Prototype Environment for Financial Risk Modeling

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Zurich University of Applied Sciences

Artificial Intelligence in Industry and Finance
Focus Session on Fintech-Driven Automation in the Financial Industry.
ZHAW, Winterthur, September 6th, 2018
Outline

- Introduction: Why an R – ACTUS interface and why a visual demonstrator
- The R – ACTUS interface
- A proof of concept using the R – ACTUS interface
- An ACTUS-based visual demonstrator for stress testing and systemic analysis
- Summary – Conclusion
Introduction

- Up to now:
  - The economy as a network of contracts
  - ACTUS: concepts
  - Smart contracts
  - Requirements for stress testing
  - Automated reporting: concept and demo

- Here something to play around with ACTUS-based modeling:
  - R-packages targeted to the technically savvy
  - An interactive demonstrator for visualization
ACTUS Contract Types

* Definitions and explanations to the Contract Types may be found in the «CT-Description» Excel sheet.

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The ACTUS – R Interface: The Philosophy

- Provide the means for using ACTUS contract types on a prototyping level to the mathematically educated user
- Add the analytical power of R to enable rapid prototyping of sophisticated models
The ACTUS Logic

Risk Factors Inputs

Credit Risk Factors

Market Risk Factors

Behavior Risk Factors

Financial Contracts (Data + Algorithms)

e_1 \quad e_2 \quad e_3 \quad \ldots \quad e_{n-1} \quad e_n

cfl_1 \quad cfl_2 \quad \ldots \quad cfl_n

Analytical Results

Liquidity \quad Income \quad Value

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The ACTUS – R Interface: The R-Packages

- rActus
  - R-Interface to the ACTUS Java library
  - Gives access to contract types
    - PAM
    - ANN
    - LAM
    - SWAPS
    - STK
  - User can create contract, define market environment, create the contract events and visualize the cash flows
  - No analytics
- A simple example
The R-Packages: Examples
The ACTUS – R Interface: The R-Packages

- rflPortfolio
  - Supports analysis of whole portfolios
- rflContracts
  - Supports demonstration of single contracts

- Parallel execution at R-level possible with
  - SparkR -> Bachelor thesis
  - Directly in R (example?)
The ACTUS – R Interface: The Bottleneck

• The bottleneck: R – Java communication
  ➢ R is written in C/C++
  ➢ Java and C/C++ are “disjunct worlds”
  ➢ The communication passes through the Java Native Interface (JNI),
  ➢ The JNI is slow
  ➢ rActus requires a lot of communication between R and Java, which makes it slow
  ➢ Can only be used for a handful of contracts

• Work-around:
  ➢ Pass a whole portfolio in one chunk to the java library
  ➢ Use parallel computing, directly in R or through SparkR

• This bottleneck can only be overcome through transferring the source code to C++. 
Proof of Concept 
with a Portfolio of Real Bonds
Sample overview: Number of Observations = 3809

**Sector** (according to European System of Accounts 2010 issued by the European Union)
All observations of the General Government (S_13) sector which is subdivided into
- Central Govt. (S_1311)
- State Govt. (S_1312)
- Local Govt. (S_1313)
- Social security funds (S_1314)

<table>
<thead>
<tr>
<th>N-Obs</th>
<th>Central Govt.</th>
<th>State Govt.</th>
<th>Local Govt.</th>
<th>Social security funds</th>
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<tbody>
<tr>
<td>1290</td>
<td>1944</td>
<td>491</td>
<td>84</td>
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</table>

**Country** (according to ISO 3166-1 system)

<table>
<thead>
<tr>
<th>Country</th>
<th>N-Obs</th>
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<tbody>
<tr>
<td>AT</td>
<td>149</td>
</tr>
<tr>
<td>BE</td>
<td>413</td>
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<tr>
<td>CY</td>
<td>46</td>
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<td>DE</td>
<td>1712</td>
</tr>
<tr>
<td>ES</td>
<td>346</td>
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<tr>
<td>FI</td>
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<td>IE</td>
<td>81</td>
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<tr>
<td>IT</td>
<td>108</td>
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<tr>
<td>MT</td>
<td>42</td>
</tr>
<tr>
<td>NL</td>
<td>33</td>
</tr>
<tr>
<td>PT</td>
<td>20</td>
</tr>
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</table>

**Contract Deal Date**

<table>
<thead>
<tr>
<th>earliest</th>
<th>latest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986-06-20</td>
<td>2015-03-31</td>
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**Maturity Date**

<table>
<thead>
<tr>
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<th>latest</th>
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<tr>
<td>2015-04-01(1)</td>
<td>2090-11-08(2)</td>
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**Cycle Of Interest Payment**

- 1M-
- 1Q-
- 1Y-
- 6M-
- NULL(3)

<table>
<thead>
<tr>
<th>earliest</th>
<th>latest</th>
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<tr>
<td>4</td>
<td>391</td>
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<tr>
<td>2237</td>
<td>474</td>
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<tr>
<td>703</td>
<td></td>
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</table>

**Notional Principal** (note, different currencies)

<table>
<thead>
<tr>
<th>minimum</th>
<th>median</th>
<th>maximum</th>
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<tbody>
<tr>
<td>0.0(4)</td>
<td>76,690,000.0</td>
<td>38,530,000,000.0</td>
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**Nominal Interest Rate**

<table>
<thead>
<tr>
<th>minimum</th>
<th>mean</th>
<th>maximum</th>
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<tbody>
<tr>
<td>0.0(3)</td>
<td>0.0155</td>
<td>0.2319</td>
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</tbody>
</table>

---

(1) Matured bonds, (2) Data quality issue, (3) Zero coupon bonds, (4) Data quality issue
### Sample contract events with cash flows per 5/1/15

<table>
<thead>
<tr>
<th>Contract ID</th>
<th>Event Date</th>
<th>Event Type</th>
<th>Event Value</th>
<th>Time (in years)</th>
<th>Nominal Value</th>
<th>Nominal Rate</th>
<th>Nominal Accrued</th>
<th>Currency</th>
<th>Country</th>
<th>Sector</th>
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<td>0.0352</td>
<td>1515555.6</td>
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<td>DE</td>
<td>S_1312</td>
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<tr>
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<td>2015-12-02T00:00Z[UTC]</td>
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<td>0.586111</td>
<td>500000000.0</td>
<td>0.0352</td>
<td>0</td>
<td>EUR</td>
<td>DE</td>
<td>S_1312</td>
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<tr>
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<td>0.0352</td>
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<td>DE</td>
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<td>S_1312</td>
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<td>0</td>
<td>EUR</td>
<td>GR</td>
<td>S_1311</td>
</tr>
</tbody>
</table>

The 4,000 bonds generate a total of 3,866,785 contract events.

Processes ca. 4000 contracts/sec on MBP with 2.5GHz Intel Core i7.
Aggregate liquidity (i.e. state-contingent cash flows) from central government issued bonds expected over the next years:

- by cash flow type (interest or principal)
- by country of issuance

**Proof of Concept:** Liquidity Analysis

Aggregate, state-contingent cash (in-) flows (millions of EUR) of 'central government' debt by type and year.

Aggregate, state-contingent cash (in-) flows (millions of EUR) of 'central government' debt by country and year.
Stress testing 1: Market exposures

Base scenario:
Use Euro-area yield curve observed on 5/1/15 for discounting

Stress scenarios:
We apply 100 yield curve “shocks” (shift, steepening, bending, etc.) in order to assess the impact on “Fair value”
Proof of Concept: Credit Exposure

Analysis of central government credit exposures:

We show the aggregate, yearly cash flows by central government’s credit rating (S&P).

Stress testing:

Assuming default of e.g. all “speculative” bonds in year 1 will lead to a loss of the dark blue colored aggregate cash flows (no recovery).

Monte-Carlo:

Simulation of defaults based on a stochastic credit rating migration matrix model provides an expected value for liquidity (no recovery).
Interactive Graphical
Financial Risk Demonstrator

• Philosophy
  ➢ To provide a graphical, interactive tool for demonstration purposes using the ACTUS contracts.
  ➢ The tool should be extendable in a simple way.
  ➢ Programming the tool should not require extensive resources.

• The solution
  ➢ R is used at rapid prototyping platform.
  ➢ A simulation and analysis engine has been built using the R – ACTUS interface.
  ➢ A graphical frontend has been build using the R-Shiny package.
  ➢ This work was the contents of a Bachelor’s thesis: Denis Iseli, Dominique Neff: Real-Time Monitoring of Financial Systems with ACTUS, Winterthur, June 2018, unpublished.
Financial Risk Demonstrator:
Key Points

- Models different banks (currently 8 banks)
- Has a database of ACTUS contracts
- At present restricted to the contracts types PAM, ANN, LAM, SWAPS
- Banks modeled by a simple balance sheet:

![Balance Sheet Diagram]

- Leaf no. 1: Mortgage
  Contract ID: a4cd14fccc6ce6083c6d625326d4fc2325ad7
- Leaf no. 2: Loan.A
  Contract ID: 955c768403b0
- Leaf no. 3: Saving Account
  Contract ID: 97576398a76f6ff0d043c6d
- Leaf no. 4: Loan.L
  Contract ID: 74c95b6dc08d
- Leaf no. 5: Swap.RFL
  Contract ID: 9ee18b04f97a
- Leaf no. 6: Swap.PFL
  Contract ID: a7a1f62c6224
Financial Risk Demonstrator: Key Points

• Key performance indicators:
  - Liquidity
  - Nominal value
  - Fair value (net present value)
  - Interest income
  - Equity ratio

• Stress testing:
  - 4 interest rate scenarios:
    Parallel shift, steepening/flattening, user defined, stochastic

• Systemic analysis:
  - Representation of the interdependencies of the system of banks
  - Simple illustration of contagion by computing the effect on solvency if one bank goes bankrupt
Financial Risk Demonstrator: The Tool

- Can be run locally
- In principle accessible through the internet: http://finlab.engineering.zhaw.ch/shiny/BA_FS2018/ (at the moment not operational)
- Because of R – Java bottleneck, slow performance
  - Screenshots
Financial Risk Demonstrator: Screenshots

Real-Time Monitoring of Financial Systems with ACTUS

Betreuer: Wolfgang Breymann
Nebenbetreuer: Nils Andri Bundl

Financial systems are complex networks of banks (as network nodes) and payment obligations among these banks (as network edges). In such a system, two main sources of risk are considered: (1) the risk of banks to default individually due to some exogenous shock to their capital buffer, and (2) the risk of default contagion or, in other words, the risk of the default of one bank spreading to another bank in the network due to shared network links. The last financial crisis has shown that the latter risk can be considerable, yet current regulations such as capital requirements or the liquidity coverage ratio focus on assessing the health of banks individually and thereby disregard network effects. In this Bachelor Thesis, we aim at developing a graphical interface that allows to dynamically specify simple toy bank networks with nodes consisting of a set of ACTUS contracts that give rise to payment obligations among banks. These obligations may be dependent upon some market risk factors (e.g. interest payments in variable rate bonds) which build the source for exogenous shocks to the toy bank network. Based on such a set-up the students should develop and implement meaningful monitoring and visualization tools such as total payment obligations between any two banks (net liquidity) that allows the regulator to assess in real-time the financial health of the network. Finally, the effect of adding new ACTUS contracts among any two banks in the network should be analyzed.

by Denis Iseli und Dominique Neff, W15b, ZHAW
## Financial Risk Demonstrator: Screenshots

![Financial Risk Demonstrator Screenshot](image-url)

### Bank Information Table

<table>
<thead>
<tr>
<th>Bank Name</th>
<th>LegalEntityID</th>
<th>Street</th>
<th>Number</th>
<th>ZipCode</th>
<th>City</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Judocus Bank</td>
<td>231380Q1LIUD4ROSUY03</td>
<td>Musterstrasse</td>
<td>1</td>
<td>60306</td>
<td>Frankfurt am Main</td>
<td>Germany</td>
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<tr>
<td>Aquila Bank</td>
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<td>1</td>
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<td>184</td>
<td>Rome</td>
<td>Italy</td>
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<td>539570UZTKK1GYQIUX23</td>
<td>Avenue Anatole</td>
<td>5</td>
<td>75007</td>
<td>Paris</td>
<td>France</td>
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<td>Musterstrasse</td>
<td>1</td>
<td>20095</td>
<td>Hamburg</td>
<td>Germany</td>
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</tbody>
</table>

*by Denis Iseli und Dominique Neff, WI15b, ZHAW*
Financial Risk Demonstrator: Screenshots
Financial Risk Demonstrator: Screenshots

YC_ECB, Date: 2018-06-14 T00

by Denis Iseil und Dominique Neff, W15b, ZHAW
Financial Risk Demonstrator: Screenshots
Financial Risk Demonstrator: Screenshots

The screenshot shows a financial risk demonstrator interface for a bank named BS. The interface includes various financial metrics such as nominal value, mark to model value, equity, and equity ratio. The screenshot displays data in euros (€) and percentages (%). The interface allows users to choose an account and view liquidity and interest rate income. The data includes account information for different banks such as Judocus Bank and Aquila Bank.
Financial Risk Demonstrator: Screenshots
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## Financial Risk Demonstrator: Screenshots

**Network View:**
- Beta.Index: 1.5
- Durchmesser: 4
- AVG.Pfadlaenge: 1.84210526315789

**Contract Type:**
- Aquila Bank: Degree.In 0.2857, Degree.Out 0.1429, Closeness 1, Hub.Score 0.2863, Authoritative.Score 0.0842
- Banca Roma: Degree.In 0.1429, Degree.Out 0.4286, Closeness 0.7, Hub.Score 0.1688, Authoritative.Score 0
- Iudocus Bank: Degree.In 0.5714, Degree.Out 0.4286, Closeness 1.4, Hub.Score 0.4461, Authoritative.Score 0.6925
- DoubleD Bank: Degree.In 0.1429, Degree.Out 0.2857, Closeness 1.1667, Hub.Score 0.551, Authoritative.Score 0.1845
- BDouble Bank: Degree.In 0.2857, Degree.Out 0.1429, Closeness 0.875, Hub.Score 0.2863, Authoritative.Score 0.2543
- Hometown Bank: Degree.In 0.4296, Degree.Out 0.1429, Closeness 0.7778, Hub.Score 0.0348, Authoritative.Score 0.6402
- Madrid Bank: Degree.In 0.0, Degree.Out 0.1429, Closeness 0.4118, Hub.Score 0, Authoritative.Score 0
- Prague International: Degree.In 0.1429, Degree.Out 0.2857, Closeness 0.875, Hub.Score 0.551, Authoritative.Score 0.0698

**View Options:**
- Default
- Crash the system

**Date Input:**
- 2018-06-14
- Update all data
- Update Stresstest
Financial Risk Demonstrator: Screenshots
Financial Risk Demonstrator: Screenshots
Financial Risk Demonstrator: Screenshots
# Financial Risk Demonstrator: Screenshots

## Bank Information Table

<table>
<thead>
<tr>
<th>LEI</th>
<th>BankName</th>
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<tr>
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<tr>
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<td>Prague International</td>
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<td>2</td>
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</table>
Summary – Conclusion

- An R interface to the ACTUS library has been created that makes it possible to use ACTUS contracts in R.
- This provides a convenient means to become acquainted and experiment with the ACTUS library.
- This tool is also used in our Bachelor studies.
- A visual demonstrator has been build by two students during their Bachelor’s thesis.
- This demonstrator models a system of eight simple banks and allows to carry out stress tests and simple systemic analysis.
- The demonstrator will be extended and its performance enhanced in a project for and with ECB that is about to start.
- The ACTUS website: http://actusfrf.org