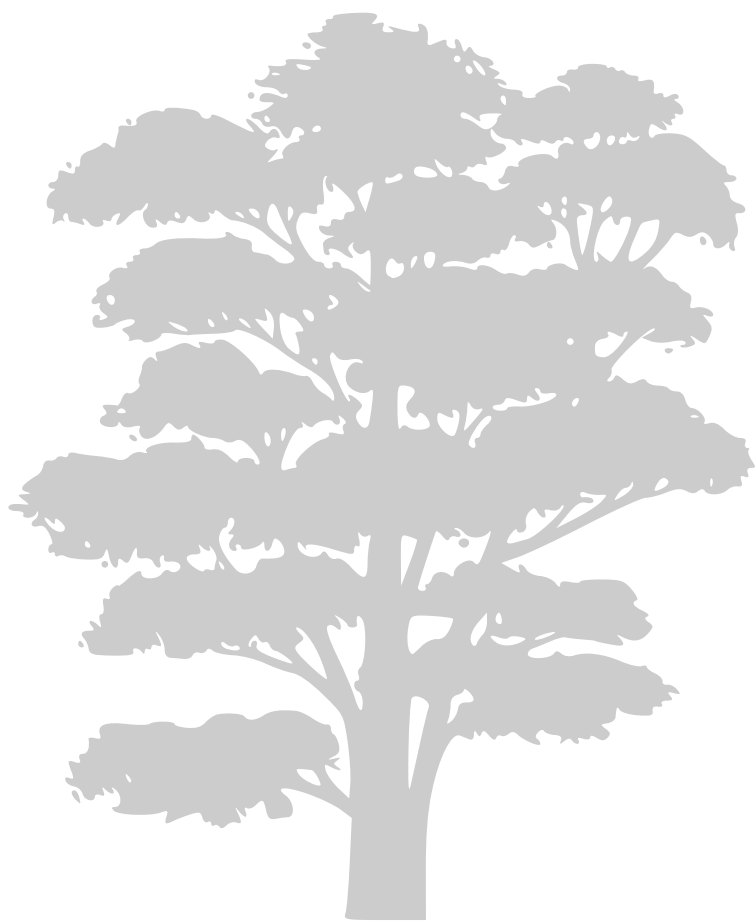


RGP

GENETIC PROGRAMMING IN R



Acknowledgments

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Introduction

This chapter provides a detailed description of the case studies conducted in the course of this thesis. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Case Study Design and Organization

TODO general overview, concepts of problem sheet, problem instance, and method, intro to experimental design and planning via SPO

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Case Studies in Finance

Although the application of GP in finance is a young field, there already exist a comparatively large body of literature on this subject (TODO lit). The largest fraction of these work applies GP to evolve trading strategies for algorithmic trading. Our case studies are no exception in this regard, but are special in the fact that they apply

the same GP framework in an array of vastly markets. TODO short intro to the three markets, etc.

Algorithmic Trading in Stock Markets (AppStock)

TODO

<i>Symbol</i>	<i>Company</i>	<i>Sector</i>
AAPL	Apple Inc.	Technology
CVX	Chevron Corp.	Basic Materials
GOOG	Google Inc.	Technology
PEP	Pepsico Inc.	Consumer Goods

Table 1: Summary Information on the Stocks included in the Case Study. This Summary Information was retrieved from Yahoo Finance on March 1, 2010.

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Algorithmic Trading in the FX Market (AppFX)

TODO

Objective Function The vTrader fitness function $fitness_{vt}$ assigns a numerical fitness to a signal generator function s . It is defined as follows:

$$fitness_{vt}(s) := \underbrace{[-1 \cdot pnl(s, T_{train})]}_{\text{performance term}} + \underbrace{c_{mdd} \cdot mdd(s, T_{train})}_{\text{penalty terms}} \cdot balance(s) \quad (1)$$

$$balance(s) := \begin{cases} c_{balance} & \text{if } skewness(s) > limit_{skewness} \\ 1 & \text{otherwise} \end{cases} \quad (2)$$

$$skewness(s) := \frac{abs(|s(T_{train})|_{long} - |s(T_{train})|_{short})}{|s(T_{train})|_{all}} \quad (3)$$

<i>Parameter</i>	<i>Description</i>	<i>Value</i>
c_{mdd}	Max-Drawdown Penalty Factor	TODO
$limit_{skewness}$	Long/Short-Skewness Limit	0.8
$c_{balance}$	Long/Short-Skewness Penalty Factor	TODO

Table 2: Default Parameter Values for the vTrader fitness function $fitness_{vt}$ used in the Case Study.

Algorithmic Trading of Emission Certificates (AppCO2)

TODO

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Case Studies in Water Resource Management

TODO

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Fill-level Prediction for Stormwater Tanks (AppStorm)

The main goal of this study is the prediction of fill levels in stormwater overflow tanks based on rainfall data in order to implement predictive control of water drain rate. Such predictions are of immense practical utility in preventing costly and damaging over- or under-loading of the sewage system connected to these stormwater overflow tanks. The task of predicting the current fill levels from the past rain data alone—not using past fill levels—is rather challenging since the hidden state of the surrounding soil influences the impact of rain in a nonlinear fashion (??).

Objective Function The quality of a fill level predictor is measured as the root mean squared error (RMSE) between true fill level and predicted fill level on the test dataset defined in Sec. ??:

$$\text{RMSE}(y_{\text{pred}}, y_{\text{real}}) := \sqrt{\text{mean}[(y_{\text{pred}} - y_{\text{real}})^2]} \quad (4)$$

A fill-level predictor is a function from a rainfall time series to a scalar fill level prediction. When predicting the fill level at time t , a fill level predictor has the rainfall time series up to time t available as input. A time series of predicted fill levels is obtained by

iteratively applying a fill level predictor to a time series of rainfall data.

Test Data TODO update ranges

Training and test time series data for this study consist of 25,344 data records. This data comprises measurements of the current fill level and the current rainfall at a real stormwater tank in Germany. These measurements were taken every 5 minutes, ranging from April, 21th 2007 (00:00 a.m.) to July, 17th 2007 (11:55 p.m.). We divided this dataset into a training dataset, ranging from April, 21th 2007 (00:00 a.m.) to April, 28th 2007 (00:00 a.m.) and a test dataset, ranging from April, 28th 2007 (00:05 a.m.) to July, 17th 2007 (11:55 p.m.). The results presented in the following are based on the test dataset, while all methods were trained on the training dataset. The training dataset consists of a short but balanced sample of dry and rainy days.

Making predictions on the training dataset had to be embedded into the fitness function of GP, therefore this dataset is comparatively small. We used the same training dataset in each case study to keep results comparable. While fill levels responds differently to rain depending on season, the response stays very stable within a season. This is why the size of our training dataset should not pose a problem to the methods under study, and also why our test dataset spans the late-spring/early summer season, but not more. In practice, the methods under study would be retrained for each season.

Prediction of NH₄N in WTP Inflow (AppNH₄N)

TODO

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Prediction of Chemical Oxygen Demand in WTP Inflow (AppO₂)

TODO

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Getting Started

This chapter provides a short real-world example of performing symbolic regression with RGP.

Problem Definition

Function Definition

At first you need to define a fitting problem-function. As an example you can use the locus of a mathematical pendulum.

```
mathematicalPendulum <- function(A = 1, g = 9.81, l = 0.1 phi = pi) {  
  omega <- sqrt(g/l)  
  function(t) A * cos(omega*t*phi)}
```

This creates a function with the arguments amplitude(A), gravity(g), length(l) and offset(phi).

Fitness Function

The fitness function is used to calculate an error measure.

To define the fitness function:

```
mp1 <- mathematicalPendulum()  
mp1fitness <- makeFunctionFitnessFunction(mp1, 0, 10, steps = 512, indsizeLimit = 16)
```

mp1 is the function as defined in the step before, **0** and **10** are the start and the end of the sequence of fitness cases. The argument **steps** gives the number of steps in the sequence. **indsizeLimit** defines a limit to the size of an individual, if the limit is exceeded the individual will receive a fitness of infinity value.

An Example for the Listings Package

Listing 1 shows an example on how to integrate R code listings into L^AT_EX documents using the nice Listings package¹. As you might have noticed, the last sentence also demonstrates how to refer to listings via the label/ref pair of L^AT_EX commands.

¹ See <ftp://ftp.tex.ac.uk/tex-archive/macros/latex/contrib/listings/listings.pdf> for further information.

Listing 1: Some Example R Code

```
makePendulum <- function(A = 1, g = 9.81,  
                          l = 0.1, phi = pi) {  
  omega <- sqrt(g / l)  
  function(time) A * cos(omega * time * phi)  
}
```

The Listings package also supports typesetting of small code snippets like `gpModel$fitness` through its `\lstinline` command. Please note the slightly peculiar way the snippets are delimited in the \LaTeX source code. You can use any character that does not occur in the snippet as a delimiter. We are using the `!` character in this example.