foveSIMM
a formally verified SIMM

In a nutshell

- **OpenSIMM**: ISDA margin model for non-cleared derivatives
  - does the model *always* perform properly?

- **formal methods**: *proof* for *all* cases, not *testing* of *many*
  - faster, cheaper, surer, eases regulatory approval
  - Intel, Facebook, Airbus, NASA, Amazon, DARPA, Microsoft

- **foveSIMM**
  - *proves* margin payments *always* increase in the confidence level, are defined, scale with portfolio size and with confidence level
  - *generates* performant, executable Scala code

OpenSIMM

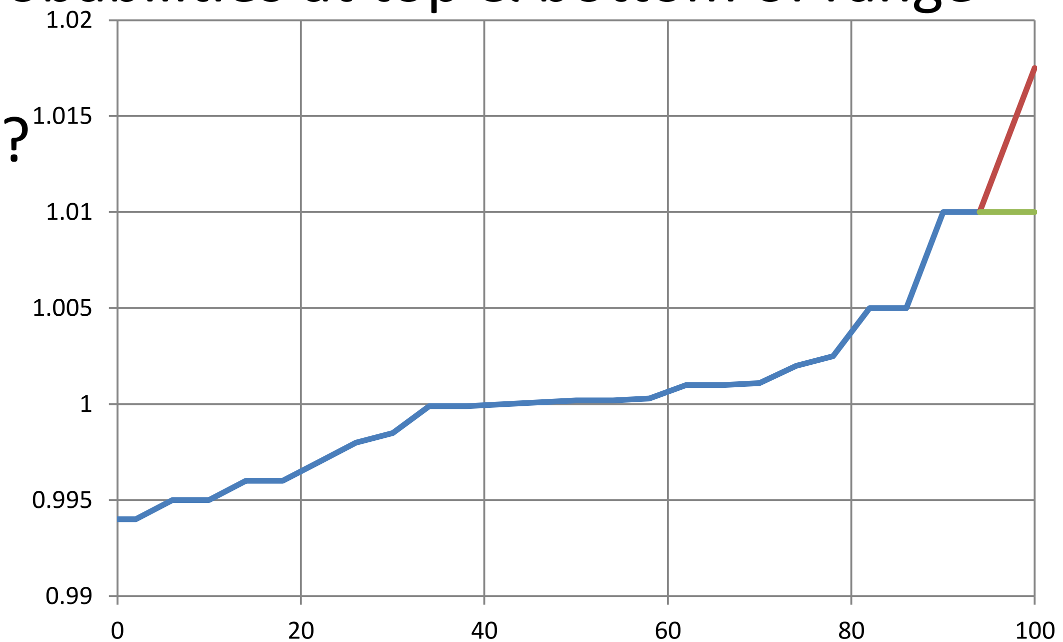
- reference implementation of ISDA's Standard Initial Margin Model (SIMM)
- written in Java 8 (heavily using its functional features)
- version used commercially is not open source

Trusting OpenSIMM

- built around a **percentile function**, $f(L, p)$
  - L, a list of shocks
  - p, a probability

- OpenSIMM fails for probabilities at top & bottom of range

- are there other errors?



Traditional development cycle (**small model** or **small change**)

1. quant builds a prototype (c. 1 month)
2. functional specs, business requirements (c. 2 months)
3. developers write code (c. 2 months)
4. testing (c. 1 month)
5. validation (c. 1 month)
    - shows correct performance on test cases
6. regulatory approval (c. 3-9 months)
    - shows correct performance on test cases

- scales poorly: new cases and interactions to test

Formal development cycle

1. quant prototype is functional, extracts production code
   - writes definitions, theorems (properties of the model)
   - with prover, writes *proofs* for *all* cases

2. validators, regulators can focus on definitions, theorems
   - prover: general purpose, open source, small core

- scales well: more libraries mean more proven results
  - wrote boundedness proof strategy in c. 1 minute
  - prover then found proof automatically in c. 20 seconds

- faster, cheaper & better risk management

Preliminary theorems

1. **bounded**: $f(L,p)$ is always less than its value at $p = \bar{p}$
2. **monotonic**: $f(L,p)$ weakly increases over $p \in [0,1]$

- thus, $f(L,p)$ is *defined* for *all* $p \in [0,1]$
  (Java's was undefined above top, $\bar{p}$ & below bottom, $\underline{p}$)

3. **homogeneity**: $f(L,p)$ scales with the portfolio size

$$f(\alpha \times L, p) = \alpha \times f(L, p)$$

e.g. doubling portfolio, *always* doubles margin

Lipschitz continuity theorem

- knowing the margin payment at p_1 bounds it at *any* p_2

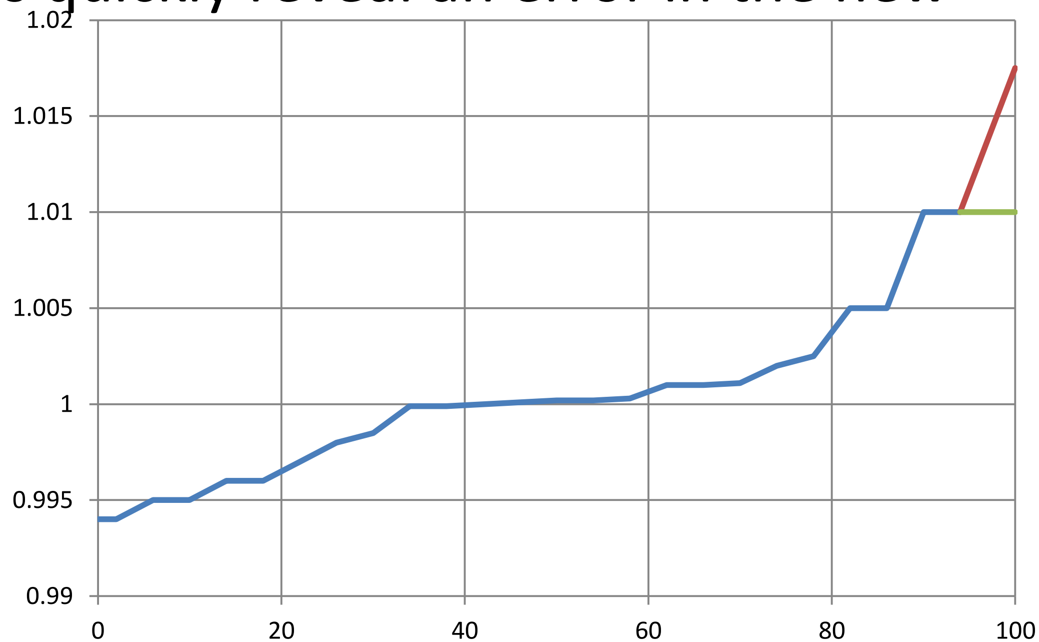
$$f(L, p_2) - f(L, p_1) \leq k \times (p_2 - p_1)$$

- typically, a model change like this would require
  - 3 weeks of **parallel runs**
  - back/stress-testing on *all* relevant portfolios

- no need to re-compute: it's proven

Validating a model change

- horizontal extension to $f(L, p)$ is very conservative
- we change the definition of $f(L, p)$ and re-run the proofs
  - losses increase above $\bar{p}$ at the *worst* historic rate
  - 10 hours to re-validate v. testing's weeks of parallel runs
  - problems with proofs quickly reveal an error in the new definition



Comparing executable code

OpenSIMM's Java	verified Scala
c. 1,700 lines of code	c. 3,000 lines of code
<1 sec run time	<1 sec run time
excludes data files c. ½ are comments	includes data files code unoptimised

- can also generate executable code in Haskell, OCaml, SML

sorry

- a proof fails if any step in it fails

- can insert a **sorry** statement in the code
  - prover skips that step, accepting it as true
  - eases modular code development

to do list

1. confirm the formulae for the IR asset class
2. read data from same input files as OpenSIMM
   - o use OpenSIMM's I/O routines, plugging Scala into Java
3. refine Isabelle code
   - o use existing library results, not our own
   - o eliminate 'sorry' statements
4. optimise the executable Scala code
5. 'sign' the executable code to certify its origins