

# Design, implementation and evaluation of data integration methods for biomedical cancer data

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# Preface

I would like to thank everybody who kept me busy the last year, especially my promotor and my assistants. I would also like to thank the jury for reading the text. My sincere gratitude also goes to my wife and the rest of my family.

*Michiel Ruelens*

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# Abstract

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# Samenvatting

In dit **abstract** environment wordt een al dan niet uitgebreide Nederlandse samenvatting van het werk gegeven. Wanneer de tekst voor een Nederlandstalige master in het Engels wordt geschreven, wordt hier normaal een uitgebreide samenvatting verwacht, bijvoorbeeld een tiental bladzijden.

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# List of Figures and Tables

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# List of Abbreviations and Symbols

## Abbreviations

LoG	Laplacian-of-Gaussian
MSE	Mean Square error
PSNR	Peak Signal-to-Noise ratio

## Symbols

42	“The Answer to the Ultimate Question of Life, the Universe, and Everything” according to [?]
$c$	Speed of light
$E$	Energy
$m$	Mass
$\pi$	The number pi



# Chapter 1

## Introduction

The first contains a general introduction to the work. The goals are defined and the modus operandi is explained.

### 1.1 The need for data integration methods

### 1.2 Goals

### 1.3 Modus operandi



## Chapter 2

# Generalized Linear Models

In this chapter I will explain the current standard in machine learning when it comes to generalized linear models. This term indicates a generalization of simple linear regression that allows for a wide range of output variables.

First I will go over the basics of linear models, gradually building up to the definition of generalized linear models. Next, I will describe what actual data looks like and how this data is transformed into a useful model.

After that I will tackle the more recent innovation of regularization that will greatly improve our previous models by exploiting the bias-variance trade-off to reduce overfitting. Lastly I will outline the validation method that will be used to test the performance of the models.

### 2.1 Classical linear models

When we think of classical linear models, we can imagine a set of numeric explanatory (or input) variables and a numerical dependent (or output) variable. By making a linear combination of the explanatory variables we attempt to estimate a value for the dependent variable. Depending on the type of dependent variable the linear method gets a different name. In the following sections I will outline several of them.

#### 2.1.1 Linear Regression

The simplest version of a linear model is called linear regression. In this case the input variables are combined using a linear combination, and the result of this calculation is immediately used as the final estimate.

//TODO MATH

For the other linear methods we will define a function each time that is applied to the result of the linear combination. We could do the same for linear regression and say that the applied function is the identity function. We could schematize this computation as follows:

//TODO SCHEMA

### 2.1.2 Linear Classification

The next method is called linear classification. The difference with linear regression is that we have a different type of output variable. In a classification task we want to predict a class from a list of potential classes. For instance, we could try to predict whether tomorrow will be a sunny day or not. Notice that there are only 2 possible outcomes: 'sunny' or 'not sunny' and we could represent these outcomes as 0 and 1 in our model. This form would be called binary classification because we have 2 possible classes. It is very easy to extend this method to multi-class classification. The computation in this method starts out exactly the same, combining the input variables using a linear combination. Next, we have to define a threshold to indicate which examples belong to one class or another. In the case of binary classification we would define 1 threshold, and if the result of the linear combination is higher than the threshold we would predict one class. If it is lower, we would predict the other class. The function used here would be called a sign function, which maps real values onto one of 2 possible outcomes. We could represent this computation with the following formula and schema:

//TODO MATH AND SCHEMA

### 2.1.3 Logistic Regression

The third method I want to present is called logistic regression. In this case, the output variable we want to predict comes from a binomial distribution. This means that they are the result of a probabilistic event. An example would be tossing a coin and checking whether the result is heads or tails. While the outcome is binary (heads or tails) we know that there is an underlying probability for the coin to be heads or tails, and we would like to know this probability.

The idea is still the same. We will make a linear combination of the input variables. However this time we will use a logistic function to produce our estimate. The logistic function is a function that maps real numbers onto the range  $[0, 1]$ . This result can then be interpreted as an estimate for the probability. We can schematize logistic regression as follows:

//TODO MATH AND SCHEMA

The logistic regression method is the one that will be most widely used throughout this thesis.

## 2.2 Training a model

In order to understand the integration strategies that will be explained later on, it is useful to know how exactly the models come to be. This section will explain what the input data for our linear models actually looks like, and how we get from this data to a model that we can use for future predictions.

### 2.2.1 The data

The data we use consists of two parts: the input data, which can be seen as a matrix where the columns are the explanatory variables and each row is an example (or patient). And secondly the output data, which can be seen as a vector where each value indicates the value of the dependent variable for a single example.

It is easy to see that the length of the output vector has to be equal to the amount of rows in the input matrix, indeed there should be one output value for each example. This amount is often called the size of the dataset and we would like it to be as big as possible. Especially when we are dealing with a large number of explanatory variables, it is essential to have a reasonably amount of examples aswell. This will be discussed in more detail later on //TODO REFERENCE.

### 2.2.2 Gradient descent

In this section I will explain how we get from the input data to the model. The idea here is that we have some for of error measure. The error measure is a sort of rating for our current model as it indicates how big the mistakes are that our current model is making. There are many different error measures we could use. The one that is used in logistic regression is explained in more detail in the following section.

Once we have a way of computing the error that our current model makes, we can try to minimize this error to obtain our 'best' possible model.

#### Error measure

In logistic regression the error measure we use is called the cross-entropy error. The formula for this error is the following:

$$E_{in}(w) = \frac{1}{N} \sum_{n=1}^N \ln(1 + e^{-y_n w^T x_n})$$

where

- $x_n$  is the vector of values for the explanatory variables for example  $n$ .
- $y_n$  is the value of the dependent variable for example  $n$ .
- $w^T$  is the transpose of the weights vector. These are the parameters of our model that we can adjust.
- $N$  is the size of our dataset.
- $E_{in}(w)$  is the in-sample error. This is the cross-entropy error that we make on the examples in our dataset. It is a function of the weights  $w$ .

The origin of this function is explained in appendix //TODO ADD APPENDIX AND REFERENCE. We can however easily notice that this is a reasonable error measure. It is an averaged sum over all examples, where for each example we compute an

individual error made on that example.

Notice that  $w^T x_n$  is the linear combination of the input variables that our current model suggests. This is the prediction that our current model would make for example  $n$  and is a real valued number. On the other hand  $y_n$  is the actual correct prediction for example  $n$  and has a value of 0 or 1.

If the signs of  $w^T x_n$  and  $y_n$  agree then our current model actually makes a correct prediction for this example. We can see that in this case the exponential becomes close to 0, making our error for example  $n$  very small, as we would expect.

If however their signs are opposite, the exponential becomes larger as our incorrect prediction becomes larger. This in turn will increase the error, again as we would expect.

Thus we can see that if we were to minimize this error, we are moving towards a model that tries to make correct predictions.

### The gradient descent method

When trying to minimize a function, a general approach would be to try and compute the derivative of the function, and find the spot where this derivative equals zero. In the case of linear regression it is actually possible to compute this minimum in one step. More details about this can be found in appendix //TODO ADD AND REFERENCE APPENDIX.

In the case of logistic regression however it is not possible to find an analytic solution to this problem. The best we can do is put ourselves somewhere on the error curve and try to move towards the minimum in small steps. This is called an iterative approach.

Remember that our error function looks like this:

$$E_{in}(w) = \frac{1}{N} \sum_{n=1}^N \ln(1 + e^{-y_n w^T x_n})$$

We can now compute its derivative with respect to  $w$ :

$$\nabla E_{in}(w) = -\frac{1}{N} \sum_{n=1}^N \frac{y_n x_n}{1 + e^{y_n w^T x_n}}$$

The problem is to find the set of weights  $w$  for which the derivative becomes 0 (or that minimizes the error). We can start out with an initial set of weights  $w(0)$  and then iteratively update these weights so we move towards the minimum. Let's call the direction in which we update our weights  $v$ . The update we make to  $w$  then becomes:

$$w(t+1) = w(t) + \eta v$$

where

- $w(t+1)$  are the updated weights for this iteration.
- $w(t)$  are the current weights before we make a move.



- $v$  is a unit vector pointing in the direction we want to move.
- $\eta$  is a number that indicates how big the move is that we make, also called the step size.

Remember that the gradient of a function at a certain point always points towards the steepest slope upwards. In our case we would like to find the minimum, so it is a good idea to move our weights in the direction of steepest descent. The direction  $v$  that we are moving towards then becomes the normalized opposite direction of the gradient:

$$v = -\frac{\nabla E_{in}(w(t))}{\|\nabla E_{in}(w(t))\|}$$

We can now summarize the gradient descent method as follows:

```
Data: x, y
initialize weights  $w(0)$ 
while Stopcondition is not met do
    Compute gradient  $\nabla E_{in}(w(t))$ 
    Compute update direction  $v$ 
    Update weights  $w(t+1) = w(t) + \eta v$ 
end
```

**Algorithm 1:** Gradient Descent algorithm

There are two more non-trivial issues in this computation: the initialization of the weights and the stopcondition.

Weight initialization is sometimes a very tricky thing to do, in the case of logistic regression however it is acceptable to set  $w(0)$  equal to the zero-vector as this corresponds to no correlation between any of the input variables and the output variable, and the result of the sigmoid function would be 0.5 or 50% meaning the model has no preference for either outcome.

The stopcondition however is a bigger issue and usually the way to go here is to make a combination of several stop criteria. One criteria would be to simply limit the amount of iterations to a fixed number. This could avoid endlessly overfitting. Another criteria is to set up a target error we want to achieve (a small number), and stop when we have reached this target. This however raises the question of picking the target error, and this is mostly an application dependent choice.

In the version of logistic regression explained here, it can however be shown that the error surface we are dealing with is a very nice convex surface. This makes it very easy to find its minimum and we don't need very complex initialization and stopping criteria to get good results. In other machine learning methods however these surfaces aren't always as nice, and the issue of local minima versus global minima becomes a big deal. There has been much research on this topic however and many sophisticated methods have been developed to deal with this issue.

## 2.3 Overfitting

Now that we have established a method of computing our models, it is time to deal with an issue known as overfitting. Overfitting points to the fact that there are several mechanisms at work when we are building a model that prevent us from reaching the perfect model. These mechanisms essentially originate from noise and uncertainty in many aspects of the learning process (the input data, choice of model, choice of algorithm, ...). We can however try to decompose this noise into several components and then attempt to influence them by making changes to our model computation. I will present two ways in which overfitting can be tackled: regularization and validation.

### 2.3.1 The problem of overfitting

Let's introduce some notation. From now on I will refer to the notion of 'in-sample error' or in symbolic notation  $E_{in}$  as the error that a model makes on the examples in our training set. The training set consists of the examples that were used to train (compute) the model in the first place.

Similarly I will define 'out-of-sample error' or  $E_{out}$  as the error we make on examples that were not used for training the model. Notice that  $E_{in}$  is something I could compute because I have access to the training data, but  $E_{out}$  is a quantity I cannot exactly compute but I could try to estimate it if I have some examples left that I did not use for training. Notice also that it is  $E_{in}$  that we minimize during our model computation, but it is  $E_{out}$  that we actually want to minimize! Indeed,  $E_{out}$  corresponds to the error that we get when we are going to deploy our model in practice and use it on examples we have never seen before. We can do this because we believe that  $E_{in}$  tracks  $E_{out}$  to a certain degree. And thus if we manage to minimize  $E_{in}$  we also minimize  $E_{out}$  to some extent.

We can only speak of overfitting when we are comparing two models. We say that one model, call it model A, is overfitting with respect to another model, model B, when model A managed to get a lower  $E_{in}$  than model B, but model B has a lower  $E_{out}$ .

Another way of looking at it is during the learning process. Let's have model A be the model that we computed when we started from model B and performed one more iteration of the training algorithm. Thus model A is 'more trained' than model B. Now let's suppose model A is overfitting:

$$E_{in}^{modelA} < E_{in}^{modelB} \tag{2.1}$$

$$E_{out}^{modelA} > E_{out}^{modelB} \tag{2.2}$$

The additional iteration has decreased the in-sample error, and thus we are able to fit our training data better, but the out-of-sample error has increased, meaning that our model doesn't generalize as well to other examples outside the training set. This means that we are actually fitting our training data too well, while we are not really getting a better grasp of the underlying pattern that we wish to learn. We are

overfitting the training data.

### **2.3.2 The bias and variance trade-off**

### **2.3.3 Regularization**

### **2.3.4 Validation**

The sample size dilemma

Cross-validation

## **2.4 Conclusion**



## Chapter 3

# The Next Chapter

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### 3.1 The First Topic of this Chapter

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#### 3.1.1 An item

A master thesis is never an isolated work. This means that your text must contain references. On-line documents[?] as well as books[?] can be referenced.

### 3.2 Figures

Figures are used to add illustrations to the text. The Figure 3.1 shows the KU Leuven logo as an illustration.



FIGURE 3.1: The KU Leuven logo.

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	each	.01
gnu	stuffed	92.50
emu		33.33
armadillo	frozen	8.99

TABLE 3.1: A table with the wrong layout.

Item		
Animal	Description	Price (\$)
Gnat	per gram	13.65
	each	0.01
Gnu	stuffed	92.50
Emu	stuffed	33.33
Armadillo	frozen	8.99

TABLE 3.2: A table with the correct layout.

### 3.3 Tables

Tables are used to present data neatly arranged. A table is normally not a spreadsheet! Compare Table 3.1 en Table 3.2: which table do you prefer?

### 3.4 Lorem Ipsum

This section is added to check headers and footers. So this chapter must at least contain three pages. To make sure that we get the required amount, the `lipsum` package isn't used but the text is put directly in the text.

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Phasellus volutpat, nunc et pharetra semper, sem justo adipiscing mauris, id blandit magna quam et orci. Vestibulum a erat purus, ut molestie ante. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Proin turpis diam, consequat ut ullamcorper ut, consequat eu orci. Sed metus risus, fringilla nec interdum vel, interdum eu nunc. Suspendisse vel sapien orci.

#### 3.4.5 Morbi et mauris tempus purus ornare vehicula

Mauris sit amet diam quam, eget luctus purus. Sed faucibus, risus semper eleifend iaculis, mi turpis bibendum nisl, quis cursus nibh nisl sit amet ipsum. Vestibulum tempor urna vitae mi auctor malesuada eget non ligula. Nullam convallis, diam vel ultrices auctor, eros eros egestas elit, sed accumsan arcu tortor eget leo. Vestibulum orci purus, porttitor in pharetra eget, tincidunt eget nisl. Nullam sit amet nulla dui, facilisis vestibulum dui.

Donec faucibus facilisis mauris ac cursus. Duis rhoncus quam sed nisi laoreet eu scelerisque massa tincidunt. Vivamus sit amet libero nec arcu imperdiet tempor quis non libero. Sed consequat dignissim justo. Phasellus ullamcorper, velit quis posuere vulputate, felis erat tincidunt mauris, at vestibulum justo lectus et turpis. Maecenas lacinia convallis euismod. Quisque egestas fermentum sapien eu dictum. Sed nec lacus in purus dictum consequat quis vel nisl. Fusce non urna sem. Curabitur eu diam vitae elit accumsan blandit. Nullam fermentum nunc et leo dictum laoreet. Donec semper varius velit vel fringilla. Vivamus eu orci nunc.

### 3.5 Conclusion

The final section of the chapter gives an overview of the important results of this chapter. This implies that the introductory chapter and the concluding chapter don't need a conclusion.

Nunc sed pede. Praesent vitae lectus. Praesent neque justo, vehicula eget, interdum id, facilisis et, nibh. Phasellus at purus et libero lacinia dictum. Fusce aliquet. Nulla eu ante placerat leo semper dictum. Mauris metus. Curabitur lobortis. Curabitur sollicitudin hendrerit nunc. Donec ultrices lacus id ipsum.



## Chapter 4

# The Final Chapter

Morbi malesuada hendrerit dui. Nunc mauris leo, dapibus sit amet, vestibulum et, commodo id, est. Pellentesque purus. Pellentesque tristique, nunc ac pulvinar adipiscing, justo eros consequat lectus, sit amet posuere lectus neque vel augue. Cras consectetur libero ac eros. Ut eget massa. Fusce sit amet enim eleifend sem dictum auctor. In eget risus luctus wisi convallis pulvinar. Vivamus sapien risus, tempor in, viverra in, aliquet pellentesque, eros. Aliquam euismod libero a sem.

### 4.1 The First Topic of this Chapter

#### 4.1.1 Item 1

##### Sub-item 1

Nunc velit augue, scelerisque dignissim, lobortis et, aliquam in, risus. In eu eros. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Curabitur vulputate elit viverra augue. Mauris fringilla, tortor sit amet malesuada mollis, sapien mi dapibus odio, ac imperdiet ligula enim eget nisl. Quisque vitae pede a pede aliquet suscipit. Phasellus tellus pede, viverra vestibulum, gravida id, laoreet in, justo. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Integer commodo luctus lectus. Mauris justo. Duis varius eros. Sed quam. Cras lacus eros, rutrum eget, varius quis, convallis iaculis, velit. Mauris imperdiet, metus at tristique venenatis, purus neque pellentesque mauris, a ultrices elit lacus nec tortor. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent malesuada. Nam lacus lectus, auctor sit amet, malesuada vel, elementum eget, metus. Duis neque pede, facilisis eget, egestas elementum, nonummy id, neque.

##### Sub-item 2

Proin non sem. Donec nec erat. Proin libero. Aliquam viverra arcu. Donec vitae purus. Donec felis mi, semper id, scelerisque porta, sollicitudin sed, turpis. Nulla in urna. Integer varius wisi non elit. Etiam nec sem. Mauris consequat, risus nec

congue condimentum, ligula ligula suscipit urna, vitae porta odio erat quis sapien. Proin luctus leo id erat. Etiam massa metus, accumsan pellentesque, sagittis sit amet, venenatis nec, mauris. Praesent urna eros, ornare nec, vulputate eget, cursus sed, justo. Phasellus nec lorem. Nullam ligula ligula, mollis sit amet, faucibus vel, eleifend ac, dui. Aliquam erat volutpat.

### 4.1.2 Item 2

Fusce vehicula, tortor et gravida porttitor, metus nibh congue lorem, ut tempus purus mauris a pede. Integer tincidunt orci sit amet turpis. Aenean a metus. Aliquam vestibulum lobortis felis. Donec gravida. Sed sed urna. Mauris et orci. Integer ultrices feugiat ligula. Sed dignissim nibh a massa. Donec orci dui, tempor sed, tincidunt nonummy, viverra sit amet, turpis. Quisque lobortis. Proin venenatis tortor nec wisi. Vestibulum placerat. In hac habitasse platea dictumst. Aliquam porta mi quis risus. Donec sagittis luctus diam. Nam ipsum elit, imperdiet vitae, faucibus nec, fringilla eget, leo. Etiam quis dolor in sapien porttitor imperdiet.

## 4.2 The Second Topic

Cras pretium. Nulla malesuada ipsum ut libero. Suspendisse gravida hendrerit tellus. Maecenas quis lacus. Morbi fringilla. Vestibulum odio turpis, tempor vitae, scelerisque a, dictum non, massa. Praesent erat felis, porta sit amet, condimentum sit amet, placerat et, turpis. Praesent placerat lacus a enim. Vestibulum non eros. Ut congue. Donec tristique varius tortor. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Nam dictum dictum urna.

Phasellus vestibulum orci vel mauris. Fusce quam leo, adipiscing ac, pulvinar eget, molestie sit amet, erat. Sed diam. Suspendisse eros leo, tempus eget, dapibus sit amet, tempus eu, arcu. Vestibulum wisi metus, dapibus vel, luctus sit amet, condimentum quis, leo. Suspendisse molestie. Duis in ante. Ut sodales sem sit amet mauris. Suspendisse ornare pretium orci. Fusce tristique enim eget mi. Vestibulum eros elit, gravida ac, pharetra sed, lobortis in, massa. Proin at dolor. Duis accumsan accumsan pede. Nullam blandit elit in magna lacinia hendrerit. Ut nonummy luctus eros. Fusce eget tortor.

Ut sit amet magna. Cras a ligula eu urna dignissim viverra. Nullam tempor leo porta ipsum. Praesent purus. Nullam consequat. Mauris dictum sagittis dui. Vestibulum sollicitudin consectetur wisi. In sit amet diam. Nullam malesuada pharetra risus. Proin lacus arcu, eleifend sed, vehicula at, congue sit amet, sem. Sed sagittis pede a nisl. Sed tincidunt odio a pede. Sed dui. Nam eu enim. Aliquam sagittis lacus eget libero. Pellentesque diam sem, sagittis molestie, tristique et, fermentum ornare, nibh. Nulla et tellus non felis imperdiet mattis. Aliquam erat volutpat.

## 4.3 Conclusion

Vestibulum sodales ipsum id augue. Integer ipsum pede, convallis sit amet, tristique vitae, tempor ut, nunc. Nam non ligula non lorem convallis hendrerit. Maecenas hendrerit. Sed magna odio, aliquam imperdiet, porta ac, aliquet eget, mi. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Vestibulum nisl sem, dignissim vel, euismod quis, egestas ut, orci. Nunc vitae risus vel metus euismod laoreet. Cras sit amet neque a turpis lobortis auctor. Sed aliquam sem ac elit. Cras velit lectus, facilisis id, dictum sed, porta rutrum, nisl. Nam hendrerit ipsum sed augue. Nullam scelerisque hendrerit wisi. Vivamus egestas arcu sed purus. Ut ornare lectus sed eros. Suspendisse potenti. Mauris sollicitudin pede vel velit. In hac habitasse platea dictumst.

Suspendisse erat mauris, nonummy eget, pretium eget, consequat vel, justo. Pellentesque consectetur erat sed lacus. Nullam egestas nulla ac dui. Donec cursus rhoncus ipsum. Nunc et sem eu magna egestas malesuada. Vivamus dictum massa at dolor. Morbi est nulla, faucibus ac, posuere in, interdum ut, sapien. Proin consectetur pretium urna. Donec sit amet nibh nec purus dignissim mattis. Phasellus vehicula elit at lacus. Nulla facilisi. Cras ut arcu. Sed consectetur. Integer tristique elit quis felis consectetur eleifend. Cras et lectus.

Ut congue malesuada justo. Curabitur congue, felis at hendrerit faucibus, mauris lacus porttitor pede, nec aliquam turpis diam feugiat arcu. Nullam rhoncus ipsum at risus. Vestibulum a dolor sed dolor fermentum vulputate. Sed nec ipsum dapibus urna bibendum lobortis. Vestibulum elit. Nam ligula arcu, volutpat eget, lacinia eu, lobortis ac, urna. Nam mollis ultrices nulla. Cras vulputate. Suspendisse at risus at metus pulvinar malesuada. Nullam lacus. Aliquam tempus magna. Aliquam ut purus. Proin tellus.



## Chapter 5

# Conclusion

The final chapter contains the overall conclusion. It also contains suggestions for future work and industrial applications.

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.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In

hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

# Appendices





# Appendix A

## The First Appendix

Appendices hold useful data which is not essential to understand the work done in the master thesis. An example is a (program) source. An appendix can also have sections as well as figures and references[?].

### A.1 More Lorem

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

#### A.1.1 Lorem 15–17

Nulla in ipsum. Praesent eros nulla, congue vitae, euismod ut, commodo a, wisi. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Aenean nonummy magna non leo. Sed felis erat, ullamcorper in, dictum non, ultricies ut, lectus. Proin vel arcu a odio lobortis euismod. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Proin ut est. Aliquam odio. Pellentesque massa turpis, cursus eu, euismod nec, tempor congue, nulla. Duis viverra gravida mauris. Cras tincidunt. Curabitur eros ligula, varius ut, pulvinar in, cursus faucibus, augue.

Nulla mattis luctus nulla. Duis commodo velit at leo. Aliquam vulputate magna et leo. Nam vestibulum ullamcorper leo. Vestibulum condimentum rutrum mauris. Donec id mauris. Morbi molestie justo et pede. Vivamus eget turpis sed nisl cursus tempor. Curabitur mollis sapien condimentum nunc. In wisi nisl, malesuada at, dignissim sit amet, lobortis in, odio. Aenean consequat arcu a ante. Pellentesque porta elit sit amet orci. Etiam at turpis nec elit ultricies imperdiet. Nulla facilisi.

In hac habitasse platea dictumst. Suspendisse viverra aliquam risus. Nullam pede justo, molestie nonummy, scelerisque eu, facilisis vel, arcu.

Curabitur tellus magna, porttitor a, commodo a, commodo in, tortor. Donec interdum. Praesent scelerisque. Maecenas posuere sodales odio. Vivamus metus lacus, varius quis, imperdiet quis, rhoncus a, turpis. Etiam ligula arcu, elementum a, venenatis quis, sollicitudin sed, metus. Donec nunc pede, tincidunt in, venenatis vitae, faucibus vel, nibh. Pellentesque wisi. Nullam malesuada. Morbi ut tellus ut pede tincidunt porta. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam congue neque id dolor.

### A.1.2 Lorem 18–19

Donec et nisl at wisi luctus bibendum. Nam interdum tellus ac libero. Sed sem justo, laoreet vitae, fringilla at, adipiscing ut, nibh. Maecenas non sem quis tortor eleifend fermentum. Etiam id tortor ac mauris porta vulputate. Integer porta neque vitae massa. Maecenas tempus libero a libero posuere dictum. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Aenean quis mauris sed elit commodo placerat. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Vivamus rhoncus tincidunt libero. Etiam elementum pretium justo. Vivamus est. Morbi a tellus eget pede tristique commodo. Nulla nisl. Vestibulum sed nisl eu sapien cursus rutrum.

Nulla non mauris vitae wisi posuere convallis. Sed eu nulla nec eros scelerisque pharetra. Nullam varius. Etiam dignissim elementum metus. Vestibulum faucibus, metus sit amet mattis rhoncus, sapien dui laoreet odio, nec ultricies nibh augue a enim. Fusce in ligula. Quisque at magna et nulla commodo consequat. Proin accumsan imperdiet sem. Nunc porta. Donec feugiat mi at justo. Phasellus facilisis ipsum quis ante. In ac elit eget ipsum pharetra faucibus. Maecenas viverra nulla in massa.

## A.2 Lorem 51

Maecenas dui. Aliquam volutpat auctor lorem. Cras placerat est vitae lectus. Curabitur massa lectus, rutrum euismod, dignissim ut, dapibus a, odio. Ut eros erat, vulputate ut, interdum non, porta eu, erat. Cras fermentum, felis in porta congue, velit leo facilisis odio, vitae consectetur lorem quam vitae orci. Sed ultrices, pede eu placerat auctor, ante ligula rutrum tellus, vel posuere nibh lacus nec nibh. Maecenas laoreet dolor at enim. Donec molestie dolor nec metus. Vestibulum libero. Sed quis erat. Sed tristique. Duis pede leo, fermentum quis, consectetur eget, vulputate sit amet, erat.

## Appendix B

# The Last Appendix

Appendices are numbered with letters, but the sections and subsections use arabic numerals, as can be seen below.

### B.1 Lorem 20-24

Nulla ac nisl. Nullam urna nulla, ullamcorper in, interdum sit amet, gravida ut, risus. Aenean ac enim. In luctus. Phasellus eu quam vitae turpis viverra pellentesque. Duis feugiat felis ut enim. Phasellus pharetra, sem id porttitor sodales, magna nunc aliquet nibh, nec blandit nisl mauris at pede. Suspendisse risus risus, lobortis eget, semper at, imperdiet sit amet, quam. Quisque scelerisque dapibus nibh. Nam enim. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nunc ut metus. Ut metus justo, auctor at, ultrices eu, sagittis ut, purus. Aliquam aliquam.

Etiam pede massa, dapibus vitae, rhoncus in, placerat posuere, odio. Vestibulum luctus commodo lacus. Morbi lacus dui, tempor sed, euismod eget, condimentum at, tortor. Phasellus aliquet odio ac lacus tempor faucibus. Praesent sed sem. Praesent iaculis. Cras rhoncus tellus sed justo ullamcorper sagittis. Donec quis orci. Sed ut tortor quis tellus euismod tincidunt. Suspendisse congue nisl eu elit. Aliquam tortor diam, tempus id, tristique eget, sodales vel, nulla. Praesent tellus mi, condimentum sed, viverra at, consectetur quis, lectus. In auctor vehicula orci. Sed pede sapien, euismod in, suscipit in, pharetra placerat, metus. Vivamus commodo dui non odio. Donec et felis.

Etiam suscipit aliquam arcu. Aliquam sit amet est ac purus bibendum congue. Sed in eros. Morbi non orci. Pellentesque mattis lacinia elit. Fusce molestie velit in ligula. Nullam et orci vitae nibh vulputate auctor. Aliquam eget purus. Nulla auctor wisi sed ipsum. Morbi porttitor tellus ac enim. Fusce ornare. Proin ipsum enim, tincidunt in, ornare venenatis, molestie a, augue. Donec vel pede in lacus sagittis porta. Sed hendrerit ipsum quis nisl. Suspendisse quis massa ac nibh pretium cursus. Sed sodales. Nam eu neque quis pede dignissim ornare. Maecenas eu purus ac urna tincidunt congue.

Donec et nisl id sapien blandit mattis. Aenean dictum odio sit amet risus. Morbi purus. Nulla a est sit amet purus venenatis iaculis. Vivamus viverra purus vel

magna. Donec in justo sed odio malesuada dapibus. Nunc ultrices aliquam nunc. Vivamus facilisis pellentesque velit. Nulla nunc velit, vulputate dapibus, vulputate id, mattis ac, justo. Nam mattis elit dapibus purus. Quisque enim risus, congue non, elementum ut, mattis quis, sem. Quisque elit.

Maecenas non massa. Vestibulum pharetra nulla at lorem. Duis quis quam id lacus dapibus interdum. Nulla lorem. Donec ut ante quis dolor bibendum condimentum. Etiam egestas tortor vitae lacus. Praesent cursus. Mauris bibendum pede at elit. Morbi et felis a lectus interdum facilisis. Sed suscipit gravida turpis. Nulla at lectus. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Praesent nonummy luctus nibh. Proin turpis nunc, congue eu, egestas ut, fringilla at, tellus. In hac habitasse platea dictumst.

### B.2 Lorem 25-27

Vivamus eu tellus sed tellus consequat suscipit. Nam orci orci, malesuada id, gravida nec, ultricies vitae, erat. Donec risus turpis, luctus sit amet, interdum quis, porta sed, ipsum. Suspendisse condimentum, tortor at egestas posuere, neque metus tempor orci, et tincidunt urna nunc a purus. Sed facilisis blandit tellus. Nunc risus sem, suscipit nec, eleifend quis, cursus quis, libero. Curabitur et dolor. Sed vitae sem. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Maecenas ante. Duis ullamcorper enim. Donec tristique enim eu leo. Nullam molestie elit eu dolor. Nullam bibendum, turpis vitae tristique gravida, quam sapien tempor lectus, quis pretium tellus purus ac quam. Nulla facilisi.

Duis aliquet dui in est. Donec eget est. Nunc lectus odio, varius at, fermentum in, accumsan non, enim. Aliquam erat volutpat. Proin sit amet nulla ut eros consectetur cursus. Phasellus dapibus aliquam justo. Nunc laoreet. Donec consequat placerat magna. Duis pretium tincidunt justo. Sed sollicitudin vestibulum quam. Nam quis ligula. Vivamus at metus. Etiam imperdiet imperdiet pede. Aenean turpis. Fusce augue velit, scelerisque sollicitudin, dictum vitae, tempor et, pede. Donec wisi sapien, feugiat in, fermentum ut, sollicitudin adipiscing, metus.

Donec vel nibh ut felis consectetur laoreet. Donec pede. Sed id quam id wisi laoreet suscipit. Nulla lectus dolor, aliquam ac, fringilla eget, mollis ut, orci. In pellentesque justo in ligula. Maecenas turpis. Donec eleifend leo at felis tincidunt consequat. Aenean turpis metus, malesuada sed, condimentum sit amet, auctor a, wisi. Pellentesque sapien elit, bibendum ac, posuere et, congue eu, felis. Vestibulum mattis libero quis metus scelerisque ultrices. Sed purus.

# Bibliography

## Fiche masterproef

*Student:* Michiel Ruelens

*Titel:* Design, implementation and evaluation of data integration methods for biomedical cancer data

*Nederlandse titel:* Design, implementatie en evaluatie van data integratie methoden voor biomedische data

*UDC:* 621.3

*Korte inhoud:*

Hier komt een heel bondig abstract van hooguit 500 woorden. L<sup>A</sup>T<sub>E</sub>X commando's mogen hier gebruikt worden. Blanco lijnen (of het commando `\par`) zijn wel niet toegelaten!

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Thesis voorgedragen tot het behalen van de graad van Master of Science in de ingenieurswetenschappen: elektrotechniek, optie Elektronica en geïntegreerde schakelingen

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