Università di Genova
DIPARTIMENTO INFORMATICA, BIOINGEGNERIA, ROBOTICA E INGEGNERIA DEI SISTEMI

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Enhanced Regular Corecursion for Data Streams

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Introduction

As we venture deeper into the Internet of Things (IoT) era, stream processing is becoming increasingly important. With our recent work, we propose a stream calculus to lay the foundations of a tool for real time analysis of potentially infinite flowing data series.

Main Objectives

- Develop a calculus to define and manipulate infinite streams
- Provide a procedure to check whether a stream is well-defined
- Achieve a good compromise between expressive power and decidability

State of the Art

Two complementary approaches to manipulate streams:

Lazy Evaluation

Streams defined by arbitrary functions and inspected as much as needed.

Pros

- Widely known and well-established solution for stream processing
- Supports both regular (cyclic) and non-regular streams

Cons

- Operations that need to inspect the whole stream cannot be computed
- Allows the definition of incorrect streams due to high expressive power

Examples

```
one_two = 1:2:one_two    //1:2:1:2:1:...
from n = n:from(n+1)  //naturals from n
head (from 0)    ⟶ 0
allPositive one_two ⟶ ⊥ //non-termination
bad_stream = 0:tail bad_stream
```

Regular Corecursion

Streams are finitely represented by sets of equations. The executions avoids non-termination by keeping track of already processed calls.

Pros

- The entire stream can be inspected because it is finitely represented by a set of equations

Cons

- Fails to model non-regular streams

Examples

```
allPositive(one_two())   ⟶ true
head(from(0)) ⟶ ⊥ //non-termination
```

Our Solution

- Enhances regular corecursion
  - Not only constructors are allowed in equations defining streams
  - Supports regular and (some) non-regular streams
- Provides a procedure to check whether a stream definition is correct
  - `bad_stream()` ⟶ runtime error

Examples

Simple cyclic streams

```
repeat(n) = n:repeat(n)  //n:n:n:n:...
one_two() = 1:2:one_two()  //1:2:1:2...
```

Note: `[+]` `[*]` `[/]` are pointwise operations on streams, `^` computes the tail.

Non-regular streams

```
nat() = 0:(nat()[+]repeat(1))
fact() = 1:((nat()[+]repeat(1))[*]fact())
fib() = 0:1:(fib()[+]fib()^)
```

`nat()` ⟶ | 0 | 1 | 2 | 3 | ... |

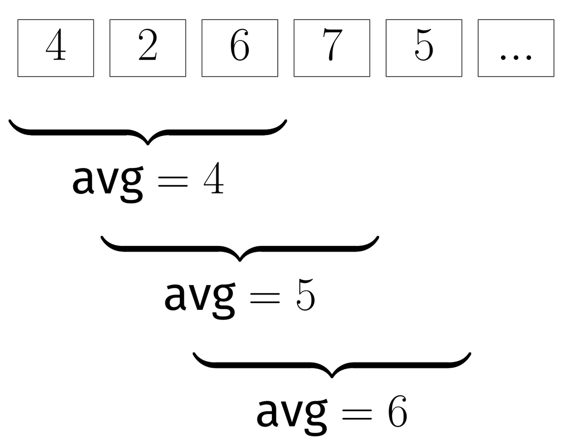
`fact()` ⟶ | 1 | 2 | 6 | 24 | ... |

`fib()` ⟶ | 0 | 1 | 1 | 2 | ... |

Functions for stream processing

```
aggr(n,s) = if n<=0 then repeat(0)
            else s[+]aggr(n-1,s^)
avg(n,s) = aggr(n,s)[/]repeat(n)
```

Below you find an example of execution of avg over a window of size 3



Forthcoming Research

- Make function definitions more *flexible*
  - The user is allowed to specify the behaviour in presence of a cycle
- Introduce a static type system to prevent runtime errors

Reference paper:

Davide Ancona, Pietro Barbieri, Elena Zucca. Enhanced Regular Corecursion for Data Streams. ICTCS21

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