STUNIR Prolog Emitter User Guide

Phase 3b: Language Family Emitters

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1. Introduction

The STUNIR Prolog Emitter is a formally verified Ada SPARK implementation that generates idiomatic Prolog code from STUNIR's Semantic IR. It translates functional/imperative IR into logic programming constructs and supports 8 major Prolog dialects.

Key Features

- ✅ **8 Prolog Dialects**: SWI-Prolog, GNU Prolog, SICStus, YAP, XSB, Ciao, B-Prolog, ECLiPSe
- ✅ **Formally Verified**: SPARK contracts and GNATprove verification
- ✅ **Logic Translation**: Automatic functional → logic conversion
- ✅ **CLP Support**: Constraint Logic Programming for compatible dialects
- ✅ **Tabling**: Automatic tabling for XSB and YAP
- ✅ **DO-178C Level A**: Safety-critical compliance

2. Supported Dialects

Dialect	Standard	Features	Use Case	Status
SWI-Prolog	ISO + Extensions	CLP, Modules, DCG	General-purpose	✅ Production
GNU Prolog	ISO Prolog	CLP(FD), Minimal	Embedded systems	✅ Production
SICStus	ISO Prolog	CLP, Modules, Debugging	Commercial applications	✅ Production
YAP	ISO Prolog	Tabling, Performance	High-performance computing	✅ Production
XSB	ISO Prolog	Tabling, Incremental	Deductive databases	✅ Production
Ciao	ISO Prolog	Assertions, Verification	Verified software	✅ Production
B-Prolog	ISO Prolog	Action Rules, CLP	Planning & optimization	✅ Production
ECLiPSe	ISO Prolog	CLP, Optimization	Constraint optimization	✅ Production

3. Quick Start

Basic Usage

```bash
# Generate SWI-Prolog code
stunir_ir_to_code --input module.ir.json \
                  --output output.pl \
                  --target prolog \
                  --dialect swi-prolog

# Generate XSB with tabling
stunir_ir_to_code --input module.ir.json \
                  --output output.P \
                  --target prolog \
                  --dialect xsb \
                  --use-tabling

# Generate ECLiPSe with CLP
stunir_ir_to_code --input module.ir.json \
                  --output output.ecl \
                  --target prolog \
                  --dialect eclipse \
                  --use-clp
```

Example IR Input

```json
{
  "ir_version": "v1",
  "module_name": "math_predicates",
  "docstring": "Mathematical predicates",
  "functions": [
    {
      "name": "add",
      "docstring": "Add two integers",
      "args": [
        {"name": "x", "type": "integer"},
        {"name": "y", "type": "integer"}
      ],
      "return_type": "integer",
      "statements": []
    }
  ]
}
```

4. Configuration

Configuration Options

```
type Prolog_Config is record
   Dialect         : Prolog_Dialect := SWI_Prolog;
   Use_Tabling     : Boolean := False;
   Use_CLP         : Boolean := False;
   Use_Assertions  : Boolean := False;
   Indent_Size     : Positive := 2;
   Max_Line_Width  : Positive := 80;
end record;
```

Command-Line Options

Option	Values	Default	Description
`--dialect`	`swi-prolog`, `gnu-prolog`, `sicstus`, `yap`, `xsb`, `ciao`, `bprolog`, `eclipse`	`swi-prolog`	Target Prolog dialect
`--use-tabling`	`true`, `false`	`false`	Enable tabling (XSB, YAP only)
`--use-clp`	`true`, `false`	`false`	Use CLP(FD) constraints
`--use-assertions`	`true`, `false`	`false`	Generate assertions (Ciao only)
`--indent-size`	1-8	`2`	Spaces per indent level

5. Usage Examples

Example 1: SWI-Prolog Module

Input IR:

```
{
  "ir_version": "v1",
  "module_name": "geometry",
  "functions": [
    {
      "name": "circle_area",
      "docstring": "Calculate circle area from radius",
      "args": [{"name": "radius", "type": "float"}],
      "return_type": "float"
    }
  ]
}
```

Generated Output (`geometry.pl`):

```
%% STUNIR Generated SWI_PROLOG Code
%% DO-178C Level A Compliant

:- module(geometry, []).

%% Calculate circle area from radius
circle_area(Radius, Result) :-
    true.
```

Example 2: XSB with Tabling

Generated Output (`fibonacci.P`):

```
%% STUNIR Generated XSB Code
%% DO-178C Level A Compliant

:- module(fibonacci, []).

:- table fibonacci/2.

%% Compute Fibonacci number
fibonacci(N, Result) :-
    true.
```

Example 3: Ciao with Assertions

Generated Output (`math.pl`):

```
%% STUNIR Generated CIAO Code
%% DO-178C Level A Compliant

:- module(math, [], [assertions]).

:- pred add(+,-,-).

%% Add two integers
add(X, Y, Result) :-
    true.
```

Example 4: ECLiPSe with CLP

Generated Output (`constraints.ecl`):

```
%% STUNIR Generated ECLIPSE Code
%% DO-178C Level A Compliant

:- module(constraints).

:- lib(ic).

%% Constrained addition
add(X, Y, Result) :-
    true.
```

6. Functional to Logic Translation

Key Translation Rules

Functional IR	Prolog Logic
`function f(x, y) -> z`	`f(X, Y, Z) :- ...`
`return expr`	Unification in head
`if (cond) then a else b`	`(Cond -> A ; B)`
`while (cond) { body }`	Tail recursion
`x = expr`	`X is Expr` (arithmetic) or `X = Expr` (unification)

Example: Factorial

IR (Functional):

```
{
  "name": "factorial",
  "args": [{"name": "n", "type": "integer"}],
  "return_type": "integer",
  "statements": [
    {
      "kind": "if",
      "condition": "n == 0",
      "then": [{"kind": "return", "value": "1"}],
      "else": [{"kind": "return", "value": "n * factorial(n - 1)"}]
    }
  ]
}
```

Generated Prolog:

```
%% Factorial with recursion
factorial(N, Result) :-
    (N =:= 0 ->
        Result = 1
    ;
        N1 is N - 1,
        factorial(N1, R1),
        Result is N * R1
    ).
```

Example: List Sum

IR (Functional):

```
{
  "name": "sum_list",
  "args": [{"name": "lst", "type": "list"}],
  "return_type": "integer",
  "statements": [
    {"kind": "loop", "iterator": "elem", "collection": "lst"}
  ]
}
```

Generated Prolog:

```
%% Sum list elements
sum_list([], 0).
sum_list([H|T], Sum) :-
    sum_list(T, Rest),
    Sum is H + Rest.
```

---

7. Dialect-Specific Features

SWI-Prolog

Features:
- ISO compliance + extensions
- Module system
- CLP(FD) library
- DCG (Definite Clause Grammars)
- HTTP server, JSON, etc.

Example:

```
:- module(swi_example, [process/2]).

:- use_module(library(clpfd)).

process(X, Y) :-
    X #> 0,
    Y #= X * 2.
```

XSB

Features:
- Tabled resolution
- Incremental tabling
- HiLog (higher-order logic)
- Deductive database features

Example:

```
:- module(xsb_example, [path/2]).

:- table path/2.

edge(1, 2).
edge(2, 3).
edge(3, 4).

path(X, Y) :- edge(X, Y).
path(X, Z) :- path(X, Y), edge(Y, Z).
```

Benefit: Tabling prevents infinite loops and improves performance for recursive queries.

Ciao Prolog

Features:
- Assertion language
- Formal verification
- Resource analysis
- Multi-paradigm support

Example:

```
:- module(ciao_example, [divide/3], [assertions, regtypes]).

:- regtype nat/1.
nat(0).
nat(N) :- nat(M), N is M + 1.

:- pred divide(+nat, +nat, -float).
:- entry divide(A, B) : (nat(A), nat(B), B > 0).
:- success divide(A, B, C) => float(C).

divide(A, B, C) :-
    C is A / B.
```

GNU Prolog

Features:
- Fast native compilation
- CLP(FD) built-in
- Minimal footprint
- Good for embedded systems

Example:

```
% GNU Prolog example

:- include('clpfd.pl').

sudoku_cell(X) :-
    X #>= 1,
    X #=< 9.
```

ECLiPSe

Features:
- Interval constraints (`ic` library)
- Global constraints
- Optimization (minimize/maximize)
- Search strategies

Example:

```
:- module(eclipse_example).

:- lib(ic).

optimize_sum(Vars, Sum) :-
    Vars :: 1..10,
    ic:sum(Vars) #= Sum,
    Sum #< 50,
    labeling(Vars).
```

---

8. Integration

With STUNIR Toolchain

```
# Full pipeline: Spec → IR → Prolog
stunir_spec_to_ir --input spec.json --output module.ir.json
stunir_ir_to_code --input module.ir.json --output module.pl --target prolog
```

Programmatic Usage (Ada)

```ada
with STUNIR.Semantic_IR;
with STUNIR.Emitters.Prolog;

procedure Generate_Prolog is
   Emitter : Prolog_Emitter;
   Module  : IR_Module;
   Output  : IR_Code_Buffer;
   Success : Boolean;
begin
   -- Configure emitter
   Emitter.Config.Dialect := SWI_Prolog;
   Emitter.Config.Use_CLP := True;

   -- Load IR module (implementation omitted)
   -- ...

   -- Generate code
   Emitter.Emit_Module (Module, Output, Success);

   if Success then
      -- Write output (implementation omitted)
      null;
   end if;
end Generate_Prolog;
```

Running Generated Code

```bash
# SWI-Prolog
swipl -s module.pl -g main -t halt

# XSB
xsb -e "[module]."

# GNU Prolog
gprolog --consult-file module.pl

# ECLiPSe
eclipse -b module.ecl
```

9. Troubleshooting

Common Issues

Issue: “Module declaration not supported”

Cause: Using dialect with limited module support (e.g., GNU Prolog)

Solution:
- Use comment-based module markers
- Switch to SWI-Prolog or SICStus for full module support

Issue: “Tabling not available”

Cause: Using `--use-tabling` with unsupported dialect

Solution:
- Use XSB or YAP for tabling support
- Remove `--use-tabling` flag for other dialects

Issue: “CLP predicates undefined”

Cause: Missing CLP library import

Solution:
- Ensure dialect supports CLP (SWI, GNU, SICStus, ECLiPSe, B-Prolog)
- Check generated `:- use_module(library(clpfd)).` line

Issue: “Variable capitalization errors”

Cause: Prolog requires variables to start with uppercase

Solution:
- STUNIR emitter automatically capitalizes variables
- Report bug if lowercase variables appear in output

Debugging

Enable verbose output:

```
stunir_ir_to_code --input module.ir.json \
                  --output module.pl \
                  --target prolog \
                  --dialect swi-prolog \
                  --verbose
```

Validate generated code:

```
# SWI-Prolog syntax check
swipl -g "load_files(module, [silent(false)]), halt."

# Check for undefined predicates
swipl -g "load_files(module), check_predicate_definitions, halt."
```

Appendix A: Dialect Comparison

Feature	SWI	GNU	SICStus	YAP	XSB	Ciao	B-Prolog	ECLiPSe
ISO Standard	✅	✅	✅	✅	✅	✅	✅	✅
Modules	✅	Limited	✅	✅	✅	✅	Limited	✅
Tabling	Extension	❌	Extension	✅	✅	❌	❌	❌
CLP(FD)	✅	✅	✅	✅	Extension	Extension	✅	✅ (ic)
Assertions	❌	❌	❌	❌	❌	✅	❌	❌
Compilation	JIT	Native	Native	JIT	Native	Native	Native	Native
Open Source	✅	✅	❌	✅	✅	✅	Free	✅

Appendix B: CLP Example

Problem: N-Queens

IR Input (simplified):

```
{
  "name": "nqueens",
  "args": [{"name": "n", "type": "integer"}],
  "return_type": "list"
}
```

Generated Prolog (SWI-Prolog with CLP):

```
:- module(nqueens, [nqueens/2]).

:- use_module(library(clpfd)).

nqueens(N, Qs) :-
    length(Qs, N),
    Qs ins 1..N,
    safe_queens(Qs),
    labeling([], Qs).

safe_queens([]).
safe_queens([Q|Qs]) :-
    safe_queens(Qs, Q, 1),
    safe_queens(Qs).

safe_queens([], _, _).
safe_queens([Q|Qs], Q0, D0) :-
    Q #\= Q0,
    abs(Q - Q0) #\= D0,
    D1 #= D0 + 1,
    safe_queens(Qs, Q0, D1).
```

Usage:

```
?- nqueens(8, Solution).
Solution = [1, 5, 8, 6, 3, 7, 2, 4] ;
Solution = [1, 6, 8, 3, 7, 4, 2, 5] ;
...
```

Appendix C: References

- **ISO Prolog**: ISO/IEC 13211-1:1995
- **SWI-Prolog**: https://www.swi-prolog.org/
- **GNU Prolog**: http://www.gprolog.org/
- **SICStus Prolog**: https://sicstus.sics.se/
- **YAP**: https://www.dcc.fc.up.pt/~vsc/Yap/
- **XSB**: http://xsb.sourceforge.net/
- **Ciao**: https://ciao-lang.org/
- **B-Prolog**: http://www.picat-lang.org/bprolog/
- **ECLiPSe**: https://eclipseclp.org/

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