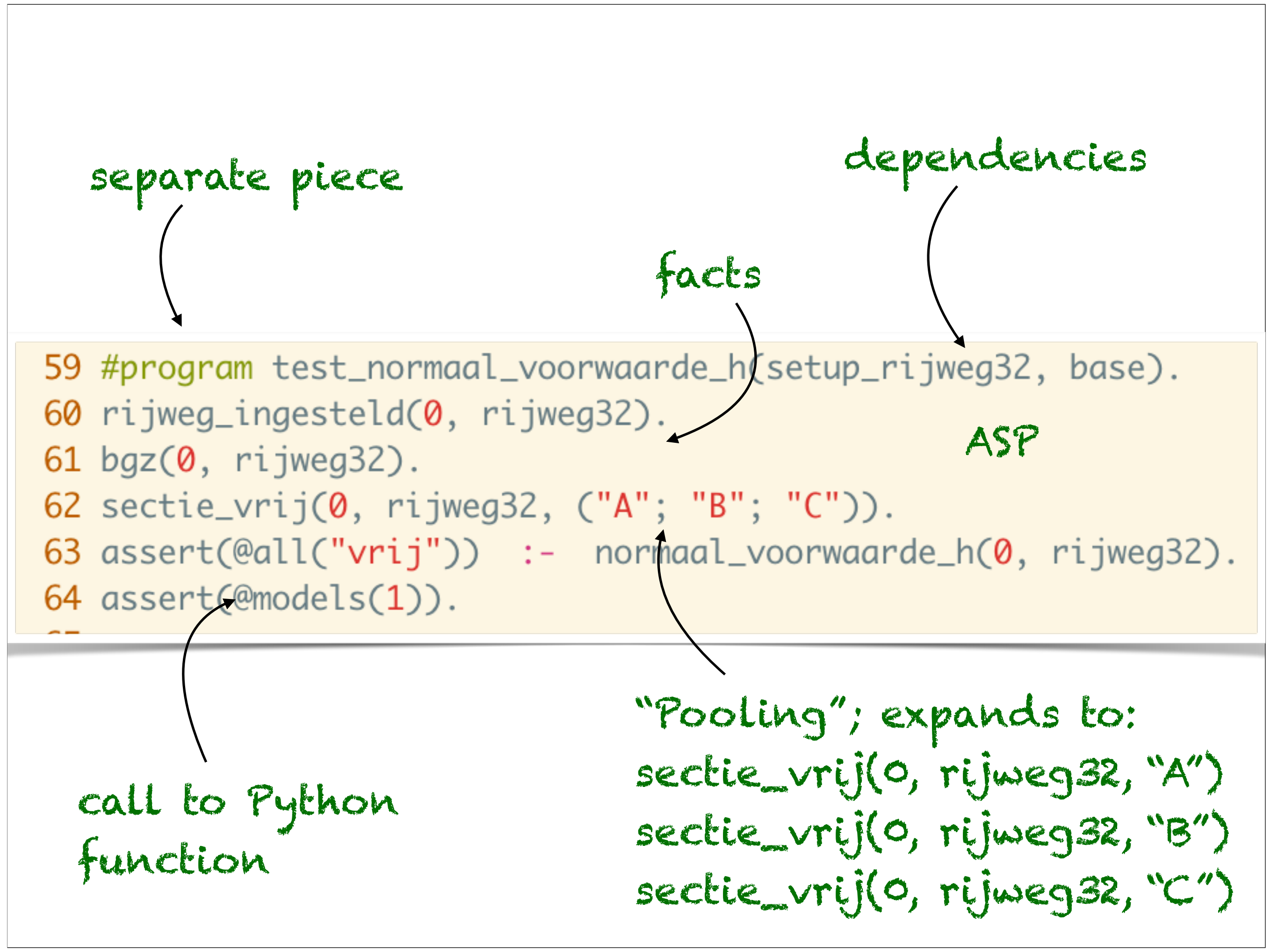
Tests also document the behaviour.
Executed on demand: on import
Regardless the context
CONTEXT is the CURRENT software CRISIS



Almost silent until 2024, now, blogs begin to appear

Clojure is a bit more integrated: special function with asserts (not separate tests)

PRESS for ASP example: explain #program, facts and @-callouts



Explain #program, facts and @-callouts
; = pool expansion

Why In-source?

- Reduce test code base **maintenance**
- Automatic and **deterministic** collection of tests (import)
- Automatic **subset** selection
- Easier **refactoring** (move code)
- **Intuitive** test shifting from unit/integration/system
- Test different **environments** (tests part of program)
- **Less framework'ish** in general (more control, less magic)

and now: ASP

Answer Set Programming

soda.lp

```
% choice
beer; wine; soda.

% rules
drunk :- beer.
drunk :- wine.
```

```
Solving...
Answer: 1
soda
Answer: 2
wine drunk
Answer: 3
beer drunk
```

variables.lp

```
% available drinks
beverage(wine, 11).
beverage(beer,  5).
beverage(soda,  0).

% choice: party or not
{ party }.

% when party, drink some
{ drink(D, P) }  :-  party,  beverage(D, P).

#show party/0.
#show drink/2.
```

- What we need today:
  - facts
  - rules & variables
  - constraints
  - conditional literals
  - aggregates
  - optimisation

explained when we meet them

soda.lp: facts, choice, disjunction
clingo 0 beer.lp. => explain 1 answer ‘soda’ and not ‘drunk’. (Drunk is not there)
party.lp: set choice: 0 or more
2 choices: party or not, drink some or not.
explain models

```
% facts (atoms)
beer(valdieu, 8).
beer(radler, 0).
pils(gulpener, 6).
ale(kilkenny, 4).

% rule: head :- body
alcoholic(B)  :-  beer(B, _).

% disjunction
beer(B, A)  :-  pils(B, A).
beer(B, A)  :-  ale(B, A).

% conjunction
special(B)  :-  beer(B, A),  A > 5.

% choice
{ drink(radler, 0) }.
{ drink(B, A) }  :-  beer(B, A).

% constraint, it cannot be that...
:-  drink(B, A),  A = 0.

% conditional literals ('such that')
specials(T)  :-  T = { beer(B, A)  :  special(B) }.

% output control
#show drink/2.
#show specials/1.
```

crash course ASP

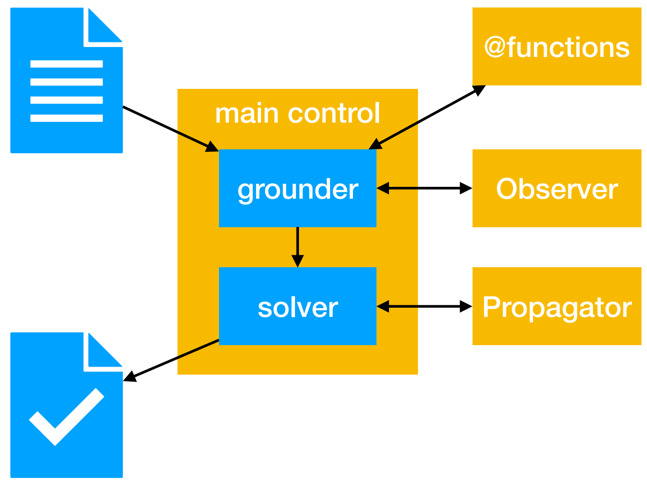
see Codespace

we’ll repeat it when
we meet them again

see code base!

Potassco

- an ASP implementation by University of Potsdam
- Try it online: https://potassco.org/clingo/run/



- **API's**
  - C++/Python/Lua
  - Embedded #script
  - Callout @function
  - Intercept
    - Observer
    - Propagator
  - Main control

```
#script (python)
from clingo import Function

def make_atom(name, arg):
    return Function(name.name, [arg])

#end.

beverage(wine, 11).
beverage(beer,  5).

drink(@make_atom(B, P))  :-  beverage(B, P).
```

How to test ASP?

a #program
named test_...

setup, fixtures etc

```
#program test_small_graph_of_three_nodes(base, general_checks).
edge(1, 2, 1).  edge(2, 3, 1).  edge(3, 1, 1).          % probl
assert(@all("3 nodes"))  :-  { node(N) }  =  3.
assert(@any("steps"))  :-  { step(1,2; 2,3; 3,1) } = 3.
models(1).
```

expected models

asserts

@all:
  be in every model
@any:
  be in at least one model

@all/@any are Python call-outs.
They register the assert so it can be check afterwards

ASP Test Idioms

sets => aggregate

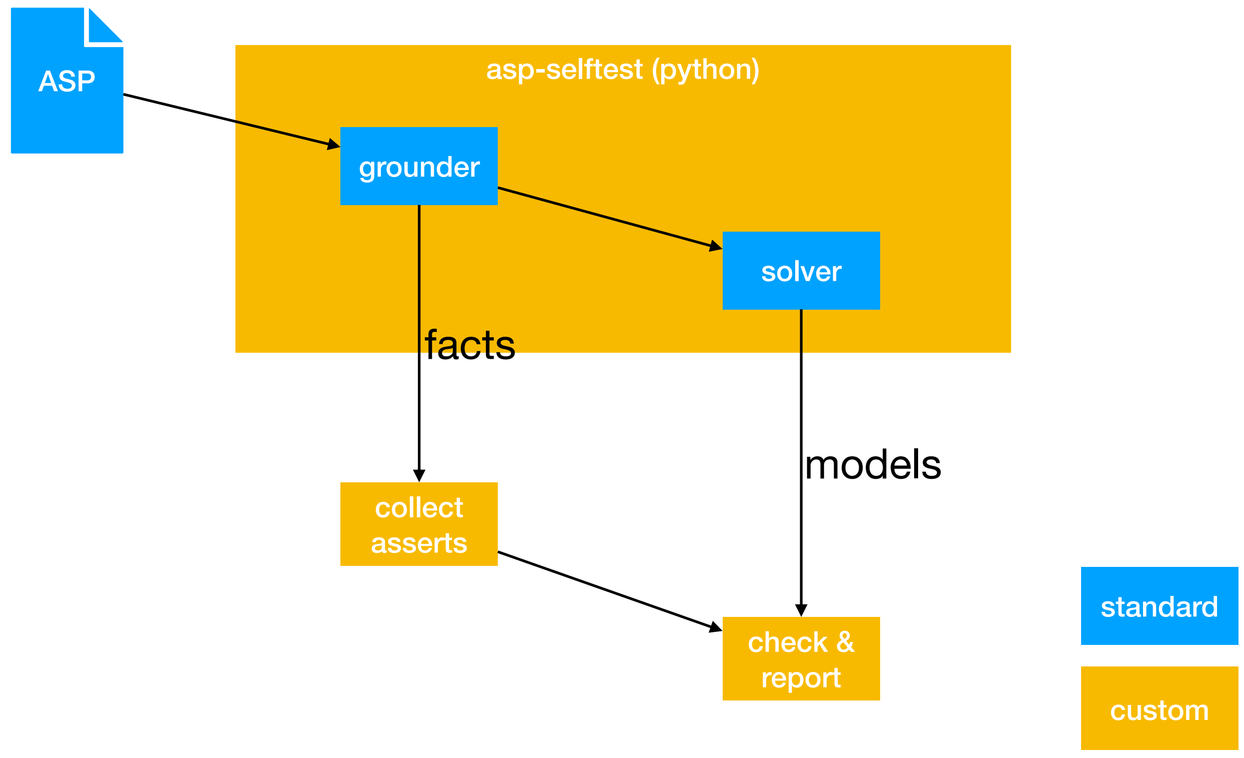
implicit aggregate #count

```
#program test_single_node_graph(base, general_checks).
edge(1, 1, 1).
assert(@all("1 nodes"))  :-  { node(N) } = 1.
assert(@any("steps"))  :-  { step(_, _) }  =  0.
models(1).
```

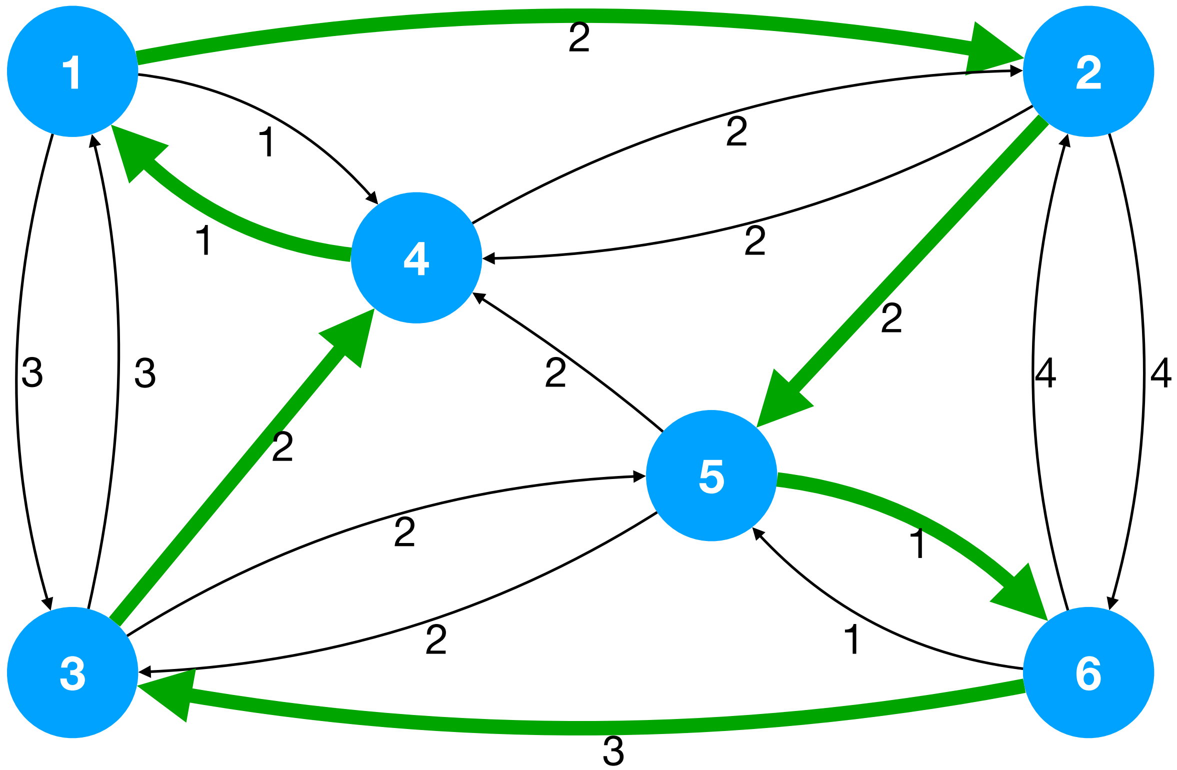
{...} = 0 instead of 'not step(_, _)'

aggregates: #sum, #count, #minimize operate on sets.
not step(…) would be optimised away

Design


ASP
asp-selftest (python)
grounder
solver
facts
models
collect asserts
check & report
standard
custom

Hamiltonian Path



Hands-On (after the break)

```
%%%%%%%% Problem Instance %%%%%%%%

% edge(From, To, Cost). We use facts.
edge(1 ,2 ,2). edge(2 ,4 ,2). edge(3 ,1 ,3). edge(4 ,1 ,1). edge(5 ,3 ,2). edge(6 ,2 ,4).
edge(1 ,3 ,3). edge(2 ,5 ,2). edge(3 ,4 ,2). edge(4 ,2 ,2). edge(5 ,4 ,2). edge(6 ,3 ,3).
edge(1 ,4 ,1). edge(2 ,6 ,4). edge(3 ,5 ,2).                edge(5 ,6 ,1). edge(6 ,5 ,1).


assert("6 nodes")  :-  { node(N) } = 6.
assert("incident in", N)  :-  node(N),  edge(_, N, _).
assert("incident out", N)  :-  node(N),  edge(N, _, _).
assert("valid costs", S, E) :- edge(S, E, C),  C > 0,  C < 10.
assert("minimal cost")  :-  #sum { C, A, B  :  step(A, B),  edge(A, B, C) } < 12.


%%%%%%%% Problem Encoding %%%%%%%%

%%%% Preparation %%%%
% Infer nodes from edges. We use a simple disjunctive rule: head :- body.
node(N)  :-  edge(N, _, _).    % variable N,  wildcard _
node(N)  :-  edge(_, N, _).    % disjunction/or


%%%% Generation %%%%
% Choose an arbitrary step. We use conditional literal ("such that") + choice
step(A, B)  :  edge(A, B, _).

% if you have one step, choose a connected one, but not back.
step(B, C)  :  edge(B, C, _),  C <> A   :-   step(A, B).

% Path to given node via step's. We use a disjunctive rule with conjunction
```

hamiltonian-cycle-1.lp

We can’t fix the test ‘steps’ because:
- first we need to understand the problem, so
- run the code with clingo 0
- there are 3 models with 3 paths
- our test asserts 1 specific path
- we cannot differentiate models

hamiltonian-cycle-2.lp

We number of steps issues a warning:
- first understand the problem:
- Clingo expands this rule for every node N.
- The rule gets instantiated (grounded) for every node N
- but the head remains the same every time
- so we get a disjunction!
- this is usually not intended, so it warns about it
- fix it by introducing N in the head, for example:

assert(@all(“number of steps”, N)) :- …

```
assert(@all("number of steps"))    :-  { step(A, B) } = S,  S = { node(N) }.
```

hamiltonian-cycle-3.lp
1/2 challenges:

1. relate steps and cost
- there must be a model with specific costs and steps:

```
  assert(@any("steps and costs"))  :-
       cost(11),  { step(1,2; 2,5; 5,6; 6,3; 3,4; 4,1) } = 6
```

```
assert(@all("number of steps"))    :-  { step(A, B) } = S,  S = { node(N) }.
```

hamiltonian-cycle-3.lp
2/2 challenges:

1. The challenge is to change the program so it accepts single node graphs.

Solution:
next slide

Solution:

1. only choose a step when more than 1 node:

```
step(A, B)  :  edge(A, B, _)  :-  { node(_) } > 1.
```

2. adjust the constraint on path:

```
:-  node(N),  step(_, _),  not path(N).
```

3. relax the ‘no self reference’ assert by adding:

```
assert(@all("no self reference"))  :-  node_count(1).
```

4. allow for costs of zero in ‘cycle costs’:

```
assert(@all("cycle cost”))  :-
            node_count(N),  cost(S),  0 <= S < 100.
```

5. only checks steps when more than 1 node:

```
assert(@all("number of steps", N)) :-
           node_count(N),  N = { step(A, B) },  N > 1.
```