

# Probabilistic Functional Programming

---

Donnacha Oisín Kidney

July 6, 2018

How do we model stochastic and probabilistic processes in programming languages?

The same way we model any other process: using the semantics and features built into the language.

```
from random import randrange
```

```
def roll_die():  
    return randrange(1,7)
```

Problem: semantics are unclear.<sup>1</sup>

```
int getRandomNumber()  
{  
    return 4; // chosen by fair dice roll.  
             // guaranteed to be random.  
}
```

---

<sup>1</sup>Randall Munroe. *Xkcd: Random Number*. en. Title text: RFC 1149.5 specifies 4 as the standard IEEE-vetted random number. Feb. 2007. URL: <https://xkcd.com/221/> (visited on 07/06/2018).

```
randomly_chosen = roll_die()
```

```
def roll_die_2():  
    return randomly_chosen
```

What's the difference between `roll_die` and `roll_die_2`?

Problem: not as powerful as we'd like.

```
def expect(predicate , process , iterations ):
    success = sum(predicate(process()))
                for _ in range(iterations))
    return success / iterations
```

```
expect(lambda y: 5 == y, roll_die , 100)
0.17
```

Solution: design a DSL for probabilistic programs which solves the problems above.

Three questions for this DSL:

- Why should we implement it? What is it useful for?
- How should we implement it? How can it be made efficient?
- Can we glean any insights on the nature of probabilistic computations from the language? Are there any interesting symmetries?

The first approach<sup>2</sup> starts with a simple and elegant answer to the second question.

We'll model a distribution as a list of events, with each possible event tagged with its probability.

```
newtype Dist a = Dist { runDist :: [(a, Rational)] }
```

The die now looks like this:

```
die = Dist [(1, 1/6), (2, 1/6), (3, 1/6), (4, 1/6), (5, 1/6), (6, 1/6)]
```

---

<sup>2</sup>Martin Erwig and Steve Kollmansberger. "Functional Pearls: Probabilistic Functional Programming in Haskell". In: *Journal of Functional Programming* 16.1 (2006), pp. 21–34. ISSN: 1469-7653, 0956-7968. DOI: 10.1017/S0956796805005721. URL: <http://web.engr.oregonstate.edu/~erwig/papers/abstracts.html%5C#JFP06a> (visited on 09/29/2016).