A generic back-end for exploratory programming

Damian Frölich[1,2] and Thomas van Binsbergen[1]

[1]University of Amsterdam
[2]VU Amsterdam

February 2021

Programming forms

- Edit → Compile → Run
  - Slow interactivity
  - Shallow interactivity

https://xkcd.com/303/

REPL

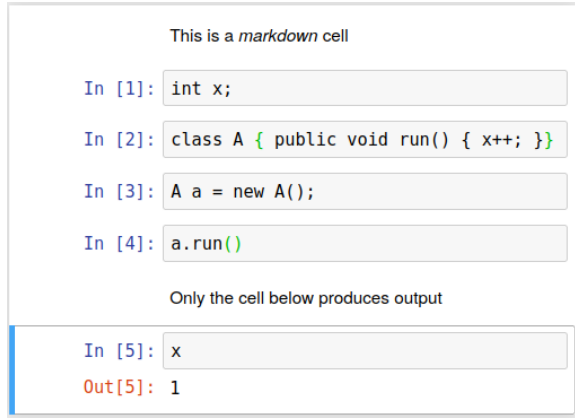
- Incremental programming
- Immediate feedback
- Provides some form of exploratory programming

Notebook

- Alternative interface
- Combines with literate programming

Inconsistent interfaces

```
jshell> int x;
x ==> 0
jshell>
  class A {
    public void run() {
        x++;
    }
  }
|  created class A
jshell> A a = new A();
a ==> A@5ce65a89
jshell> a.run()
jshell> x
x ==> 1
```



Extension of a language

- (some) Interfaces require an extension on the original language
  - Not always documented
  - Independent of original language

Principled approach[1]

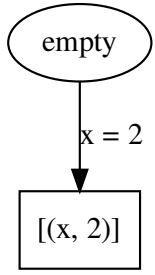
- Definitional interpreter
  - Difference between base and extension language
  - Generic interfaces
  - **Exploratory programming**

```
Config eval((Phrase)`<Expression e> ;`, Config c)
  = catchExceptions(collectBindings(
      setOutput(createBinding(eval(c, e)))));

Config eval((Phrase)`<Statement s>`, Config c)
  = catchExceptions(collectBindings(
      setOutput(exec(s, c))));

Config eval((Phrase)`<ClassDecl cd>`, Config c)
  = catchExceptions(collectBindings(
      declareClass(cd, c)));

Config eval((Phrase)`<VarDecl vd>`, Config c)
  = catchExceptions(collectBindings(
      declareVariables(vd, c)));

Config eval((Phrase)`<MethodDecl md>`, Config c)
  = catchExceptions(collectBindings(
      declareGlobalMethod(md, c)));

Config eval((Phrase)`<Phrase p1> <Phrase p2>`, Config c)
  = eval(p2, eval(p1, c));
```

[1] Binsbergen et al. 2020

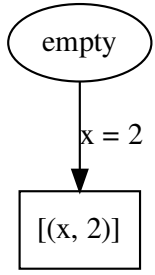
Exploratory programming

- Exploring interpreter
  - Current configuration
  - Execution graph
  - Operations
    - Display
    - Execute
    - Revert

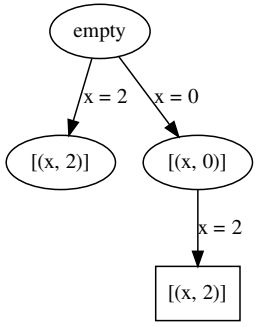


Exploratory programming

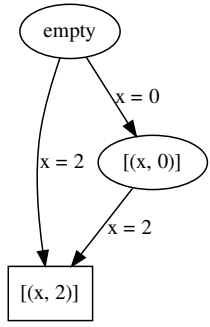
- Exploring interpreter
  - Current configuration
  - Execution graph
  - Operations
    - Display
    - Execute
    - Revert
- Execution graph behaviour
  - Stack
  - Tree
  - Graph
  - Graph-structured Stack(GSS)



Behaviour examples



Tree behaviour



Graph behaviour

Definition

A language L is a structure $\langle P, \Gamma, \gamma^0, I \rangle$ with:

- P a set of programs,
- Γ a set of configurations,
- $\gamma^0 \in \Gamma$ an initial configuration and
- I a definitional interpreter assigning to each program $p \in P$ a function $I_p : \Gamma \to \Gamma$.

Definition

A language L is a structure $\langle P, \Gamma, \gamma^0, I \rangle$ with:

- P a set of programs,
- Γ a set of configurations,
- $\gamma^0 \in \Gamma$ an initial configuration and
- I a definitional interpreter assigning to each program $p \in P$ a function $I_p : \Gamma \to \Gamma$.

```
whileInterpreter :: Command -> Config -> Config

data Config = Config { cfgStore :: Store, cfgOutput :: Output }
type Store = Map String Literal
type Output = [String]
initialConfig = Config { cfgStore = empty, cfgOutput = []}
```

Definition

A language $L = \langle P, \Gamma, \gamma^0, I \rangle$ is *sequential* if there is an operator $\otimes$ such that for every $p_1, p_2 \in P$ and $\gamma \in \Gamma$ it holds that $p_1 \otimes p_2 \in P$ and that $I_{p_1 \otimes p_2}(\gamma) = (I_{p_2} \circ I_{p_1})(\gamma)$.

Definition

A language $L = \langle P, \Gamma, \gamma^0, I \rangle$ is *sequential* if there is an operator $\otimes$ such that for every $p_1, p_2 \in P$ and $\gamma \in \Gamma$ it holds that $p_1 \otimes p_2 \in P$ and that $I_{p_1 \otimes p_2}(\gamma) = (I_{p_2} \circ I_{p_1})(\gamma)$.

While is sequential

```
whileInterpreter (Seq p_1 p_2) gamma ==
   (whileInterpreter p_2 . whileInterpreter p_1) gamma
```

Contribution

Provide a generic exploring interpreter allowing experimentation with the different execution graph behaviours for different type of languages and interfaces.

Exploring interpreter

```
data Explorer programs configs = Explorer
{ defInterp :: programs -> configs -> configs
, config :: configs
, execEnv :: Gr _ programs
}
```

```
type Ref = Int
data Explorer programs configs = Explorer
{ ...
, execEnv :: Gr Ref programs
, currRef :: Ref
, cmap    :: Map Ref configs
}
```

```
data Explorer programs configs = Explorer
{ ...
, sharing :: Bool
, backtracking :: Bool
}
```

	Sharing	No sharing
No backtracking	Graph	Tree
Backtracking	GSS	Stack

Full definition

```
data Explorer programs configs = Explorer
{ defInterp :: programs -> configs -> configs
, config :: configs
, execEnv :: Gr Ref programs
, currRef :: Ref
, cmap    :: Map Ref configs
, sharing :: Bool
, backtracking :: Bool
}
```

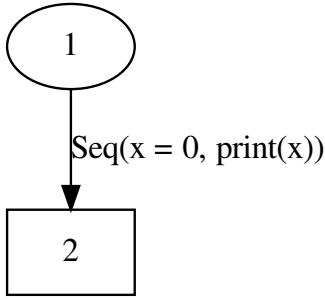
```
mkExplorerStack :: (a -> b -> b) -> b -> Explorer a b
mkExplorerStack = mkExplorer False True

mkExplorerTree  :: (a -> b -> b) -> b -> Explorer a b
mkExplorerTree  = mkExplorer False False

mkExplorerGraph :: (a -> b -> b) -> b -> Explorer a b
mkExplorerGraph = mkExplorer True False

mkExplorerGSS :: (a -> b -> b) -> b -> Explorer a b
mkExplorerGSS = mkExplorer True True
```

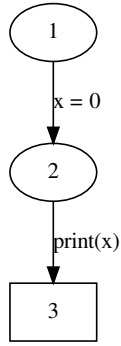
Operations

```
revert :: Ref -> Explorer p c -> Maybe (Explorer p c)
execute :: (Eq c, Eq p) => p -> Explorer p c -> Explorer p c
```

Unpacking

Sequence of programs results in one transition





```
foldr :: Foldable t => (a -> b -> b) -> b -> t a -> b
                       ^^^^^^^^^^^^^
```

```
foldr :: Foldable t => (a -> b -> b) -> b -> t a -> b
                       ^^^^^^^^^^^^^
```

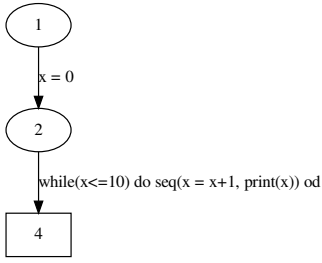
```
executeAll :: (Eq c, Eq p) => [p] -> Explorer p c -> Explorer p c
executeAll = flip (foldr execute)
```

Future work

Side effects?

- `execute :: Monad m => p -> Explorer p c -> m (Explorer p c)`

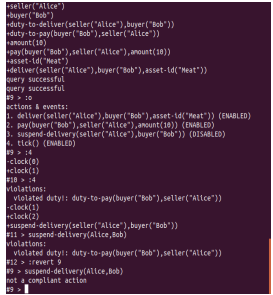
Debugging

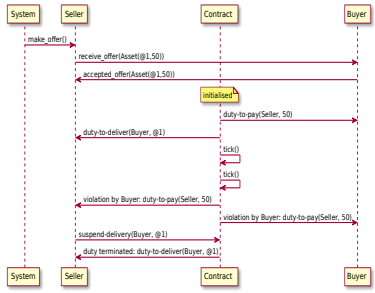


Interface exploration

- Different type of interfaces
- Integration with different exploration behaviours

Evaluation with eFLINT





A generic back-end for exploratory programming

The implementation opens up exploration of the exploring interpreter in a language independent manner

Damian Frolich
University of Amsterdam and VU Amsterdam
d.frolich@uva.nl

Thomas van Binsbergen
University of Amsterdam
ltvanbinsbergen@acm.org