



BAG PACKER PROGRAM
P2 PROJECT
GROUP B130
SOFTWARE
DEPARTMENT OF COMPUTER SCIENCE
AALBORG UNIVERSITY
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Faculty Office for Engineering and Science

Strandvejen 12-14

Phone 96 35 97 31

Fax 98 13 63 93

<http://tnb.aau.dk>

Title:

Bag Packing Program

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Project group:

B130

Participants:

Dag Toft Børresen Pedersen

Christian Jødal O'Keeffe

Niels Brøndum Pedersen

Aleksander Sørensen Nilsson

Mette Thomsen Pedersen

Rasmus Fischer Gadensgaard

Kasper Plejdrup

Supervisor:

Karsten Jahn

Finished: The 24th of May 2012

Synopsis:

This report contains documentation of which problems some people might have packing their suitcases before a flight travel. These chapters will lead up to a statement of the problem which will be used in the development of a solution.

The solution will be a program based on the programming language C#. There will be a chapter describing how the structure of the program will be, and the reason behind the construction. There will also be a section about the reflections made, when the program was being made.

One of the last chapters will concern the testing and conclusion of the finished program. What could have been done better to the program and why does it not work, if that is the case. This chapter will also concern the reflection on the product to see if it actually solves the problem or why it does not solve the problem.

The product of the project is a program that helps the user pack a suitcase efficiently, and through a 3D-image of the packed suitcases the user will see where in the suitcase each item must be put.

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Date: Aleksander Sørensen Nilsson

Date: Christian Jødal O'Keefe

Date: Dag Toft Børresen Pedersen

Date: Kasper Plejdrup

Date: Mette Thomsen Pedersen

Date: Niels Brøndum Pedersen

Date: Rasmus Fischer Gadensgaard

Prolog

This project is made by Rasmus Fischer Gadensgaard, Christian Jødal O’Keeffe, Kasper Plejdrup, Aleksander Sørensen Nilsson, Niels Brøndum Pedersen, Mette Thomsen Pedersen and Dag Toft Børresen Pedersen from Denmark. We are group B130. The project began on 8.2.2012 and was finished on the 24.5.2012, at the University of Aalborg, where we are studying Software.

Most of us come from Tech College Aalborg, but some come from other colleges. We all chose University of Aalborg because we like the PBL model. PBL stands for Problem Based Learning and it is a unique learning method that is only used at University of Aalborg and Roskilde University Centre.

The goal with this project is to give us skills in using the programming language C# (C-Sharp), and make us better at team-working. This project is about optimizing and analysis of algorithms, and our main question is: How can a program be developed which helps the customer through the progress of packing one or more suitcases the most effective way by size and weight?

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Introduction

1

This project is based on the subject "pack the suitcase" with a focus on helping users to pack a suitcase properly, with an eye on weight optimization. From this project a product should emerge that will try and deal with a problem within the subject's field. When the product is done, it should be tested and based on the test it will be possible to evaluate the product's capability at solving the problem.

It is a requirement that the program is made in the program language C#. It is not a requirement that the program has a graphical user interface (GUI), but it has been chosen to do anyway. A part of the project is to document a problem and analyze it, to find the reason behind the problem. When the analysis is done, the product should be designed to handle the problem and thus solve it.

This is the essential of problem-based learning: To find a problem and then solve it and hopefully gain some knowledge in the process. For this to be an effective model all the group members must participate in the process and acquire knowledge by working with the project.

This project was in the project catalog, can seen in appendix A, which was made by the semester coordinator, Hans Hüttel, and this project was chosen after a long discussion based on the expectations in the group and the given time.

Problem Analysis 2

This project is based on the idea that it can be hard for some people to pack a suitcase properly. It can also be hard to take in account that the suitcase must not exceed the maximum weight limit of some types of trips, and some people might get fined for packing a suitcase too heavily. What can be done to make it easier for people to pack their suitcases? To find the answer to this, and to find a solution to this problem, it is necessary to take a closer look at the "Why there is a maximum weight on suitcases when one is traveling"-question.

2.1 Problem of packing

In the modern society, families or groups of friends tend to go on vacation to other countries to relax and enjoy their vacation or explore the world [Baumgarten, 2012].

When going on a vacation or a business trip packing a suitcase is normally needed. You need all your personal items and clothes with you. The length of the stay, the purpose of the trip, and the number of people traveling together effects the weight and size of the needed luggage. This can be a problem due to the different rules or limits to your luggage when using different means of transportation.

The time spend away affects how much clothes the traveler will need to bring and/or if the traveler will need to wash the cloth while away. A longer stay means of cause that the traveler will need more clothes. This affects the size and weight of the luggage because you will need more or fewer items with you on different trips.

The amount of items to bring also depends on what kind of trip it is and the purpose of the trip. For example if the purpose of the trip is a sport competition, you might need to bring some equipment, you would not normally bring on a holiday trip or other kind of trips. If it is a short business trip all you might need could be a briefcase with your papers and a suit to wear.

The amount of luggage depends on the amount of people on the trip, because everyone needs their own personal items, and their own clothes. This can be a problem if the persons have a lot of shared items that has to be spread in different suitcases and need to be found afterwards and it might also effect the total weight of the luggage.

It can be frustrating, when traveling with many and/or heavy suitcases, if you need to carry the luggage far. It can also be hard to manoeuvre if where you are suppose to walk is a small space or a narrow passage or if simply filled with a lot of people constantly blocking your way.

There can also be a problem with too large or heavy suitcases if you are traveling by plane since this can result in a fee. The size of the fee varies from airline to airline and can be found on the airlines website e.g. [SAS, 2012]. One of the reasons that this fee has been introduced is so the airlines bag-handlers do not risk getting injuries by carrying too many, heavy suitcases.

To avoid this fee it can be an advantage to pack the suitcases properly and limit the choice of items to bring so the total weight does not exceed the allowed weight.

2.1.1 Packing

Because of the weight and size restrictions at the airports it can sometimes be difficult to get all the items you want to bring into a suitcase that is small enough and not exceed the allowed weight. It can sometimes be necessary to acquire more suitcases for the trip or leaving some of the items you wanted to bring. Bringing more luggage means you have to pay more to get the extra luggage with you on the plane. A way you might be able to avoid buying and paying for extra suitcases is to pack the suitcases more than the suitcases are meant to contain. This mean that the suitcases packed more compact. This on the other hand increases the bags weight [SAS, 2012]. This should be thought through because too much weight can be unhealthy to carry around.

Fees regarding luggage by flight

The increased weight means the bags might exceed the limit for weight and therefore trigger a fee for overweight luggage. It seems people often pack their luggage more compact instead of taking extra bags with them on vacation. Generally people take a lot with them on vacation and they might not have packed their luggage the most effective way [of Transportation Statistics , RITA].

Airline	First quarter	Second quarter	Third quarter	Summery for the three quarters in 2011
Delta	197,971	226,291	232,508	656,770
American	137,210	156,114	152,750	446,074
US Airways	120,925	134,752	128,761	384,439
Continental	76,304	91,332	94,301	261,937
United	66,245	71,111	74,758	212,114

Table 2.1: This table contains the top 5 of the companies that have collected the most fees regarding luggage in 2011. The numbers are from [of Transportation Statistics , RITA] and the fourth quarter is not released yet, therefore missing

An American website for statistics, [of Transportation Statistics , RITA], shows the amount of fees given regarding luggage that have been registered at the U.S. airlines. Table 2.1 is a segment of the statistic table found at [of Transportation Statistics , RITA]. Through this it is possible to see that there are people that exceed the set of limits given by the airline. A note regarding this source is that the size of the fee is a combination of

the different rules and related fees. Therefore the statistics do not give an accurate image of the problem with weight limit, but a more general image of the problems with luggage exceeding the given limits.

Different Transport Methods

The problem with packing luggage is mostly the same if it is by train, car, or flights. But flights is the one transport where it plays the biggest role for the traveler because it has economical consequences. With train and car it is more or less up to the traveler how heavy the luggage is allowed to be. There are restrictions to how big the bags are allowed to be in the train. For train the limits are 100 x 60 x 30 cm [DSB].

When going on vacation, and using the car as transportation, the size of the car sets the limit in size of the luggage, since you cannot just pay to get more luggage with you than fits into your car. The weight might also have a influence on the amount of luggage there can be in the car. Because the car might not be able to drive well if the certain car is over the excess weight, since there are cars that can lift more than others.

Souvenirs on Vacation

There can be many good experiences and memories on a vacations. The memories tend to be bound to photos, items and souvenirs and thereby makes it easier to remember. Souvenirs can have a certain value and can be used to fill the home with memories about the past experiences. With this in the mind, it is important to make room for possible souvenirs or other things that simply had to be bought while away.

These souvenirs can be a problem to bring home. As earlier mentioned the weight and size of the luggage is a problem before the departure, therefore it will normally also be a problem on the trip home. This means that if a family packs just to the limits and then buy things and souvenirs on their vacation they will get into trouble when packing the luggage for the trip home.

Packing as a family

When traveling as a family it is an option to pack clothing, accessories and other relevant item in a more effective way. This is done by using all the bags in the most effective way and thereby not take the ownership of the bags into consideration. This method means that the bags will not be sectioned but the packed item will be packed into different bags despite the ownership of the item to active the most effective way of packing. Original bags tends to be packed so the bags are sectioned by the owner of the items so it is easier to find the desired item. This method is mostly used because it makes it much easier to known were to find the desired item. When this method of packing is used, it will be more effectively packed, but it have to be kept in mind that the weight should be distributed evenly, so none of the luggages are too heavily packed compared to an other.

Round Up

So the problem is packing the luggage in the most effective way and spreading the weight in the available suitcases, without violating the different rules or limits to size and weight. It can also be a problem to pack the suitcases to the trip home due to the bought souvenirs or other items. The reason to the problem could be that people find it difficult to pack the luggage for a trip and therefore pack more than they actually need on the trip.

The consequences of luggage exceeding the weight limits at the airlines are that the traveler will have to pay a fee for the extra weight. Train passengers that exceed the size limits might not be allowed to have their luggage with them if the dimensions of the suitcases are too big. There is not a specific program on the market that specifically helps packing luggage for a trip, but there exist at least one program that can pack a container [SolvingMaze]. This method of packing a container can be compared to packing luggage. A other solution is a smart-phone application that help with packing a suitcases by making a check-list over what to have with you on the trip [Top Iphone Application, 2011], see section 2.4.

2.2 Luggage rules

This section will focus on the general rules regarding luggage when going abroad, whether by plane, train or cruise ship.

2.2.1 Luggage table

This section will contain a table which displays the various limits for luggage in different public transportations. The table will be used to give a general overview of the different limits for luggage for different types of transportations.

Type of luggage	Dimension limit	Weight limit
Check-in luggage(Airplane)	158 cm *	20-23 kg
Extra luggage(Airplane)	158/277 cm *	20/45 kg
Carry on(Airplane)	50-55 x 40 x 18-25 cm	5-8 kg
Luggage(Train)	100 x 60 x 30 cm	Within reason **
Check-in luggage (Cruise)	75 x 50 x 29 cm	30 kg
Hand Luggage (Cruise)	55 x 35 x 25 cm	Within reason **

Table 2.2: This table displays a summary of the different rules given below.

* The sum of the dimensions; height, weight and depth must not exceed the given value. Depending on how much is paid on extra luggage different dimension and weight limits are given.

** There are no set limits, it just have to be carry able and not be a bother for other passengers

2.2.2 Charter trips on air planes

Given below is the various restrictions when travelling by plane.

Checked-in luggage

Check-in luggage is the luggage that will go in the planes cargo hold.

Items not allowed:

- Explosives, including detonators, fuses, grenades, mines and explosive compounds
- Gasses, propane, butane
- Flammable liquids, including petrol, methanol

- Flammable solid matter and reactive, including magnesium, matches, fireworks, flares
- Oxidising and oxidised compounds and organic peroxides, including bleach, auto repair-kits.
- Toxic or contagious compounds, including rat poison, infected blood.
- Radioactive materials, including medical isotopes and isotopes for industrial use
- Corrosive compounds, including quicksilver, car batteries.
- Compounds from combustible systems, which have contained fuel.

Due to the volatile or dangerous nature of the items listed above they have been deemed unsafe and thus not allowed on the plane without explicit permission from the airport.

Carry on

Carry on luggage is what the passenger is allowed to bring aboard in the cabin.

Approved items:

- Liquids, perfume, gel and spray – max. 100 ml – equal to one deciliter pr. container
- You are only allow to bring these containers (bottles, cans, tubes and, so on), if they are contained in a transparent plastic bag, which have to be closed (1 litre bag per passenger).
- The bag have to be resealable.
- Past security, wares can be purchased (including spirits, perfume and other liquids). Wares are handed out in sealed bags, these bags may only be opened after the final destination have been reached.
- It is now a requirement that you take off your overcoat, take laptops and other larger electronic devices out of the bag before the security check-in.
[Airlines]

2.2.3 Rules on trains

There are different rules depending on which train company you are using.

The Danish train company, DSB, have very few rules regarding the luggage you are allowed to bring with you.

The only rule is that your luggage need to be able to lie on the luggage rack or under the seat and not be bothering or putting any other person on the train in danger [DSB].

Another example could be Indian Railways where the luggage is allowed to have different weight depending on which class you are on. They have no other rules regarding luggage [Indian Railways].

2.2.4 Rules on cruise ships

On board a cruise ship the "rules" are not really rules more like guidelines as they encourage the passengers to not exceed the limits. Furthermore the passengers luggage should be kept in their cabin during the trip[MSCcruise].

2.3 Luggage allowance

Due to the hijacking and crashing of the airplanes into the World Trade Center on the 9th of September 2001, the security of airports have increased dramatically. Some of the hijackers carried knives and box cutters and this led to an immediate restriction of any and all types of sharp objects. The reason the hijackers could get these weapons on board the plane, was lax security around for instance Swiss army knives and blades like a box cutter. Along with stricter rules for items allowed on the plane, a thorough check up of the security personnel hired by the airport have been issued. After the change, airports are no longer allowed to hire their own security personnel due to a lack of discipline and training and in some cases hiring of personnel with a criminal background.[Zielbauer, 2001]

On the 5th of October 2006 more regulations were introduced to prevent passengers from bringing liquids of too large a quantity on board (see section 2.2). To construct a bomb a certain amount of "liquid" is required for it to have enough power to be a threat, and studies have showed that several 100 milliliter containers stored in a 1 liter bag equals around 500 milliliters of liquids which in turn is not enough to make a bomb that can take down a plane. This restriction covers all types of liquids because the screening points at the security can not distinguish one liquid from another without the security personnel manually checking the various liquids, which would severely slowdown the whole process.[EU-Kommisionen]

Due to these restrictions packing a bag is not as simple as it used to be. A lot of items are no longer allowed and thus it can be difficult to know what is allowed and what is not. As the restriction covers all sorts of liquids packing a simple toilet bag is time consuming.

2.4 Solutions on the market

This chapter are used to research the marked and thereby get a image of what solutions there already exist on the marked. Through the research it is also possible to determine, how the existing solution helps the user with the stated problem. By looking at existing solutions it can used to determine what features that would be needed in the program for this project, and from these solutions get inspiration. The amount of lists and guides on the market is huge. These lists and guides offers help and provide tips for packing for traveling. Some of these lists and guides have been developed into applications that are available for the customer to use. An application or in short app, is a program that fulfill different kind of services for the user. Apps are used in the web browser, computer, smart phone, and tablets. The term app is general mentioned in context to smart phones and tablets.

There also exists programs, that have integrated algorithms to handle optimization of the packing, on the marked that can be used. First a look into these lists and guides and the more advance solution thereafter.

2.4.1 App - Packing Pro

Packing pro is an app developed for the Iphone and Ipad that offers templates for check lists to the customer. Packing Pro uses a touch interface which means that the user by using the finger can navigate around.



Figure 2.1: Picture of 2 of Packing Pros menus from [Top Iphone Application, 2011]

Packing pro is designed with a panel in the bottom of the screen that allows the user navigate through the menus. Packing Pro provides the user with a help menu that contain information on how to use the app. On figure: 2.1 can an example of how a check list could look like.

These templates are designed to different purposes regarding the customer, gender, type of trip, and purpose of the trip. The customer can then load the wanted template for the purpose. The user also have the possibility to create their own lists by adding things that should be remembered for the trip by them self. And to select an existing list and delete the objects that were found irrelevant by the user. The user can then check object on the lists off as it get packed. Packing Pro is a management tool that helps the customer get an overview of all the things to remember. As the name implies(pro) the app have to be bought before it can be used [Top Iphone Application, 2011].

Packing Pro works as check list and help the user remember what to pack, but it does not preform any organization of luggages content itself. So Packing Pro itself does not solve the described problem but helps the user remembering what to pack. So a feature to consider from this program is the check list function that gives the user an overview of things to pack. A function that would not be needed is the compatible with Iphone/Ipad operating system. It would be nice if the program made work cross platforms but it is still not required to solve the problem.

2.4.2 App - Checkmark Packlist

Checkmark Packlist is a free app for the smart phones running the Android system. Checkmark Packlist offers different templates for check lists that the customer can use. One of these templates is the list for packing for a trip. That way the customer can select and use this template for remembering what they will need to pack for the trip. Checkmark Packlist uses touch to navigate in the program. This means that the customer with their fingers can navigate through the check list and check off things that have been packed.



Figure 2.2: Picture of the Checkmark Packlist in action from [GreenbeanSoft, 2010]

On figure: 2.2 there can be seen an example of the product and how Checkmark Packlist looks like for the user. Checkmark Packlist does not provide a customization tool that lets the customer add more categories to the check list. This is only a feature provided in the paid version of Checkmark Packlist [GreenbeanSoft, 2010].

This app does not provide a solid solution for luggage packing but helps the user remember what there should be packed for trip. This check list feature gives a guiding effect and this is a useful feature and can be used in the product design to solve the problem. A feature to consider is the mobility by designing the program for hand held devices.

2.4.3 Online check/tip list

The online check list works as a reminder when packing luggage. It also gives tips and tricks that could be considered when packing for the trip. There exists a lot of different websites offering this service for free. Some are posted by an organization and others by a person on a forum. This means that all electronic devices as computers, tablets, and smart phones that have access to the Internet can open the website address.

An example of this kind of website is the following source [Foster]. This website offers a list of 10 tips that can be helpful for the customer when they are packing for a trip.

The website is purely text based and helps the user packing through the tips on the website. The site does not help with the actual packing, instead it helps with the planing of materials that the user might want to have on the trip. The website is designed with a menu left that let the user navigate through the different content of the website.

The online check/tip list in itself does not give the customer a solution to the packing problem. The websites instead help the customer planing the trip. The type of check/tip list used on [Foster] does not apply as a useful feature that could be used in the final program. Instead it would more be focus on helping the user with the packing.

2.4.4 The e-Commerce shipping calculator

The e-Commerce shipping calculator is an advanced program that helps the customer pack large containers and calculates the price of the shipment. By typing the size, weight, location, and destination of the items that should be shipped, the program can calculate what the prize is going to be and generates a 3D(3 dimensional) model of the container where the given items are placed in the best possible way so there are a minimum of wasted space. On their website [SolvingMaze] they offer a demo(demonstration) of their program. Their demo runs through the web browser and thereby should be accessible from computers connected to the internet. The demo is design to have the containers dimension variables and weight limit as input fields. Under the container is there are list of item where each item can have different dimensions and weights. To right of these field is the 3d model placed that will be generated.



Figure 2.3: Screen shot of the program running taken from [SolvingMaze]

The customer have to type all known data in and press "Calculate Rates" and the program will then form a 3d model, this can be seen on figure: 2.3. This product have a number of useful features that can be used in the final product. This solution can take items dimensions and weight and calculate the most optimal placement in the container. This can be related to packing your luggage for a trip.

2.4.5 Recapitulation

This sections main object is to look at the wanted features and recap them. Packing Pro and Checkmark Packlist is similar in the way that they help the user. They both provide the user with a sort of check list that can be check off and thereby help the customer remember what have not been packed yet. One of the differences is that Packing Pro

have a price while Checkmark Packlist is free. But this difference means that Packing Pro allows the user to edit the check list while that are not possible in Checkmark Packlist. These two apps do not help the user arrange the luggage content or take in consideration of size and weight of it. Thereby is two apps do not help people with the packing itself but more what should be remembered for the trip. The online check/tip list provide the user with advices for the trip and what to pack. Advices are great to get a general idea of what to take pack but it still does not give a more effective way to pack. The e-Commerce shipping calculator is the one solution with the most wanted features. One of the strong feature that can be used is the ability to calculate the most effective that a container should be packed. A important side note is that the intentions is not to pack bags but the feature can be related to packing content of a bag.

Included in product	Solutions			
		App - Packing / Packing Pro	App - Checkmark Packlist	Online check/tip list
Guide the user*		x	x	x
Distribute weight				x
Distribute space				x
On the road		x	x	x
Where in the suitcase				x
Packing list		x	x	x

Table 2.3: Table for the different products on the market and their features. *The program should be able to guide the user through the different steps of the program.

Table 2.3 consists of features listed vertical and existing solution on the market listed horizontal. The crosses indicates when the particular product have the particular feature. The purpose of the table is to give a overview of the products and their features that was found essential to the problem. Table 2.3 shows tha there are a lot of help regarding what to bring but when it comes to packing it is only one of the selected solution that had this feature.

2.5 Problem Statement

In this section a problem statement will be formulated which will be used to develop a method to the problem of this project and to get a more precise problem to work with. The method is used to try and solve the problem stated in the thesis statement. The problem analyses shows that there are two general types of programs on the market. One type is a form of a packing list that tells the user what they might want to pack,

the other type of program is a packing program which packs containers for the user and calculates the shipping cost to a designated location. These two types of programs only fulfill parts of the criteria this project have put forward. With this in mind a thesis statement have been formulated to help shape the solution for this projects problem.

- How can a program be developed which helps the customer through the progress of packing one or more suitcases the most effective way by size and weight?

The meaning of this thesis statement is to research and develop a program that in some way could handle the problem, but the consumer also plays a role in the problem. Therefore the consumer must also be taken into account when it is being developed. The reason for this is to make the program as user friendly as possible.

Sub Statements

The sub statements have been made to help find a solution to the thesis statement. These sub statements describe some of the steps that need to be made in order to find the solution for the thesis statement.

- **How can it be checked that the weight in the suitcases are evenly distributed and it does not exceed the allowed weight or the volume in the bag?**

The program will need to handle and solve calculations with weight and volume. Through these algorithms the program should find the must most effective solution for the given data. It will also have to check that the solutions weight does not exceed the given limits or the volume of the luggage.

- **Which functions are needed to get the program to compute the most effective way to fit the items into the suitcases?**

Some functions are needed for the program to find the most effective solution. The functions will use an algorithm for optimising and thereby the program will fulfil its purpose.

- **How should the program communicate with the user and inform where the items are placed, and tell how much space is left?**

The program will have to be developed and tested so the customer can use the program to its full extent. Therefore it is important not to use advanced technical language or unexplained abbreviations.

- **How can a program be developed so it takes the length of the journey into account, and enable the user to update the program on the go?**

The program should also be developed so it is possible for the user to update the programs database while on vacation thereby get a packing order for the new content of the bags.

From this thesis statement there will be developed a list of requirements for the program, which it will need, to solve the given problem and be user friendly. The system requirements can be seen on section 4.1

2.6 Method

This project structure will be based on Aalborg PBL (problem based learning). The Aalborg PBL is a method whereby the learning process lies in the work with a problem and try to develop a solution for the given problem. The Aalborg PBL method also trains the students ability to work together in a project group and give them tools to handle the processes that goes with working in a group.

The first stage of the project is the problem analysis in chapter 2, which purpose is to find and document that there is a problem to begin with. From the problem analysis a thesis statement is formed and is used to produce a list of product requirements. The requirements are then used to design and develop a product that should solve the problem stated in the thesis statement. The design will be describe in chapter 4. The development will also have it own chapter were the program will be describe and how the different functions are made. This can be seen in chapter 5. The program are then tested on the target group of the problem. The testing phase will be described in chapter 6. The result of the testing will lead to improvements and a conclusion of the project. The conclusion will sum up the project and try to answer the thesis statement, the conclusion can be seen in chapter 8. This is the main course of the project, when using the Aalborg PBL model. This project form is used because it finds and document a problem and then through the work with the problem gives an estimated solution to the problem.

To document the problem, a lot of information is needed. The information is found through different sources such as; books, article, websites, etc. When using information found through the internet or other sources it is important to evaluate the used sources. This is done to filter out unreliable sources and thereby achieve a better and more trustworthy project. This process of evaluation is also known as source criticism and are general used when using others materials as documentation. Therefore it is also a relevant method to use when using sources in the project work.

Theory 3

In this chapter there will be taken a closer look on the theoretical aspect of writing a sorting program. First off is a quick description the NP-problem followed by a look on different ways to pack different objects. With a good grasp on the different algorithms and the most effective way to pack items, the process of developing a program should be easier.

3.1 Knapsack Problems

The knapsack problem is basically creating an algorithm which packs a list of items into a knapsack. Each item is assigned a weight and a value. The total weight of the items must not exceed the maximum weight capacity. At the same time, the knapsack must be packed so the summarized values of the items are as high as possible. There exists a vast amount of derivatives of the knapsack problem. For example the 0-1 knapsack problem [Kellerer, 2004], which dictates that each item can only have the status 1 or 0, which equals packed or unpacked. This means that each item can only be packed once, where in the regular knapsack problem, items can be packed multiple times to maximize the total value of the knapsack. A knapsack problem can be formulated as the solution to the following linear integer programming formulation:

$$\text{maximize } \sum_{j=1}^n p_j x_j$$

Meaning: Maximizes the total value (p) of items (j) in knapsack

$$\text{subject to } \sum_{j=1}^n w_j x_j \leq c,$$

$$x_j \in \{0, 1\}, j = 1, \dots, n.$$

Meaning: Total weight (w) of items(x) may not exceed the knapsacks capacity (c)

[Kellerer, 2004]

Another derivative is the bin packing problem, which will be described in the following section.

3.2 Bin packing problem

The bin packing problem is a combinatorial NP-hard problem [Korte and Vygen, 2002]. This means that the problem is at least as hard as an existing NP-complete problem. NP-complete means, in simple terms, that every combination must be examined, and then the best combination must be chosen. An example is the Traveling Salesman Problem (TSP), where a list of cities and distances between the cities is given. The problem is then to find the shortest route to visit all cities, and to end at the starting point. The problem consists of fitting objects of different sizes into bins of identical sizes [Rosen, 1991]. This could for example be fitting various packages into shipping containers. There are various approaches to solve the bin packing problem. Bin packing problem is focusing on bins instead of suitcases but they are basically the same, the only difference is the size. Some of the popular methods will be described in the following section. To describe these packing algorithms, illustrations will be used. The illustrations shows how the packing algorithms works in one dimension - but it gives a nice basic understanding of the algorithms. Figure 3.1 is an illustration of the unpacked elements:

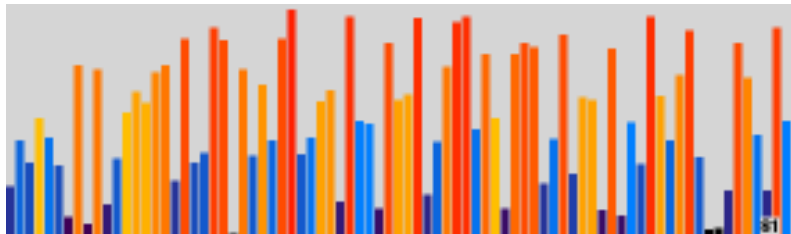


Figure 3.1: Initial elements (source: [Arizona.edu])

Given below are examples of different fitting methods used when packing bins.

3.2.1 First fit (FF)

The first fit algorithm creates a list of the objects needed to be fitted into bins. It then runs through the list, checking if an item can fit in each bin. If it cannot fit in the first bin, it will check if it can fit in the second bin and so on. If it does not fit in any bins, it opens a new bin, and fits the object there. Figure 3.2 is an illustration of the elements packed with the First fit algorithm.

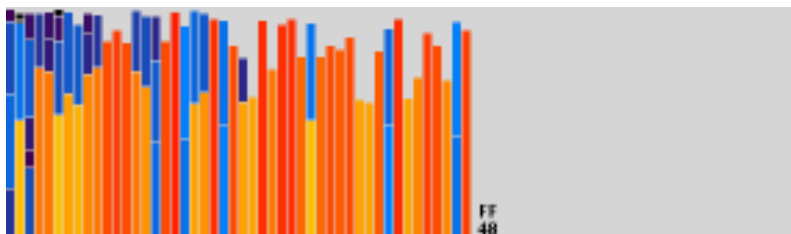


Figure 3.2: Elements after FF has been applied (source: [Arizona.edu])

3.2.2 Best fit (BF)

The best fit algorithm is much the same as the first fit algorithm, except it does not fit the object into the first bin that can contain it, the algorithm compares it to each open bin, where the object fit. It will then place the object in the bin which will have the least

space left when the object is packed. Figure 3.3 is an illustration of the elements packed with the Best fit algorithm.



Figure 3.3: Elements after BF has been applied (source: [Arizona.edu])

3.2.3 Last fit (LF)

This algorithm packs the object in the last open bin which has room for it. This algorithm is thereby the opposite of the first fit algorithm. Figure 3.4 is an illustration of the elements packed with the Last fit algorithm.



Figure 3.4: Elements after LF has been applied (source: [Arizona.edu])

3.2.4 Worst fit (WF)

The algorithm checks all the bins, and packs the object in the bin which has most empty space. As its name suggest, this algorithm is the opposite of the Best fit algorithm. Figure 3.5 is an illustration of the elements packed with the Worst fit algorithm. As the figure shows, the worst fit algorithm is in fact more effective than its name might suggest.



Figure 3.5: Elements after WF has been applied (source: [Arizona.edu])

3.2.5 Almost worst fit (AWF)

Similar to the worst fit algorithm, but the almost worst fit algorithm packs the object in the second most empty bin. Figure 3.6 is an illustration of the elements packed with the almost worst fit algorithm.



Figure 3.6: Elements after AWF has been applied (source: [Arizona.edu])

3.2.6 First fit decreasing(FFD)

The above algorithms are very ineffective because the biggest objects might be placed at the end of the list, and thus be packed in the end, where it is more effective to first pack these large objects. The first fit decreasing algorithm takes this into account and sorts the list before attempting to pack the items. This way the biggest items will be packed first.

3.2.7 Best fit decreasing(BFD)

Again this is the same as the best fit algorithm, but with the list being sorted before attempting to pack the objects.

3.2.8 Round up

It seems that it is more effective to sort the lists before attempting to pack objects into bins. This way bigger objects are packed first, and the smaller objects can then be fitted around the bigger objects. However in some situations it is necessary to use unsorted lists. For example in a factory with continuous production, it is never possible to have the complete list of objects, and thus never possible to sort the list. This theory can be used to form the algorithm of this project, and use the others mathematical experiences as a benefit.

e Fatal: Et eller
et sted skal der
enlignes mellem
ing og knapsack

Design 4

In the design chapter a look will be taken on the specification requirements and why those features are needed or wanted in the program. There are also a section detailing some features that will be nice to have if there is enough time to implement them in the program.

4.1 Specification Requirements

Through the problem analysis it has been documented that there are some strict rules regarding some forms of public transportation when going on vacation. Based on this research a list of features has been composed, which the program must fulfill to meet the base requirements. Furthermore another list has also been made composed of some additional features that would make the program better and more user friendly. They are not needed for the base requirements, but rather as improvements to make the program even more ideal for the user.

To help the user get started on the program, there will be a guide included in the program. The guide gives an explanation on how to use the program. The guide will be short and well formulated so the user with ease can read and understand the guide. The project description states that the program must be written in C#. The program itself needs to have a few features for it to solve the problem that is the focus of this project. The program needs to make sure that the weight is evenly distributed in the bags and that it does not exceed the bags weight limits. The program also needs to distribute the space of the bags to make sure that the program does not fill a bag more than there is physical room for. When the user is on the trip the program needs to have a function that allows the user to edit the list of items that are in the bag, so that if the user buys some souvenirs or throws something away, the list of items will be updated and thereby a new way to pack the luggage is given. The program also needs a function to help the user see where the items are placed in the luggage, so that the user can actually pack the suitcase(s). The program will also have to check that the suitcases are below the limits set for weight and size.

There are some features that not are essential for the program to work but will improve the program. One of these features is to handle changeable shape of items e.g. a T-shirt or other forms of clothing. This makes the program able to pack more efficient. This means that to program can handle like solid, liquid and bendable shapes. But this may not be in the program at the start since this will be hard to develop and implement. To help packing better and plan ahead, the program needs a list of different trip types which

can help the user pack the luggage for a given type of trip. Another nice feature to have is to allocate space for possible souvenirs the user might buy on the trip. These features means that the user does not need to check if there is room for the souvenirs before buying it.

4.1.1 Targeted Features

These are the essential features that the program will have.

Program language is C#: The program need to written in C# since the requirements for this project is that the program is written in C#.

Guide the user: The program will have a small "read me" file, or another form of guide, which will tell the user how to use the program.

Distribute weight: The program must be able to distribute weight of items between multiple suitcases if there are more than one suitcase.

Distribute space: The program also needs to distribute the items by space. The whole idea of the program, is that it should be able to tell the user how to pack the suitcase, and be able to tell if there is enough space for eventual souvenirs. Lastly it should inform the user how much space, if any, is left.

On the road: The program will be able to tell you, while you are on the trip, if there is enough space for a souvenirs, if you input the dimensions and weight of that item. And if you want to remove an item from your luggage it can this as well.

Baggage rules: The program will need to know basic baggage rules. For example the luggage must not weigh too much, and it must be below certain dimensions.

Structure of packing: When the user asks the program if an item will fit in the suitcase, the program will show exactly where in the suitcase the item will fit.

Packing list: To make it easier for the user to know what will be packed an editable lists will be included.

Save/Load function: To make the program easy to use on a trip, there is need for a function that can keep the data safe when the user closes the program.

4.1.2 Optional Features

These features as mentioned above, are additional features that might be able to be implemented later if possible.

Solid/liquid/bendable shapes: The program will also take in account that items

might be bendable, and therefore fit in other ways than solid items. For instance a T-shirt can be folded in many ways and thus can be considered a liquid form as it can fit almost everywhere.

Type of trip Depending on the nature of the trip different packing lists will be necessary because each trip might require different items.

4.2 Partner analysis

This section is an analysis about who and what kind of groups could use a product like the one this project is aiming to make. Instead of a specific target group this analysis will focus on cases in which someone might need this product.

Modern people who have problems packing a suitcase properly If someone do not know how to effectively pack their own suitcase, be it how to distribute the weight of the items or how to utilize the space.

Families or groups of people who share or do not mind sharing suitcases when going on a trip together When traveling in a group there is an opportunity to share space amongst each other. A program that can calculate this would be ideal to better utilize this increase in bags and thereby an increase in bag space.

Based on this analysis the general functions and design of the product is created to fit the cases described best. This will be described in greater detail in section ??.

4.3 Solution suggestions

This section will focus on different solutions to the problem about packing a suitcase. Each solution's difficulties and benefits will be explained. At the last subsection a solution will be selected and the choice explained. These solutions have been chosen based on the mind map that can be seen in appendix B.

4.3.1 Application for smartphones

This idea is to make an application that helps the user pack one or more suitcases. The user will need to type in the height, length, depth, weight and a name of the items to pack. The application will then calculate whether all the items can be packed. Because the weight of the calculations might be too much for the average smartphone, the application will need a server to make the calculations. This requires the customer to have access to the internet on the phone to be able to use the program. At the last step the application will show the user where to place each item. This means that the customer will have easy access to the program everywhere the user might bring the smartphone as long as it has access to the internet. On the other hand people without a smartphone would not be able to use the program. This solution is easy to bring everywhere because you rarely leave your phone. One of the technical problems to this solution is that C# in it self cannot program applications for smartphones, though with a plug-in the code can be translated to another language like Java (which is the language for applications on Android phones).

4.3.2 Extension for an existing program

A second solution could be to make an extension for another program that already exists. This extension should add the missing functions of the original program. It could either be an extension to the many packing lists. In that case the program should be able to use the information from the lists to calculate how to most efficiently pack all the items and afterwards show how to pack them. An example of this solution could be an extension to the e-Commerce Shipping calculator. This extension should be able to pack smaller items like a suitcase and not a container. A problem with making an extension for another program is if the other program is written in a programming language that is not compatible with a program written in C#. Another problem is writing the program if the other program is not open source and therefore the company's permission is needed before the coding can begin. If the existing program is not open source the company's permission and cooperation will be needed in the making of an extension of their product. On the other hand it is possible to make a program that focus more specifically on what is missing in the other program and therefore cover more of the important features. So this solution would need the company's permission to make use of their code if it is not open source, and it would have to be determined if the program would be able to work together with an extension written in C#. The solution would be able to cover more of the problem since the existing program would already have some of the features needed and the extension could cover even more.

4.3.3 Program for the computer

A third solution could be a program for the computer. The user will need to supply the program with the height, length, depth, weight and a name of the items to pack, and the program will then calculate if all the items can be packed and where in the suitcase. After the calculation the program will show where to put all the items. This will be by showing where the individual items need to be on a 2D or 3D figure of the suitcase. Making a program for the computer means the customer will need to bring his computer on the trip if he wants to use it on-the-road, but it will not need internet since the computer is strong enough to make all the calculation on its own. This solution requires some time to learn 3D editing if the display figure of the suitcase should be in 3D and this should be taken into account in the time schedule. This solution makes it is easy to test as the code will be self written and it does not need internet to work, but on the other hand the customer needs to bring the computer if the user wants to use it on-the-road.

4.3.4 Choice of solution

When understanding the three solutions it is possible to determine, which of the solutions best solve the described problem. To determine the best solution it is needed to look at the pros and cons of each solution. The pro about the first solution is that it is easy for the user to bring the program. The cons are that you will need internet to use the program and this can be expensive on a vacation. Another con is that this solution requires time to learn of how to write an application for a smartphone. The pro about the extension for another program is that since some code is already written there is more time to be more specific in what the original program is missing. On the other hand it can be a problem if the original program is written in a programming language that is not good at working together with a program written in C#. It is also a problem if the original program is not open source, because the company who own the program then needs to give permission to use their code. If the original program is not open source can it be a problem to get this permission without long negotiation with the company. The last solution is a program for

the computer. A pro about this solution is that it does not need internet to run since the computer is strong enough to make the calculation on its own. Another pro is that since no code from others is needed there is no problem about different programming languages needing to work together. It is also easier to make the program exactly as needed since it is being made from scratch. A con is that some people do not want to bring their computer on a trip and can therefore not use the program while away. So when looking at all the solutions the choice is going to be the last solution about a program for the computer since it is the solution with the most pros and fewest cons. It can be a problem on the go, but every solution has a problem on the go - the app will need internet access, and both the program needs a computer. Many people have a computer on a vacation, so the problem is not that big. Also more time is not needed, which means there are more time to make the program and thereby more time to finish the program before the deadline.

4.4 Program planning

The purpose of this section is to plan how the program should work and describe the flow of the program. The program is illustrated in the flowchart seen on fig 4.1 to give an overview of the whole program. A flowchart is a useful tool when programming because it explains the structure of the program.

To give a more precise explanation of a program the flowchart can be formed into pseudo code which is a level of abstraction above real code. Pseudo code is used as a schematic for the program and thereby gives some foresight into any problems that can be encountered when writing the actual code. Pseudo code can be seen on Figure 4.2. Thus planning ahead and designing the program so a minimum amount of code errors and unexpected problems occur. The program planning will be used to make it easier to develop the program, and help make a better product in terms of structure.

When the program starts, it should show the main window. Here the user can load saved lists, manage the item list or the suitcase list, the instructions are shown, there is a button that will show information about the program and there is also a button that will start the packing of the suitcase. In the "manage" windows the user is able to clear the list, add new items, edit items, delete items, and save the list. If one or both of the lists are empty when the user clicks the "Start packing"-button the program will inform the user that there needs to be at least one item and one suitcase for the program to be able to pack the suitcase(s) and item(s). After managing the list the user is asked to click the "Start packing"-button.

The program then performs the algorithms to place the items in the most efficient way regarding volume and weight. The program will also check that the suitcases does not exceed the weight limit set by the user. When the program successfully place an item, the item will be marked as packed. If the program can not fit the item in any of the accessible suitcases the item will be marked as not packable. If the program reach the point where all items have gone through the process, it should then inform the user that the process is done and inform how the user have to pack the suitcases and report if there were any items that could not be packed. At the end of the program the user will be able to see a 3D-view of the suitcase and be able to select which suitcase to show. The user will be able to zoom, rotate and drag the suitcase. A list will show all the items in the suitcase and if selected, they will be marked in the suitcase.

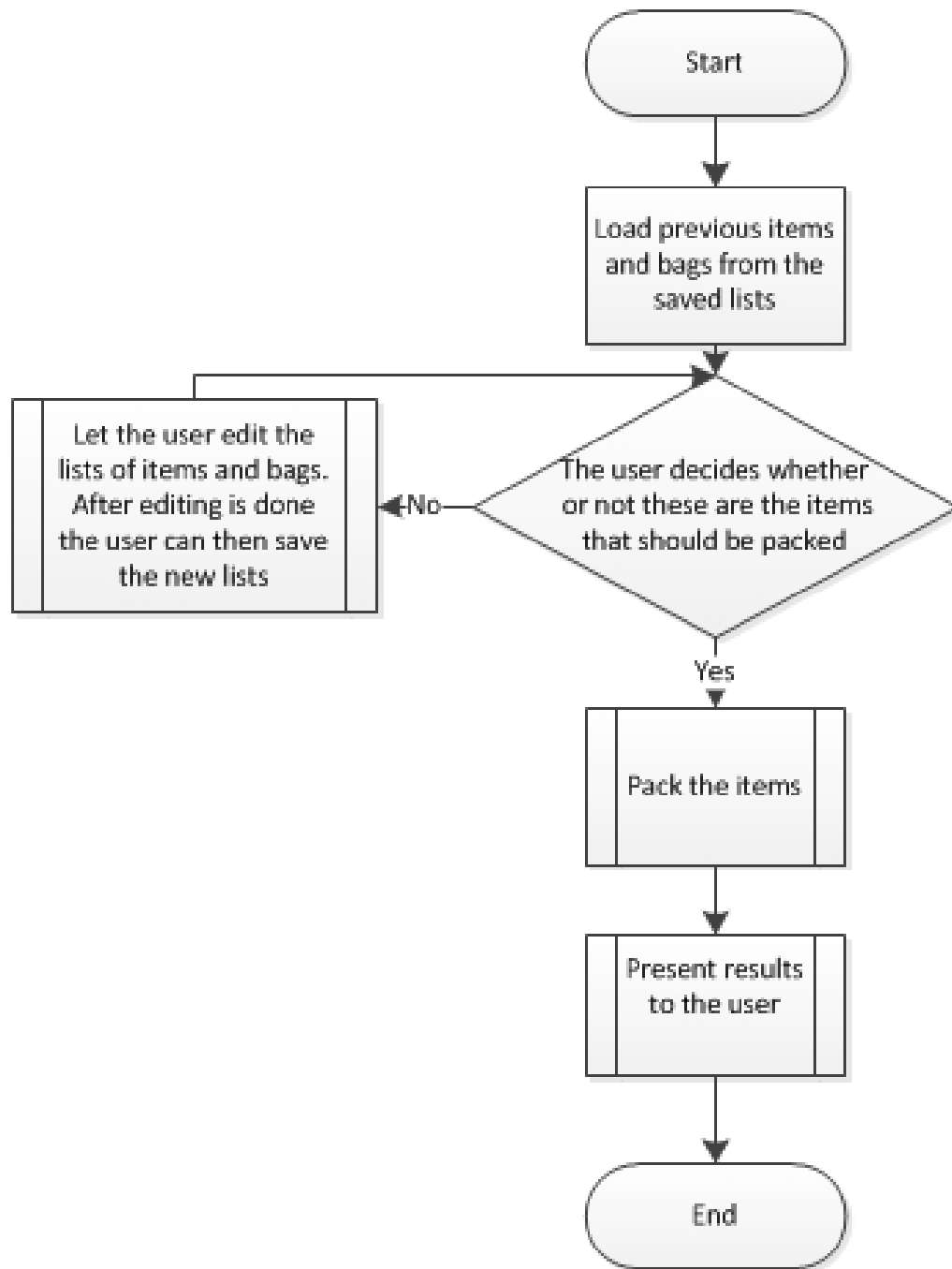


Figure 4.1: This is the flowchart of the program

Fatal: Flowchart
should be finish

Hereby the general structure of the program has been formed and can be described by a flowchart, seen on figure 4.1. The arrows shows the direction of the flow in the program. Some of the arrows also have small labels indicating which answers there were to the decisions. This flowchart can then be used as a schematic for the developing of the program and thereby a better structure of the program can be achieved.

There has been made pseudo code from the flowchart on Figure 4.1, which is one of the last steps before actually writing the program. This will give a more structured view of the events in the flowchart. The pseudo code can be seen on Figure 4.2.

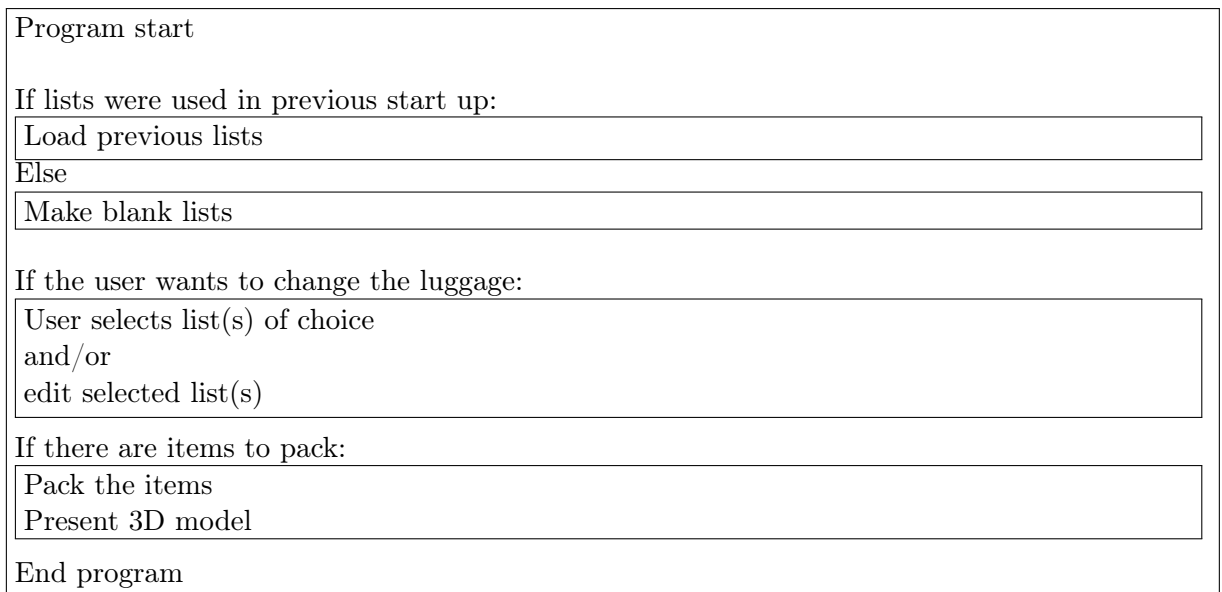


Figure 4.2: The pseudo code of the program

4.5 GUI Description

The GUI(Graphical User Interface), as the name implies, is the interface the user interacts with when operating the program. The main interface window of the program looks like this.

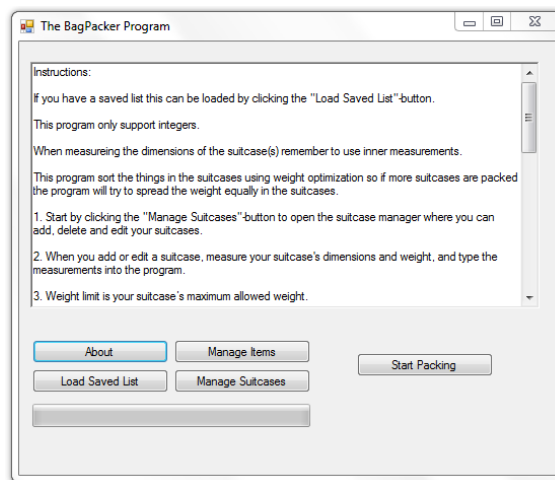


Figure 4.3: Main window

The main window contains the instructions on how to use the program, an "About" button which tells who the creators are and what they do. A "Manage Items" and "Manage Suitcases" button where the user can add/edit/delete items/suitcases. The button "Load Saved List" can be used if the user have previously made a list and wants to use it and/or add/edit some items or suitcases from the list. The "Start Packing" button initiates the program's algorithm and packs the suitcase(s). The progress bar is associated with the "Start Packing" button and starts when the user presses the button.

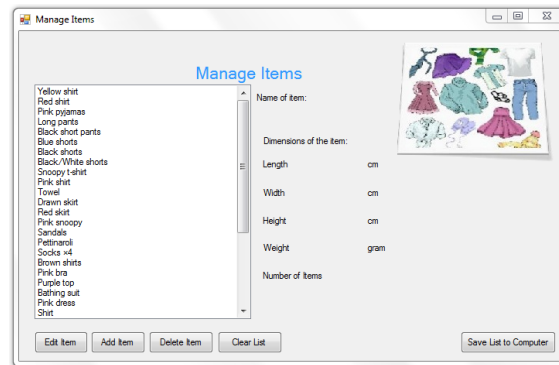


Figure 4.4: Manage items window

The Manage Items menu is where the user can add, delete and/or edit items.

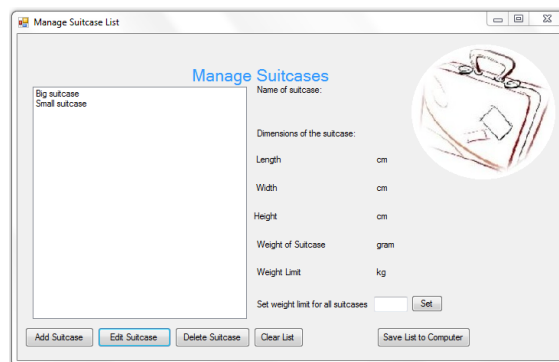


Figure 4.5: Manage suitcase window

Add/delete/edit suitcases in the Manage Suitcase menu.

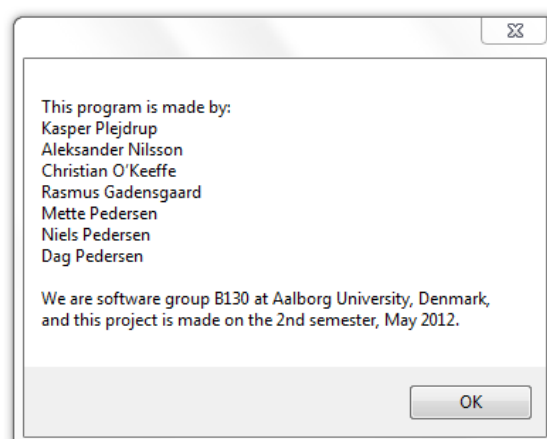


Figure 4.6: About window

The About button which tells who the programmers are, and when the program was made.

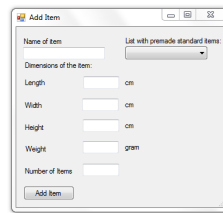
A screenshot of a software window titled "Add Item". It contains a "Name of item" text box, a "List with premade standard items" dropdown menu, and a section titled "Dimensions of the item:" with five input fields: "Length", "Width", "Height", "Weight", and "Number of items". Each field has a unit label to its right: "cm", "cm", "cm", "gram", and an empty field respectively. An "Add Item" button is at the bottom.

Figure 4.7: Add item window

When the user presses the "Add Item" button in Manage Items, this form shows. In the form there is a text box, where the user types the name of the current item. There are 5 other text boxes which are for the length, width, height, weight, and number of items.

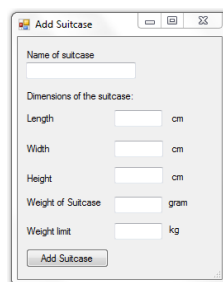
A screenshot of a software window titled "Add Suitcase". It contains a "Name of suitcase" text box, a section titled "Dimensions of the suitcase:" with five input fields: "Length", "Width", "Height", "Weight of Suitcase", and "Weight limit". Each field has a unit label to its right: "cm", "cm", "cm", "gram", and "kg" respectively. An "Add Suitcase" button is at the bottom.

Figure 4.8: Add suitcase window

When the user presses the "Add Suitcase" button in Manage Suitcases, the user can add a new suitcase. The data needed is the length, width, height, weight, and the maximum weight of the suitcase.

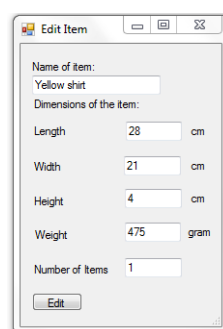
A screenshot of a software window titled "Edit Item". It contains a "Name of item:" text box with the value "Yellow shirt". Below it is a section titled "Dimensions of the item:" with five input fields: "Length" (28), "Width" (21), "Height" (4), "Weight" (475), and "Number of items" (1). Each field has a unit label to its right: "cm", "cm", "cm", "gram", and an empty field respectively. An "Edit" button is at the bottom.

Figure 4.9: Edit item window

If the user wants to edit an item, he/she can press the "Edit Item" button in Manage Items, and this form shows. In the form there are 6 text boxes for each input parameter, and a button saying "Edit", which saves the changes the user has made and closes the form.

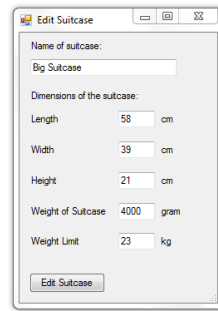


Figure 4.10: Edit suitcase window

In "Manage Suitcase", there is a button called "Edit Suitcase". It allows the user to change the data of a suitcase, if e.g. the measurements are wrong, or the user wants to use another suitcase, which do not have the same measurements.

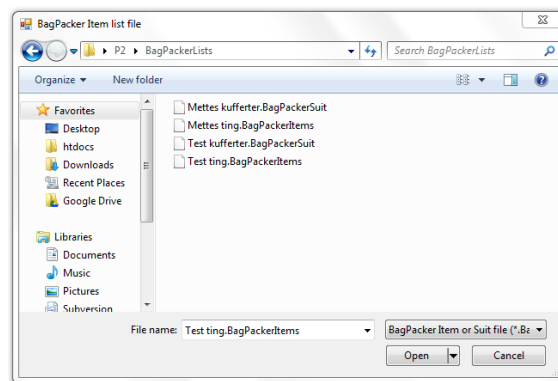


Figure 4.11: Load List

If the user already have used the program before and have saved an item list and a suitcase list, both can be loaded here.

4.5.1 3D-viewer

The 3D-viewer shows how the program have packed the different items in the suitcases.

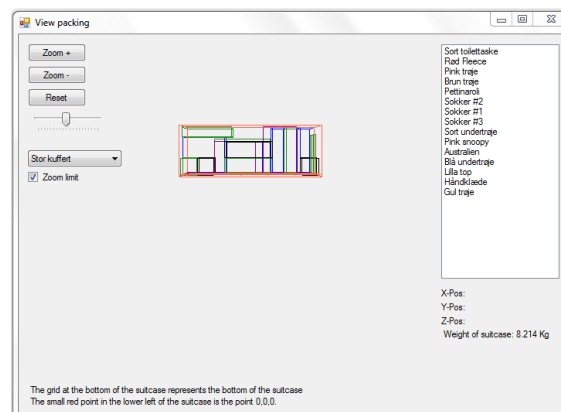


Figure 4.12: 3D Viewer window

This is the first thing the user will see when the packing starts. It shows how the items are placed in the suitcase. The image can be dragged, moved, and zoomed with the mouse, as seen below. When the user clicks on an item in the list on the right side, the marked item will be highlighted in the image. Below the list are the xyz-points to see where the item is supposed to be placed, and the current suitcase's weight.

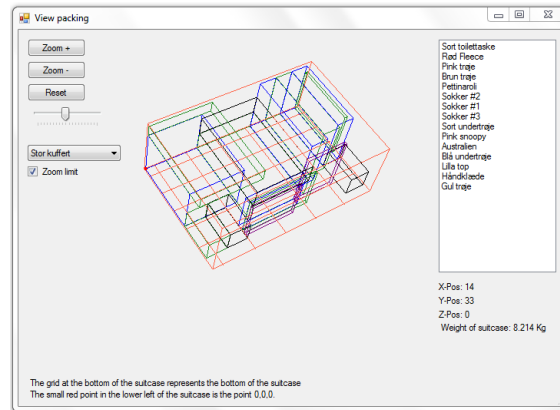


Figure 4.13: 3D Viewer2 window

On the left side of the window are two buttons, zoom in and zoom out. On the lower left side of the window is a check box called "Zoom limit". It sets the limit for how close and how far the user can zoom the image. The buttons have been made in the case the user does not have a mouse with a scrolling wheel or is on laptop. The track bar on the left is a tool to adjust the speed when the user rotates the image. The reset button resets the track bar. Below the reset button is a drop-down list containing the suitcases the user has packed items into.

The reason why it looks like it does is because it gives a good overview with the item list on the right, the 3D-image in the middle, and the image options (zoom in, zoom out, reset etc.) on the left.

In the 3D-image a small box has been made in point(0;0;0) to indicate where it is, so the user easier can navigate through the items.

4.6 The Packing Algorithm

The algorithm used for packing items in this project is based on the known theory of the Bin Packing Problem (see section 3.2). The algorithm is a mix of elements from the "First Fit Decreasing" and the "Best Fit" method. These have been combined to make the algorithm used in this project. The algorithm is inspired by Dube and Kanavathy. The following sections will describe the used code. The code will try to place all the items in the luggage so it is packed most optimally in both size and weight.

4.6.1 Optimization of weight

The optimization of the weight is done, with the target that luggage exceeds the weight limit if it could be distributed differently. Furthermore it would be preferable for the user, that the weight is evenly distributed among the luggage. To optimize the distribution

of the weight, the average weight per luggage is calculated. It is calculated as seen on equation 4.1, where N = Number of items.

$$\text{Average Weight} = \frac{\sum_{i=1}^N I_{weight}}{N} \quad (4.1)$$

It is possible to distribute the weight evenly in the suitcases, when the optimal weight for each suitcase (the average weight calculated by equation 4.1) is known. The program will try to distribute the weight equally, but not if it will mean that the luggage cannot be packed. Therefore the weight distribution is an optimization goal, but not as important as the volume of the luggage. This part of the optimization is a Best Fit, because it finds the best placement in the luggage for an optimal weight distribution.

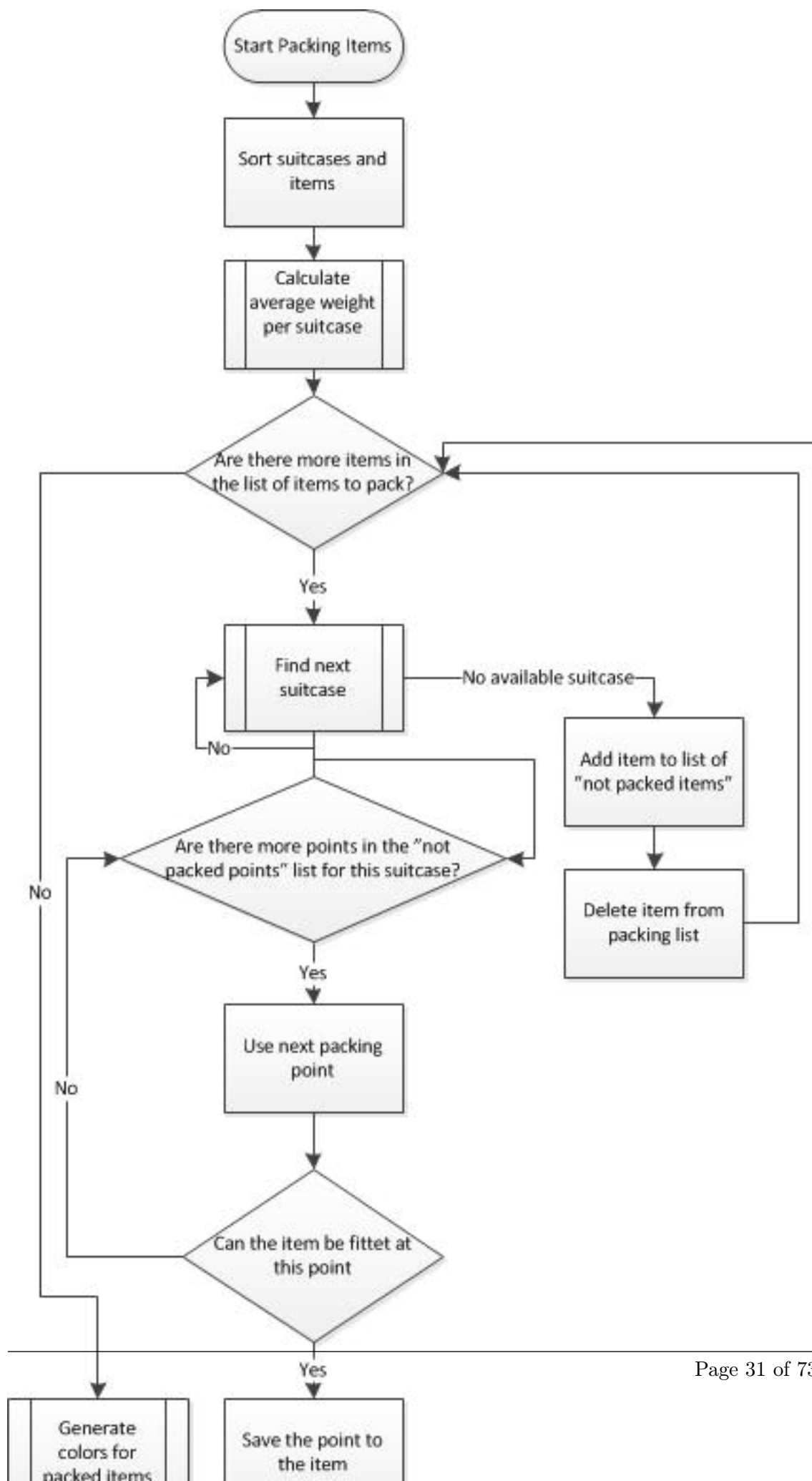
4.6.2 Description of the algorithm

The algorithm uses the First Fit Decreasing (FFD) method to pack the items in the luggage. This means that the algorithm at first sorts the items by size. It will start by packing the largest items first, which will give a better result for the packing. When the list is sorted it will then also sort the list of luggages by size. The algorithm can now go to the actual packing.

The general algorithm is:

- Sort the items by size.
- Check if the item can be in the first luggage, while the luggages total weight does not exceed the average weight per luggage.
- Check if the item can fit in the luggage, else check the next.
- If the item cannot be fitted in any luggage, exclude it from the list, and notify the user.

This is a very general overview of the algorithm, and does not explain the process of the algorithm in good enough detail. To explain the algorithm, a flowchart can be seen on figure 4.14.



As seen on the flowchart, the first process, is to sort the suitcases and items. They are sorted by size, so the biggest items are stored in the biggest suitcases. This will ensure the most effective way of packing, because it will fill the items, which are the hardest to fit, first. The next step for this algorithm is to call the function, which will calculate the average weight per suitcase for an even weight distribution. The algorithm can now start the actual packing of the items. It will run a loop, checking all the items in the list of items to pack. In the function "find next suitcase", the algorithm should find next available suitcase, checking for optimal weight distribution. To pack the item, each suitcase has a list of possible packing points, called "not packed points". This list should contain the points in the suitcase, where the next item can be fitted. This will ensure that the items are packed as effective as possible. The items will always be packed in a corner of another item, so there will be no leftover space between two items. This list of not packed points is individual for each suitcase, and if no item has been packed yet, the point $[0,0,0]$ will be used. If the item cannot be fitted in the suitcase, it will try the next suitcase. In the case that the item cannot be fitted in any suitcase, it will add the item to the list of not packed items, and delete the item from the list of items to pack. This will make it possible to separate the items which are packed and those not packed. If the item could be packed the program will save the point to the item, so the program knows the position of the item further on. The corners of the item will be saved on the "Not packed points" list, and the next item will be packed. When all the points are packed, the algorithm will call the method to generate the colors for the items as seen in section 5.3. The items must have a color, but no item must be the same color as the item next to it, so they will not be mixed for the user. If some items could not be packed, they will be shown to the user, and the form to show the suitcase in 3D will appear as described in section 5.5.

4.6.3 Summing up

This is the theory of the algorithm to pack the items in the suitcase. The algorithm is built from the most basic elements of the packing theories. This algorithm is the base for the packing program in this project, and the mix of First Fit Decreasing and Best Fit will ensure an equal distribution of weight and space and the "not packed points" list is used to make sure that as little space is wasted as possible.

Development 5

In the following section the program will be described. Each function is described in its own part to make it more clear. There are some parts of the program that will not have a description, simply because code description will not be in focus here, but this will merely tell what it does and how it works.

5.1 How the program handles different forms

The program is aimed at families who pack their suitcases together, and are not bothered by having other than their own items in their suitcase.

Because the program has different forms with different functions, it is often necessary to parse variables from one form to another. This is done by creating a new instance of the form, and parsing some inputs to the form. Just like one would create a new object and parse inputs to a constructor. An example is the form that shows the 3D-drawing of the suitcase. This should be automatically opened when the packing algorithm has packed all the items in the suitcases. The exact trigger that opens the new form, is the `frm3D.ShowDialog(this)`; This can be seen on Listing 5.1.

```
1 if (finish_packing)
2 {
3     frm3DViewer frm3D = new frm3DViewer(luggage_items_to_pack ,
4         luggages_to_pack , this);
5     tmrCheckForFinishPacking.Enabled = false;
6     finish_packing = false;
7     frm3D.ShowDialog(this);
8 }
```

Listing 5.1: Open the 3D-viewer when all items are packed. Source: frmMain.cs

It is clear that three variables are parsed; the list of the items that has been packed, the list of the suitcases, and finally the "frmMain" form is also parsed to the "frm3DViewer" form. Naturally the "frm3DViewer" form needs to know the different items and suitcases. The reason why the "frmMain" form is parsed, is that the "frm3DViewer" form resets the progress bar when the "frm3DViewer" is closed.

Let's take a look at how the "frm3DViewer" receives these inputs. The inputs lies as input parameters in the "frm3DViewer" method within "frm3DViewer" as seen on listing 5.2

```
1 public frm3DViewer(List<frmMain.luggage_item> input_lug_items ,  
2     List<frmMain.luggage> input_lugs , frmMain input_form_main)  
3 {
```

Listing 5.2: The input parameters of "frm3DViewer". Source: frm3DViewer.cs

5.2 The Development of The Packing Algorithm

The algorithm was developed from the theory described in section 4.6. The theory has been extended from the experiences when packing the program. These extensions have made the packing more effective, which results in more items being packed. To understand the different methods, the algorithm as described in section 4.6 must be extended a bit. The extension will be described in this section, with a roundup at the end. To describe the code, this section will be divided in different subsections to understand the different parts of the code.

5.2.1 Classes

To handle the information and functions needed to handle suitcases and items to pack, the classes `luggage` and `luggage_item` have been made. They do both inherit from the class `Cube_Shape`, with the variables `width`, `depth`, `height` and `name`. The `Cube_Shape` class provides the information of a cube, which both suitcases and items can be seen as.

The Class "luggage"

The class diagram of the `luggage` class can be seen on Figure 5.1. There are a lot of private fields (starting with "_") which can be accessed through properties. It contains all the values needed: the maximum weight, the weight of the suitcase etc. It also contains a set of methods which is used through the packing process. The properties which should only be accessed in the methods in the class has a private setter, so functions outside the class can only get the value, and not change the properties by a mistake. An example of this is the property "weight", which indicates the total weight of the items in the suitcase and the suitcase' weight. This value should only be set by the class it self in the methods placing an item.

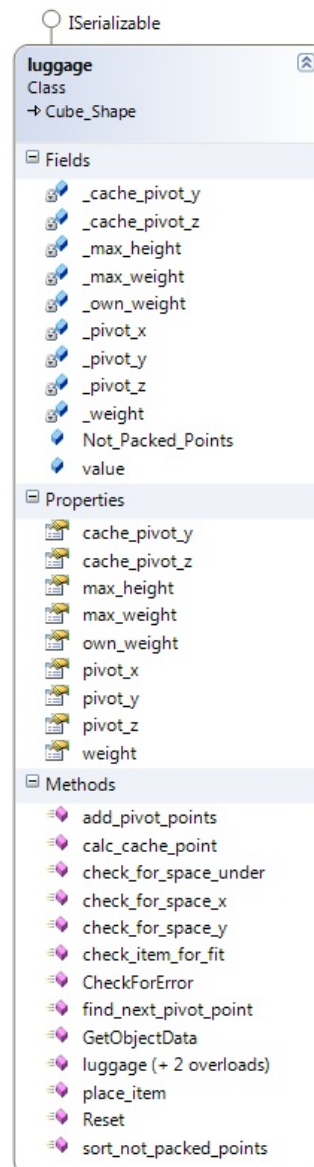


Figure 5.1: The class diagram of the luggage class

As seen on Figure 5.1 there are a set of methods in the class "luggage". These methods provide the necessary functions to handle the suitcase while packing.

The class "luggage_item"

The class luggage_item is for the items to pack in the luggage. The class diagram can be seen on Figure 5.2. As in the luggage class, this class has some variables, which can only be accessed through properties. Those properties, which should only be set inside the class have a private setter. There are also a private method "Rotate_Lug_Item", which should only be called inside the class.

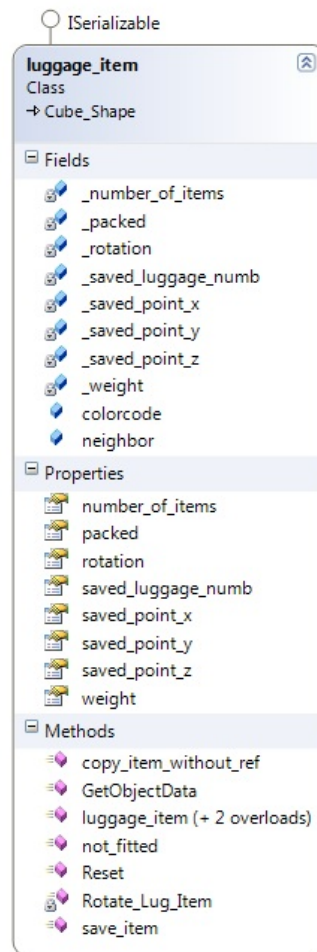


Figure 5.2: The class diagram of the luggage_item class

Using the Classes

The luggage class and the luggage_item class is used in the program with a list. These lists of the classes is made by the initialization of the program as seen on Listing 5.3, and is passed through to the other form. These lists contains the information of every suitcase, item and the result of the packing.

```

1 public List<luggage_item> luggage_items_to_pack = new List<luggage_item>();
2
3 public List<luggage> luggages_to_pack = new List<luggage>();

```

Listing 5.3: The initialization of the list containing the suitcases and luggages. (From the Main form)

5.2.2 Description of the Code

The algorithm to pack has been developed from the flowchart seen on figure 4.14. The following will describe the code and the extensions of the flowchart.

Reset and Sorting

As seen on the figure, the first thing which is done is to sort the suitcases and the items. Before sorting the lists of suitcases and luggages, it resets the values which were changed

when packing. This is to ensure the algorithm has the right values when running it twice. The reset methods for the items and the suitcases are in their respective classes as seen on Figure 5.1 and Figure 5.2. A loop will call the reset methods in all suitcases and items in the lists. This is for example to reset the values of where there are saved items in the luggage. The items and luggage is also rotated so the luggage has the longest side as width as seen on Listing 5.4. This is done, so the algorithm packs as optimal as possible. The items is likewise rotated, so the height is the smallest side. This will ensure that the algorithm will try to pack items lying, and not upright.

```

1 //Rotate so width is the longest side
2 int temp;
3 if (depth > width)
4 {
5     temp = depth;
6     depth = width;
7     width = temp;
8 }
9
10 if (height > depth)
11 {
12     temp = height;
13     height = depth;
14     depth = temp;
15 }
16
17 if (depth > width)
18 {
19     temp = depth;
20     depth = width;
21     width = temp;
22 }

```

Listing 5.4: The code to rotate the luggage until the longest side is the width. The rotation is made by switching the values of 2 sides. (From the luggage class in the Main form.)

The method to sort the luggages and items will sort them by size, so the largest items will be attempted to be packed first in the biggest suitcases. This will give a better packing, because the smallest items are easier to fit than the big items.

Weight Distribution

The average distribution of weight in the luggage is calculated before going in the loop of the packing algorithm. In the flowchart on Figure 4.14 it will "Find next suitcase" when packing an item. This is not as simple as shown in the algorithm. The next suitcase is found by not only size, but also weight. It will start with the largest luggage and see if the weight of the suitcase, its content and the item to pack will exceed the average weight per luggage. If it does it will try to use the next luggage. If the item cannot be fitted in any luggage using the average weight, it will try again with only the maximum weight of the luggage in mind, so an item can be packed even though it exceeds the average weight per suitcase. The code of this can be seen on Listing 5.5, where the `stop_check_for_avg_weight` variable checks if there should still be check for average weight. The `lug_id` variable is the index in the luggages list of the suitcase which is checked now. The `lug_items_counter` is the index of the item to pack. This loop will continue until the item is packed, or every possibility has been tried.

```

1 if (stop_check_for_avg_weight == true || (luggages_to_pack[lug_id].weight +
    luggage_items_to_pack[lug_items_counter].weight <= weight_per_luggage))

```

```

2 {
3     if (luggages_to_pack[lug_id].weight +
        luggage_items_to_pack[lug_items_counter].weight <
        luggages_to_pack[lug_id].max_weight)
4     {

```

Listing 5.5: The statements checking if the item can be fitted in this luggage by weight. (From the method `pack_items` in the Main form)

Checking For Fit in Pivot Points

If the item could be packed in a suitcase by weight, the algorithm will try to fit the items by weight. The next point is calculated by a sorted list of packing points. The list is sorted so the item is packed at the lowest points first. This is done in the `find_next_pivot_point` function in the luggage class. If the item placed in the given pivot point without exceeding the dimensions of the suitcase it will call the method in "check_item_for_fit" in the luggage class. This method will run through all the effected point and check if there are placed any items in the points. This method can be seen on Listing 5.6, where the function will check every point in the array value. This value is an indicator of how many elements which is placed in the point (the value should of course never be higher than one).

```

1 bool check_for_fit = true;
2 for (int count_z = pivot_test_point.z; count_z < pivot_test_point.z +
    test_item.height; count_z++)
3 {
4     for (int count_y = pivot_test_point.y; count_y < pivot_test_point.y +
        test_item.depth; count_y++)
5     {
6         for (int count_x = pivot_test_point.x; count_x < pivot_test_point.x
            + test_item.width; count_x++)
7         {
8             if (value[count_x, count_y, count_z] != 0)
9             {
10                 check_for_fit = false;
11             }
12         }
13     }
14 }
15 return check_for_fit;

```

Listing 5.6: The method to check if the item can be placed at the `pivot_test_point` (from the luggage class in the Main form)

If the item cannot be fitted in the point in the luggage, the item will be rotated and tried fitted again. If every rotation possibilities has been tried, it will use the next packing point - or if there are no more packing points, the next suitcase.

Placing the item

If the item could not be packed in any suitcase, it will be added to a list of not packed items, which will be printed to the user later on. It will then be removed from the packing list, and the next item will be packed. If the item could be packed, it will try to move it lower in the suitcase until it meets another item in the `check_for_space_z` in the luggage class. This will ensure an optimal packing. The item will then be packed in the suitcase by adding 1 to the value in every point the item will fill out in the suitcase, using the `place_item` method in the luggage class. The packing points is saved to the item, so it

have the information of, where it is saved. This is done by the function `save_item` from the `luggage_item` class. The corners of the item is added to the list of packing points, and the list is sorted. The item is now saved and the next item can be packed.

When Every Item is Packed

When all items have been packed (or placed in the list of not packed items), the next step in the algorithm is to generate the colors each item should be displayed with in the 3D Viewer. This code can be seen in section 5.4. The algorithm will at the end check if there has been a mistake during packing, so one of the values in the luggage has exceeded 1. If it has, it will throw an exception. It will then check, if some of the items could not be packed. This will show an error message to the user, with the information of which elements which could not be packed as seen on Listing 5.7.

```
1 if (Not_Packed_Items.Count > 0)
2 {
3     string error_message;
4
5     error_message = "All your items could not be packed. This could be
        because of lack of space or too heavy items. The rest of the items,
        has been packed. The items are:\r\n";
6
7     foreach (luggage_item not_packed_item in Not_Packed_Items)
8     {
9         error_message += not_packed_item.name + "\r\n";
10    }
11
12    MessageBox.Show(error_message, "Fatal error", MessageBoxButtons.OK,
        MessageBoxIcon.Error);
13 }
```

Listing 5.7: The code will return an error message to the user if some items could not be packed (from the method `check_error_after_packing` in the form `Main`)

5.2.3 Summing up

The algorithm checks for a lot of different criteria, also a few more than described here. This will ensure a optimal packing of the items, so the highest possible number of item can be fitted in the luggage. Therefore the algorithm has been extended since the first design in section 4.6. The extended, but still a bit simplified, flowchart can be seen on Figure 5.3.

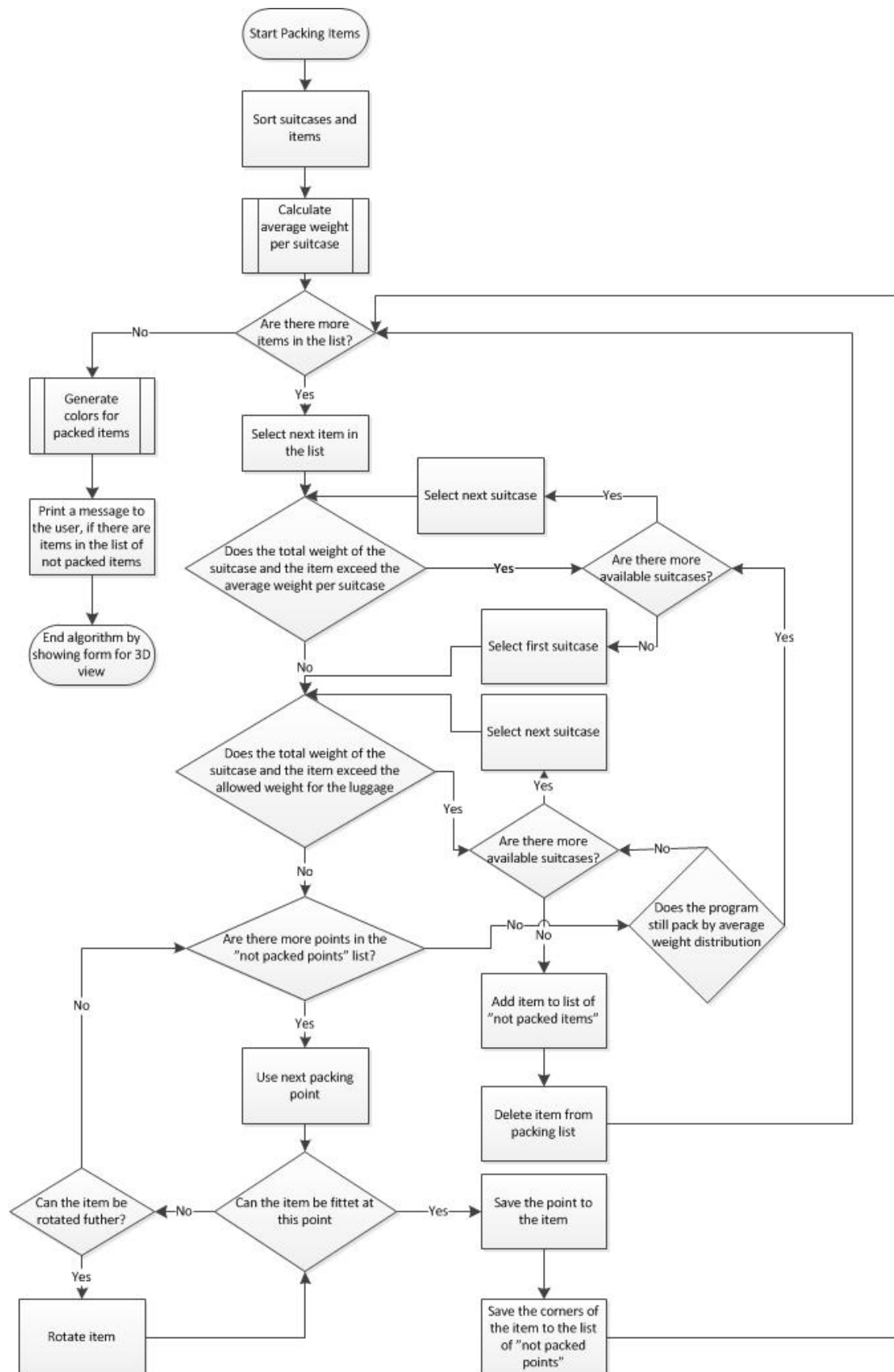


Figure 5.3: The flowchart for the packing algorithm

5.3 Color Assignment Function

This function gives each item a color and ensures that items that lie next to each other do not get the same color. The function has four steps to complete before its task is finished.

The first step is to add curtain coordinates of each item into a list. This is done for all items that are to be packed. First, a "for" loop runs through the items that are to be packed. Inside the first "for" loop there are three "for" loops that run through the x, y and z coordinates starting at the saved coordinate for the current item. The loops then runs until the limits are reached for the three "for" loops which are the height, width and length. These loops can be seen listing 5.8. At the end of the three "for" loop there are an "if" statement which controls that it is only coordinates(x, y, and z) on the outside of an item that are added. The "if" statement works by checking if one of the coordinates (x, y or z) is either at the respective start point(saved point x, y, or z) or at the maximum limit (height, weight or length) and then only allow coordinates where this is fulfilled and thereby achieve coordinates on the outside of the item. When the "if" statement is fulfilled, the three integers x, y and z are added to their representative lists that are stored in a temporary variable of type cbox. Cbox is a class that has 3 lists in it. These three lists outline the sides of their respective object. The temporary variable are then stored in the "BoxColor" list which is the final list.

```

1 for (i = 0; i <= Number; i++)
2 {
3     tmp_list = new cbox();
4     /*Loops that goes through the 3 koordinates*/
5     for (x = (luggage_items_to_pack[i].saved_point_x - marking); x <=
        (luggage_items_to_pack[i].saved_point_x +
        luggage_items_to_pack[i].width + marking); x++)
6     {
7         for (y = (luggage_items_to_pack[i].saved_point_y - marking); y <=
            (luggage_items_to_pack[i].saved_point_y +
            luggage_items_to_pack[i].depth + marking); y++)
8         {
9             for (z = (luggage_items_to_pack[i].saved_point_z - marking); z
                <= (luggage_items_to_pack[i].saved_point_z +
                luggage_items_to_pack[i].height + marking); z++)
10            {

```

Listing 5.8: The four "for" loops which controls the item and the (x; y; z) value that make the point for the items. The slice of code is taken from the function Colors in frmMain

The second step is to check which items are neighbors through two "for" loops. Thereby determining if they are located next to each other. If they are, the item number will be saved in a list that is called "neighbor". This step works by four "for" loops where the first loop keeps track of the current item that is being checked for neighbors. The second loop keeps track of the item that is being checked, and if it is a neighbor to the first one. The last two loops work with the points that are in the item's lists. But it will only run these loops if the items are in the same suitcase (Which can be seen by the "if" statement that are between the first two and the last two "for" loops). If they are next to each other it will save the item's number into a list in the other item. This is done for the other item as well. The 2 loops and setting of an item's neighbor can be seen on listing 5.9.

```

1 for (k = 0; k <= BoxColor[i].box_x.Count - 1; k++)
2 {
3     for (q = 0; q <= BoxColor[j].box_x.Count - 1; q++)
4     {

```

```

5      /*If statement that controls that there are any points that are the
6         same in the Lists.
7         This is done by comparing the 3 koordinates to each other*/
8      if (BoxColor[i].box_x[k] == BoxColor[j].box_x[q] &&
9          BoxColor[i].box_y[k] == BoxColor[j].box_y[q] &&
10         BoxColor[i].box_z[k] == BoxColor[j].box_z[q])
11      {
12          /*Only when the if statement is fulfilled the item is added to
13             the neighbor List*/
14          luggage_items_to_pack[i].neighbor.Add(j);
15          luggage_items_to_pack[j].neighbor.Add(i);

```

Listing 5.9: The 2 "for" loops and the "if" statement that check if the two items shares any point. The slice of code is taken from the function Colors in frmMain

Thereafter the list "neighbor" is gone through to remove all the duplicates of themselves from the list. This works with one "for" loop that keeps track of which items are being worked with and when the loop is done the neighbor list is sorted. Then there is a "while" loop that goes through all the neighbors (items that are next to it) and check if the item itself is in it and remove it. It will also check if the number after the current is the same, if it is the same it will remove one of them. This can be seen in listing 5.10.

```

1  if (!(count - k == 0))
2  {
3      /*If statement that compaired the curret neighbor with the neighbor
4         after ,
5         if they are identical the curret neighbor is removed*/
6      if (luggage_items_to_pack[i].neighbor[k] ==
7          luggage_items_to_pack[i].neighbor[k + 1])
8      {
9          luggage_items_to_pack[i].neighbor.RemoveAt(k);
10         k = 0;
11         count--;
12     }
13     else
14         k++;

```

Listing 5.10: "If" statements that check the item after the current item to see if they are identical. If they are remove one of them. This slice of code is taken from the function Colors in frmMain

The last step taken is to go through the item list and give a color to each item. In this part the colors are numbers, where number 0 is the standard color. First there is a "for" loop that sets the current item. Before the current item is given a number based on its neighbors, its value is set to 0. Then there is a "while" loop that goes through all the item's neighbors and check if the color is the same. If they are the same, then the item's color number is increased by 1. This can be seen in listing 5.11. When the neighbor list is finished, the color is saved in the item, the color number is set to 0 again, and the next item in the list is checked.

```

1  if (Bcolor > ColorCode.Count() - 1)
2  {
3      j = luggage_items_to_pack[i].neighbor.Count() + 1;
4      Bcolor = 0;
5  }
6  else
7  {

```

```

8      /*Here the neighborcolor is compaired to the color on the Bcolor index
9         in Colorcode.
10         If they are the same the Bcolor is counted up 1 and j set to 0 to
11            reset the while loop, else j is counted up by 1*/
12     if (ColorCode[Bcolor] == neighborcolor)
13     {
14         Bcolor++;
15         j = 0;
16     }
17     else
18     {
19         j++;
20     }
21 }

```

Listing 5.11: "If" statement that checks if an item and neighbor have the same color. The slice of code is taken from the function Colors in frmMain

5.4 How the Program Handles 3D

The 3D in this program is handled by objects called Shape3D. A Shape3D object contains an array of Polygon objects. A Polygon object contains an array of Vector objects and a Pen. A Vector object contains three integers: x, y and z, which are the coordinates of the Vector.

Instead of programming the whole 3D part ourselves, an existing solution was found and developed further. The original solution [Keselman, 2002] was only a demonstration on how to draw a cube, an axis and a more advanced polygon using C#. This solution was further developed to support drawing cubes of different sizes. Along the development, unnecessary features like drawing an axis was removed. The interface of the 3D was also improved, so that no GUI elements were created directly in the code that handled the 3D.

5.4.1 Shape3D Class

A Shape3D object contains four methods: Draw, Rotate, ScaleSize and RePaint.

The Draw method is really just a "foreach" loop which calls the Draw method in the Polygon object on all Polygon objects within the Shape3D. The Draw method in the Polygon object will be explained in .

The Rotate method in the Shape3D object is used to rotate the object. The method takes one input parameter, which is a RotateMatrix called "mat". Next the method creates a new Polygon array newP, and runs through all Polygon objects in the Shape3D. The method then calls the Rotate method within the Polygon object on the current polygon, and inserts the results into the Polygon array newP. The method also inserts the current Polygons Pen into the newP Polygons Pen. The function can be seen on Listing 5.12.

```

1 public Shape3D Rotate(RotateMatrix mat)
2 {
3     int count=0;
4     Polygon[] newP = new Polygon[poly.Length];
5
6     foreach (Polygon p in poly)
7     {
8         newP[count++] = p.Rotate(mat);
9     }
10 }

```

FixMe Fatal: in
ref

```
9         newP[count - 1].MyPen = p.MyPen;
10     }
11     return new Shape3D(newP);
12 }
```

Listing 5.12: Function in Shape3D

The ScaleSize method in the Shape3D object is almost the same as the Rotate method in Shape3D. The only difference is that instead of calling the Rotate method in the Polygon object, the ScaleSize method calls the ScaleSize method in the Polygon object.

The RePaint method in the Shape3D object is used to mark one item in the suitcase(one polygon), with a thicker line than the others. In the program this is used when the user clicks on an item in the list of items to the right of the drawing of the suitcase. If the user clicks on an item in the list, the program will mark that item with thicker lines. This function is also used when the 3D viewer is opened - a small cube with dimensions 0.5 x 0.5 x 0.5 is drawn in the suitcase's 0,0,0 point, so the user knows where the 0,0,0 point is. This cube is also marked with a thicker width than the items.

The method takes two integers as input parameters: "num" and "col_w". The "num" input is the item that has been selected, and the "col_w" is how wide the line must be. The method initiates a new Polygon array, newP, where all the polygons will be stored. The method also contains three counters. One that counts the elements in the polygon, this counter is called "element_counter". Here an element consists of four sides. Another counter called "counts" is counted up when a polygon is made thicker, this counter is called "counter". The last counter is counted up whether or not a polygon is made thicker. This counter is called "count" which keeps track of the Polygon array newP.

First the method checks if the color of the current polygon is red. This only happens if the current polygon is the cube representing the 0,0,0 point. If the color is red, the width of the polygon is set to 2, and the counter "counter" is counted up. The method now checks whether or not "counter" is 4. This occurs if all four sides of a polygon is made thick. If this is the case, the counter "counter" is set to 0, and the element counter is counted up, implying that the method now should check the next element in the Shape3D object. This can be seen on Listing 5.13.

```
1 if (p.MyPen.Color == Color.Red)
2 {
3     newP[count] = p;
4     newP[count].MyPen.Width = 2;
5     counter++;
6
7     if (counter == 4)
8     {
9         counter = 0;
10        element_counter++;
11    }
```

Listing 5.13: Function that makes an item thicker

At the end the method returns a new Shape3D object, newP, which replaces the old Shape3D, and is drawn.

5.4.2 Polygon Class

The Polygon class contains five methods: Draw, X2D, Y2D, Rotate and ScaleSize. The essential method in this class is the Draw method. This is the method that actually draws the suitcase and items on the form. The Draw method takes two input parameters; a Graphics object "g", and a Pen "MyPen". The Pen is where the color and width of the lines are stored. Before explaining how the Draw method actually works, a closer look will be taken at where it is first called.

Every time the method 'Invalidate' is called, the Draw method in the current Shape3D object is also called. The 'Invalidate' method is called every time the program needs to refresh the drawing of the suitcase and items. For example when the user changes suitcase in the drop down element, the program needs to redraw the image, so that the items in the new suitcase are drawn instead.

In the frm3DViewer, the Draw method is called inside the method MyPaint, which takes two input parameters: an 'object' "sender", and an 'PaintEventArgs' "e". The method then calls the Draw method in the Shape3D, with the parameter e.Graphics. The Draw method in Shape3D receives the 'Graphics' "g". The method then runs through each Polygon in the Shape3D and calls a Draw method in the Polygon class on each of the Polygons. It is now clear that the Draw method is called on each Polygon in a Shape3D.

The Draw method in the Polygon class begins with a "for" loop which runs through the length of the Polygon. The length of a Polygon is defined by the combined length of the Vectors within the Polygon. Inside the "for" loop, two lines are drawn with the built in method DrawLine in the Graphics class. The DrawLine method takes three input parameters, a Pen, and two points. But the Polygons do not contain any points. Therefore the Vector must be converted to points before it is drawn. The Draw method in the Polygon class can be seen on listing 5.14.

```
1 public virtual void Draw(Graphics g, Pen MyPen)
2 {
3     for (int count=0;count<Len-1;count++)
4
5         g.DrawLine(MyPen,
6                     X2D(vectors[count]),Y2D(vectors[count]),
7                     X2D(vectors[count+1]),Y2D(vectors[count+1]));
8
9         g.DrawLine(MyPen,
10                    X2D(vectors[Len-1]),Y2D(vectors[Len-1]),
11                    X2D(vectors[0]),Y2D(vectors[0]));
12
13 }
```

Listing 5.14: Draw function in the Polygon Class

The Rotate method in the Polygon class basically receives a matrix, which contains how the Polygon should be rotated. The method then run through each vector in the Polygon calling the Rotate method in the Vector class on each Vector with the rotate matrix as input. When this is done a new Polygon is returned. This is the rotated Polygon.

The ScaleSize method in the Polygon class is used to scale the polygon with a factor. This is used to zoom the drawing in and out. The method receives a float as input, runs through every Vector in the Polygon and calls the ScaleSize within the Vector class on every Vector, parsing the float as parameter. When this is done a new Polygon is returned.

This is the scaled Polygon. The ScaleSize method in the Polygon class can be seen on Listing 5.15.

```
1 public Polygon ScaleSize(float d)
2 {
3     int count=0;
4     Vector[] retVec=new Vector[Len];
5     foreach (Vector vec in vectors)
6         retVec[count++]=vec.ScaleSize(d);
7     return new Polygon(ZVal,Zero,retVec);
8 }
```

Listing 5.15: ScaleSize function in the Polygon Class

5.5 Function to draw cubes

The function called "DrawSomething" is the function which basically converts dimensions and coordinates into the vectors that are to be drawn. "DrawSomething" takes 11 input parameters. Simply put, these inputs are the dimensions and coordinates of the cube to be drawn represented as floats. Next the function takes 3 integers which are: The number of the suitcase, the item to be drawn lies in, the factor of zoom that should be applied to the item, and the index of the array of polygons that has currently been reached. Lastly, the function takes a Vector and a Pen as input.

The "Pen" represents the color and width of the cube to be drawn. For example the function could draw a red cube with 5 pixel lines. The Vector is essentially a dummy-vector, because the polygon class requires a vector in its constructor, but the Vector is set to zero in the class.

In the beginning of the function some variables are defined. These are the start location of the drawing. Four Vector arrays are created each holding 4 Vectors, which together form a square.

Three floats are defined, they will contain half of each of the dimensions of the item. The current items y and z coordinate is inverted, because of the way the Vectors will be calculated later.

The function contains a conditional expression which checks which type of cube the function should generate. This is because the function can be used to generate a suitcase, the items in the suitcase, and a small cube(which represents the 0,0,0 point of the suitcase).

The expressions checks on the lug_num variable which is really the number of the suitcase the item lies in. But if the lug_num is set to -1, it means that the function should draw a suitcase instead of an item. And because the drawing should rotate around itself, it has to take the coordinates of each item and subtract half of the suitcase dimension. This in turn makes sure that the 0,0,0 point of the coordinates systems will be placed in the middle of the suitcase, allowing the user to rotate the suitcase around itself, but the small cube is still placed in the suitcase's 0,0,0 point.

So if the function has to draw a suitcase, it sets the suitcase dimensions to the half of the dimensions received as input.

If the function is to draw an item in the suitcase, the function will find the item's dimensions and half of the suitcase's dimensions, and use these to manipulate the start

point of the current item. This is to place the item correctly inside the suitcase in the drawing, while allowing the user to rotate the suitcase around itself.

If the function receives -2 as the `lug_num`, it means that it should draw a small cube with dimensions 0.5 x 0.5 x 0.5 at the suitcase's 0,0,0 point.

After the conditional expression, the dimensions of the input item is subtracted by 0.01. This is so no item touch another item, allowing the user to identify each item easily.

The next part of the function is where the Vectors are calculated and put together into a Polygon and inserted into the array of Polygons. Only the part where the first Polygon is calculated will be explained, because the three next is essentially the same, but with the vectors pointing in other directions, forming the other side of the cube which will be drawn.

A Vector contains three points, x, y and z. It is these points that now will be calculated. Earlier four Vector arrays were created: `points1`, `points2`, `points3`, and `points4`. Each of these Vector arrays contains four vectors to form 1 side of the cube to be drawn.

Keep in mind that the y and z coordinates of the item to be drawn was inverted earlier.

To calculate the x-point of the first vector of the first side, the function takes the x-coordinate and subtracts half of the suitcase's width. This is again because the 0,0,0 point of the drawing must be in the middle of the suitcase. The y and z point of the first vector is essentially the same, but adding half of the width and depth of the suitcase.

For example if the program has a suitcase with the dimensions 50x100x80 (height x width x depth), an item with the dimensions 40x70x30 that resides in point 0,0,0 of the suitcase, the first x-point of the item would lie in point -50 ($0 - (100/2)$).

The y-point of the first vector is calculated by adding half of the depth of the suitcase in this case 25 ($0 + (80/2)$). And the z-coordinate of the first vector in the example item would then lie in point 40 ($0 + (70/2)$).

When the points has been loaded into the new Vector, the vector is scaled by a factor of "zoom_factor". This also happens when zooming in and out, but of course with different values. See to see how the function "ScaleSize" works.

FiXme Fatal:
ScaleSizefunction

These calculations are shown on Listing 5.16

```
1 points1[0] = new Vector(item_point_x - lug_half_width, item_point_z +
    lug_half_height, item_point_y + lug_half_depth).ScaleSize(zoom_factor);
```

Listing 5.16: Calculate the points of the first vector

From the calculations above the first Vectors coordinates are as follows (-50, 25, 40), and can be seen on Figure 5.4.

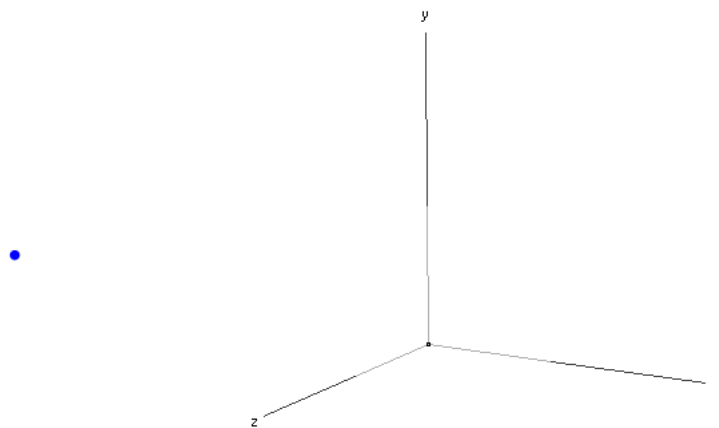


Figure 5.4: First point of the first side of the example item

Naturally the second vector of the side needs to have at least one point in common with the first vector. Else the side would not be a complete square. The common point of the first and the second Vector is the x point. The y coordinate of the second Vector is calculated by subtracting the item depth from the item's y-coordinate and then adding half of the suitcase height. With the example item, this gives an y-coordinate of the second vector of -15 ($-0 - 40 + (50/2)$).

The z-coordinate of the second Vector is calculated by adding the y-coordinate of the item to half of the suitcase depth. This gives a z-point of the second vector of 40 ($-0 + (80/2)$). The calculations can be seen on Listing 5.17.

```
1 points1[1] = new Vector(item_point_x - lug_half_width, item_point_z -  
    item_height_float + lug_half_height, item_point_y +  
    lug_half_depth).ScaleSize(zoom_factor);
```

Listing 5.17: Calculate the points of the second vector

The second Vector thereby becomes (-50, -15, 40), and can be seen on Figure 5.5.

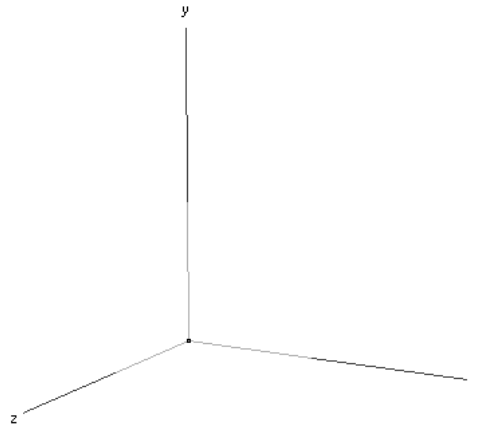


Figure 5.5: First point of the first side of the example item

Now for calculating the third Vector. The third Vector has both the y- and z- coordinates in common with the second Vector. These are thereby accordingly -15 and 40.

To calculate the x-coordinate, the x-point of the item is added to the width of the item, while the half of the width of the suitcase is subtracted from this. To continue the example, the x-coordinate of the third Vector would thereby become: 20 ($0 + 70 - (100/2)$). The calculations can be seen on Listing 5.18.

```
1 points1[2] = new Vector(item_point_x + item_width_float - lug_half_width,
    item_point_z - item_height_float + lug_half_height, item_point_y +
    lug_half_depth).ScaleSize(zoom_factor);
```

Listing 5.18: Calculate the points of the third vector

The third Vector thereby becomes (20, -15, 40), and can be seen on Figure 5.6.

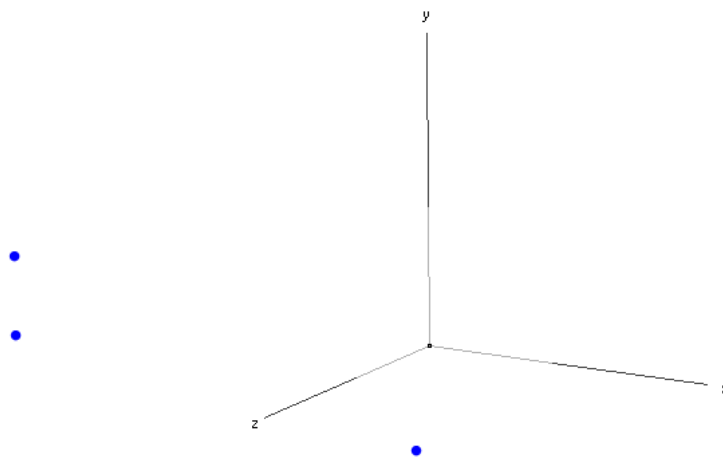


Figure 5.6: First point of the first side of the example item

The fourth Vector has both the x- and z-coordinate in common with the third Vector, while having the y-coordinate in common with the first Vector. The calculations can be seen on Listing 5.19.

```
1 points1[3] = new Vector(item_point_x + item_width_float - lug_half_width,
    item_point_z + lug_half_height, item_point_y +
    lug_half_depth).ScaleSize(zoom_factor);
```

Listing 5.19: Calculate the points of the fourth vector

The fourth Vector thereby becomes (20, 25, 50), and can be seen on Figure 5.7.

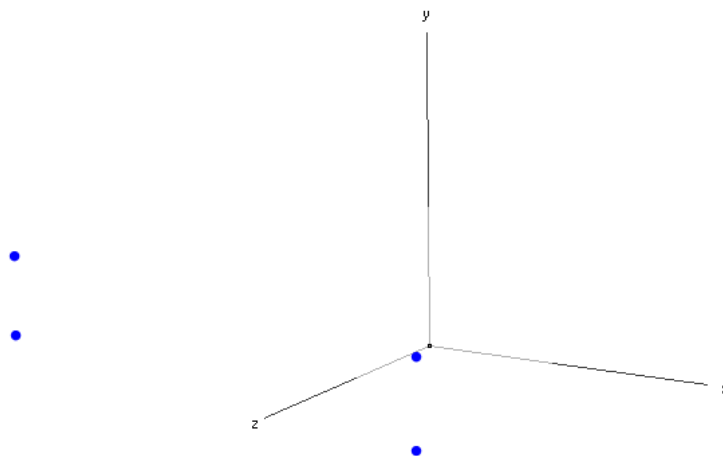


Figure 5.7: First point of the first side of the example item

By drawing a line between these four points, it is clear that these forms a square, that is the first side of the item in the example. This can be seen on Figure 5.8

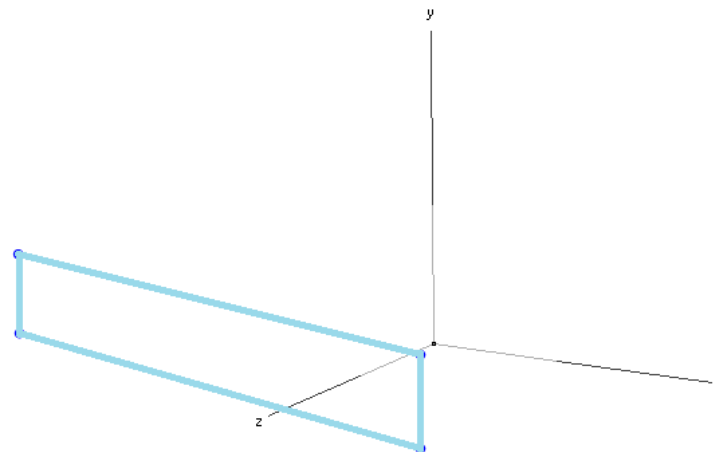


Figure 5.8: How the first side of the example item looks

When the four Vectors has been calculated, the Vectors are inserted into a new Polygon, which is inserted into an array of polygons. Next the current Polygon (the one just created), is assigned a Pen. The Pen contains the color and the width of the Polygon. This can be seen on Listing 5.20

```
1 poly_array[poly_counter] = new Polygon(1000, z, points1);  
2 poly_array[poly_counter].MyPen = new Pen(itempen.Color, itempen.Width);  
3 poly_counter++;
```

Listing 5.20: Calculate the points of the fourth vector

This was the first side of the item, it is basically the the same for the rest of the sides.

5.6 Rotate 3D-view with the mouse

To make it easier for the user to see exactly where and how the various items are packed within the suitcase, it is necessary with some kind of rotate function. As described in section 5.5, the point which the suitcase rotates around is residing within the suitcase, so that the suitcase is able to rotate around itself. When the user moves the mouse over the drawing, an event is triggered. The event triggers the function called "MouseMove", which receives two input parameters, an 'object' "sender" and a 'EventArgs' "e". The "EventArgs" contains all the information regarding the mouse which is needed to perform certain checks. The "MouseMove" function is called whenever the user moves the mouse on the form. But the function should only do something when one of the mouse button is clicked while the mouse is moved. Therefore the "MouseMove" contains two conditional statements. The first condition checks if the left mouse button is currently pressed, and the other condition checks if the right mouse button is currently pressed.

If the left mouse button is pressed, the function first defines some variables that are used later. The icon of the cursor is also changes to be the "hand" icon, representing that the drawing is rotating. Next the function gets the current x- and y-coordinates of the mouse. The coordinates of the mouse when the click occurred is now subtracted from

the current mouse coordinates. The result is how much the drawing should be rotated. But if the result is just passed as how much the drawing should rotate, it would be uncontrollable, therefore it is divided by 15, and then by a variable called "rotatesensitive". The "rotatesensitive" contains the current value of the scrollbar on the form, where the user can set the sensitive of the rotate. Next the result is passed as a new "XRotate" for the x-coordinates and a new "YRotate" for the y-coordinate. This can be seen on Listing 5.21

```
1 //Divide by rotatesensitive and 15 so that the rotating is controllable
2 rotx = rotx / (rotatesensitive * 15);
3 roty = roty / (rotatesensitive * 15);
4
5 Xmat = new XRotate(rotx);
6 Ymat = new YRotate(roty);
```

Listing 5.21: The function that handles the rotating with the mouse

This is what actually creates the rotation the next time the drawing is invalidated (refreshed) which is what happens next. Just before the "invalidate" is called, the coordinates from when the mouse was first clicked, is set to be the current mouse coordinates. This creates an even rotation, else the drawing would rotate faster and faster the farther the user moved the mouse from where it was first clicked.

5.7 File Serialize function

When the user shuts down the program, it should save the lists of the items and suitcases and open them next time the program is opened. There are many different ways for saving data. It can e.g. be saved in a raw binary file, a text file or a database like SQL. The SQL databases either needs a program that can handle SQL or an Internet connection to a server, and is therefore not used in this project. A text file is an more complex way of saving data because the program will need methods both for writing and reading the text file. The binary raw file is therefore used in the project because it is smarter than SQL and the text file.

To save the data in the program a function called File Serialize is used. The function is called when the data from the program should be saved or loaded. The function lies in the file "FileSerializer.cs", which is taken from the website "www.codeproject.com" from the "how to" "Custom Serialization Example" section. The next part of the function, is where the list of items and the luggages are loaded in the main part.

```
1 info.AddValue("weight", this.weight);
2 info.AddValue("width", this.width);
3 info.AddValue("height", this.height);
4 info.AddValue("depth", this.depth);
5 info.AddValue("name", this.name);
6 info.AddValue("number", this.number_of_items);
```

Listing 5.22: Informs that there is saved to a file. Code can be found in frmmain in the luggage_item class

On listing 5.22 it can be seen that the "File Serializer" needs some data descriptions to turn the information from the item list into a data file. This is done by stating a kind of sentence, where the first part is the name of the certain information, which needs to be saved into the file.

```
1 this.weight = info.GetInt32 ("weight");
2 this.width  = info.GetInt32 ("width");
3 this.height = info.GetInt32 ("height");
4 this.depth  = info.GetInt32 ("depth");
5 this.name   = info.GetString ("name");
6 this.number_of_items = info.GetInt32("number");
```

Listing 5.23: Informs the user that data is loaded from a previously saved file. Code can be found in frmmain in the luggage_item class

For it to open the data file the program also needs to have data description on how the data is saved in the file, see listing 5.23. The program gets the information from the file, where the name of the certain information is, and puts it into the class list for each of the information that is saved.

5.8 Instruction manual

The instruction manual is placed in the main window and is made as a help for the user. It is made as short as possible since experiences from earlier projects show that users tend to skip parts of instructions if they are too long. The instruction manual tells the user how to use the program and how it works. The instruction manual is made on basis of how it is intended to be used.

The manual is placed in the main menu because then it is the first thing the user sees, when he or she opens the program. It is also made with bullet points to keep an overview of it, and to make it easier to read.

Testing 6

This section will describe the tests, the finding from the tests and the improvement on the program that came from the finding of the tests. To help ensure the program do not have any obvious bugs, test were performed on the program which can be used to help find those bugs. Therefore it is better that a person that is not a part of the project group is going to be the one testing. If it is a person from the group who is testing, he or she might not find a bug or problem with the program, because he/she is already used to the program.

6.1 Choice of Survey Method

To test the person and see how a customer would react to the program. Tests were made where the test persons tried the program and they got interviewed afterwards. For the analysis and further work regarding the test results, a qualitative method has been chosen.

For the interview there has been made a questionnaire (which can be seen on Appendix C), that will be used as a guideline in the interview to get useful information from the test person. The qualitative method is the best suited method for the project, because it gives a more specific picture of how the test person finds the program, and what problems the test person might come across during the test. It is also a good method to get suggestions to improvements from the user since it is normally easier to explain an idea while talking rather than writing. The problem with the interview is that the time it takes to analyze is longer than a questionnaire, where you quickly can analyze a lot of data. The questions at the interview need to be well thought and precise to get useful information from the test person, as they would also need to be on a questionnaire. Based on the test, improvements should be made to the program. It is important when making a questionnaire that it is structured correctly and that the questions are precisely formulated so the test person cannot misunderstand the meaning of the question. It is important because poorly formulated questions might lead to misunderstanding the meaning of the question which can lead to wrong or useless answers. And in such case is a questionnaire just a waste of time.

So there will be made an interview based on a questionnaire after the test person has tested the program with focus on what can be improved on the program.

6.2 The First Round of Tests

Two tests of the program have been made on two test persons in the first round of tests. The main idea was to see if the program had any bugs and to get some suggestions to what could be improved and if anything was missing. The test persons were first given some instructions on what they were supposed to do in the test and were afterwards asked to read the instructions in the program. The test persons were to load two lists in the program and then add some missing items after having measured each item's weight and dimensions. Then afterwards they were asked to pack two suitcases. When the test persons were done packing an interview was made. Two group members were present at the testing. One was sitting documenting everything and afterwards interviewing the test person, while the other sat behind the test person to see what mistakes the test person made.

After the first test some labels in the program were changed to help the understanding of the use of the program. The instructions in the program were also changed to better describe the program. The first test person did not have problems at all in packing the suitcases but stated that he/she did not find the program useful. He/she suggested adding a function making the program able to take into account if an item is bendable.

The second test got interrupted because of some problems with loading one of the lists which caused a breakdown of the program. The test was retaken the day after the problem was fixed. Before the 2nd test we made some changes in the instructions, saving functions, bottom of suitcase, added some new buttons on the forms; manage suitcase, manage items, add item, and add suitcase. After we made those changes we began test 2.

The second attempt on the second test was made a short time after the first attempt. This time there were no technical problems with the program, and the test was made without more serious problems. After the test the instructions was changed again to better describe some features in the program and also describe how to rotate and drag the 3D model in the 3D-viewer. Another thing that was changed was that you now have to write the weight limit in kg instead of gram. The mistake with the program asking if you want to save the lists after you have saved them by using the button was also fixed after the test. The "Reset"-button was removed from the main window. The list in the 3D-viewer now sorts the items so the ones on the bottom is in the top of the list now. The last thing that was changed was that an image of a suitcase was added in the "Manage Suitcases"-window and a picture of several items was added to the "Manage Items"-window.

6.3 The Second Round of Tests

In the second round of tests we tested two test persons. Some small improvements to the test method were made in this round of tests. The instructions about what would happen in the test were written down instead of just told so the test person would not forget the instructions, and the instructions them self were improved so they were easier to understand for the test persons.

The second round of tests were made a week after the second test. The test went without any technical problems and was a success. After the two tests the following was changed. Since both test persons complained about the time it would take to put in all the info needed in the program, a drop down menu of some standard items has been added in the "Add item"-window in the "Manage items"-window. A better description of what

is at the bottom in the suitcase has been added in the 3D-viewer. The little box showing the (0;0;0)-coordinate has been described in the 3D-viewer too. The problem about a lot of items being packed upright was solved and the algorithm has been optimized. A better description on how to add more of the same thing has been added to the instructions. If the user are managing a already saved list and click the "Save list to Computer"-button the program will ask the user if he/she wants to overwrite the saved list. In the 3D-viewer the unit for the suitcase's weight has been added.

6.4 Conclusion on the Tests

The test went well and the group got some good feedback that lead to some great improvements to the program and the bugs in the program were fixed. Most of the test persons found the program useful if they had to pack a lot for a vacation. Testing more than once proved a very good idea since all the test persons had good suggestions to improvements and found minor bugs that quickly were fixed. If anything should be better next time, the group should be better prepare for the test and be sure to write down the instructions for the test person and be sure everything is ready for the tests. Despite some smaller problems regarding the testing, the result of the tests were useful for the project and therefore a good time investment.

Discussion 7

7.1 Discussion

The focus in this discussion is to see if the product is in conjunction with the problem analysis seen on Chapter 2 and to see if the different requirements is integrated in the product.

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specification
requirements

In the problem analysis there was stated the following requirements for the program:

- Program language is C#.
- Guide the user.
- Distribute weight.
- Distribute space.
- On the road.
- Baggage rules.
- Structure of packing.
- Packing list.
- save/load function.

And there also were some optional features that if there where time left, they might be implemented in the program:

- Solid/liquid/bendable shapes.
- Type of trip.

The whole program have been design in visual studio and the language that have been used is C#. C# is used because it suits the idea of how the program should work and also the developing environment, in this case Microsoft Visual Studio. Thereby the first requirement is fulfilled.

In section 5.2 the algorithm is explained. The algorithm distribute the items in the suitcase(s) evenly by weight and space. The algorithm also ensures that the weight limit

is not exceeded. Yet the algorithm can not pack as good as a person might be able to do. One reason that a person might be better at packing, is that the program handles all the items as boxes and do not take into account, that some items might be able to be fold and bend in different shapes. This algorithm takes both weight and space into account and that way the program is capable of distributing both the weight and the space.

To help the user to get a better visual understanding on how to pack the suitcase a 3D-image is made for the user that can rotate, zoom and be dragged. In the right side of the 3D-form a list is displayed. This list shows all the packed items in the selected suitcase. By selecting an item it will be marked in the 3D-image so the user will easily be able to identify any given item. An explanation of this function can be seen in section 5.4. To help the user furthermore an algorithm has been made that makes sure that any two items next to each other will have different colors, so they are easier to identify from each other. The function and a description of it can be seen in section 5.3. It is easy to get a good overview in the program, because the maximum number of buttons is 5 in all the different windows and no unnecessary features are in the windows. The 3D-viewer is very user friendly because the user can use the mouse to zoom and rotate the 3D-image of the suitcase containing the packed items. The GUI is described in section 4.5.

The 3D viewer and GUI guides the user in the packing process and gives the user the possibility to navigate through the program. This covers the requirement which states that the program will need to guide the user in order to help solving the given problem. The stated problem can be seen in section 2.5. The 3D viewer and GUI also provides the user with a packing list were the user can select an item and see the packed item on the provided 3D figure. This is the method used to cover the requirements "Structure of packing" and "Packing list".

The user are able to save a list he/she has made on the computer and load saved list every time he/she uses the program. This means the user can load the list any time he/she wants. Thereby the user can load the list on the vacation and use the program normally. The only condition is that the user must bring his/hers computer. The save function then covers the save/load requirement and the on the road.

So the program is based on the requirements and has been improved by using the results of the tests that have been made on the program. The tests have helped with improving the design of the program and a few function in the program. This has been a very good tool in improving and bug-testing the program. The improvement made after the tests can be seen in chapter 6.

So the product includes all the important requirement but the optional features have not been included because of the lack of time to work on these optional features. It was decided that it was more important to make the targeted features as perfect as possible, before working on optional features. The program is capable of packing one or more bags based on data on the bags and a list of items that should be packed. But the program unfortunately does not provide a packing solution as the human brain can. The reason for this is that the program does not allow object to be flexible. On the other hand the program takes weight into account which can be hard to remember when packing. The program does also remember items from last time which can save time for the user because he/she does not need to start from scratch.

In the following section, Perspectivation, the experience will be reflected upon and try to related processes in the project to the real world outside the project. There will also be thoughts on how user will use the program.

7.2 Perspectivation

When working with problem solving it is also important to look at how the user will use and interact with the solution. Through these assumptions a better solution can be formed that is more user friendly. Therefore it is a good thing to know who are going to use the solution, and from that design it more thoughtfully.

The purpose in this project was to make a program that provided the user with a packing solution and help the users to pack a suitcase more effectively. The program should also control that the weight of the suitcase does not exceed the limits given by the user. The program is made in "Visual Studio" that provides the developer with a lot of good tools to make an user interface for the user of the program. This makes the program a lot more user friendly because the user easier can interact with the program. This means that it will be a lot easier for the user to operate the program and thereby the program have bigger chance to sell if it were the intention. The user interface also means that the user do not need understand the program before they can use it. The program in this project also supports mouse control, that means that user can use his/her mouse to navigate around in the program. Because of the mouse support, and the good interface the user has less chance to fail in using the program, but by implementing an interface there is a risk for new bugs and misunderstandings in the formulations in the interface. Therefore it is important to make a clean and user friendly interface that only contains the necessary buttons and well formulated text that helps the user by informing about what they should do, and which unit the data is in.

To prepare the program and try to find eventual problems, the program has undergone some tests, where people who have not worked with the project have tried the program. Their experiences from the test were then collected and used to evaluate the program. The evaluation then led to changes that would make the program better. After the changes were made, the program were tested again with the changes and the same procedure of the test result as the earlier test. This process of repeated testing is a good procedure to develop a working program because the potential user gets to use it and experiences are made in context to the use. These experiences are then used to make the program more suited for the target audience. The downside of this procedure is that it takes a lot of man hours to do the testing and make the changes. Therefore testing is a good but expensive tool, hour-wise, to use. It should always be taken into consideration to test the program, because it is important that the program is freed of the worst bugs when released. Program bugs on releases have a negative influence on the programs sale and might scare of potential purchasers.

A side effect from making the program in "Visual Studio" is that the program only can run on Windows (Microsoft's operating system) with the .NET framework installed. The reason is that the program uses the .NET framework which only are supported by Microsoft's operating systems. This means that it is important to take a moment before developing and make a thought regarding what platform the program should be used on or better yet, if it should be able to run cross platforms. These different experience made in this project can be used in upcoming projects.

Conclusion 8

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List of Corrections

Fatal: Et eller andet sted skal der sammenlignes mellem binpacking og knapsack . . .	18
Fatal: Men den fortæller jo ikke hvor meget plads der er tilbage og om der kan være souvenirs!	20
Fatal: Der er da intet med basis regler i programmet eller noget om dimensioner! . .	20
Fatal: Flowchart should be finnish	24
Fatal: indsaet en ref	43
Fatal: ScaleSizefunctionref	47
Fatal: ref til specification requirements	59

Pak kufferten

Problemstilling

Hvis man skal ud at rejse med overnatning, skal man huske at pakke sin kuffert. Det kræver en del overvejelser. Det går ikke at glemme sit pas eller sit undertøj. Men et kuffertpakningsprogram skal kunne klare meget mere end at være en avanceret huskeseddel. Et godt program skal også kunne hjælpe med at fordele bagagen i fordel til vægt- og volumenkrav. På mange flyselskaber er der således krav til den indtjekkede bagage og håndbagagen. Mange flyselskaber tillader 20 kg indtjekket bagage og har krav til dimensionerne på håndbagage. Bestemte slags genstande må ikke forefindes i håndbagagen, andre ikke engang i indtjekket bagage. Hvis man er en familie, der skal rejse sammen, er det vigtigt at fordele indholdet i kufferter, så de mindste medlemmer ikke slæber for meget, men heller ikke for lidt. Også volumen er en udfordring, hvis man skal rejse i bil. Hvilke kufferter og kasser er der plads til i bagagerummet? Og hvordan skal bagagen placeres i bagagerummet? Man kan selvfølgelig prøve sig frem, men det ville være godt at have en algoritme til hjælp. Ideelt set skulle et pakkeprogram være en lille app, som man kan have med sig i sin telefon eller tavlecomputer og let tilgå undervejs på rejsen, når man f.eks. skal finde plads til den nyindkøbte souvenir eller de fem flasker etellerandet.

Problem

Kan man lave et program, der kan hjælpe med at planlægge pakning af kuffert?

Formål

At udvikle et stykke software, der kan være en intelligent assistent, når man skal pakke sin bagage.

Mål

At udvikle et effektivt stykke software, der gør det muligt at pakke sin bagage bedst muligt.

Teknisk-naturvidenskabelige fagområder

Optimeringsproblemer. Analyse af algoritmer. Objektorienteret programmering.

Eksempler på kontekstuelle fagområder

Hvorfor er luftfartsselskabernes pladskrav opstået, og hvordan har de udviklet sig?

Forslagsstiller

Hans Hüttel.

Mindmap B

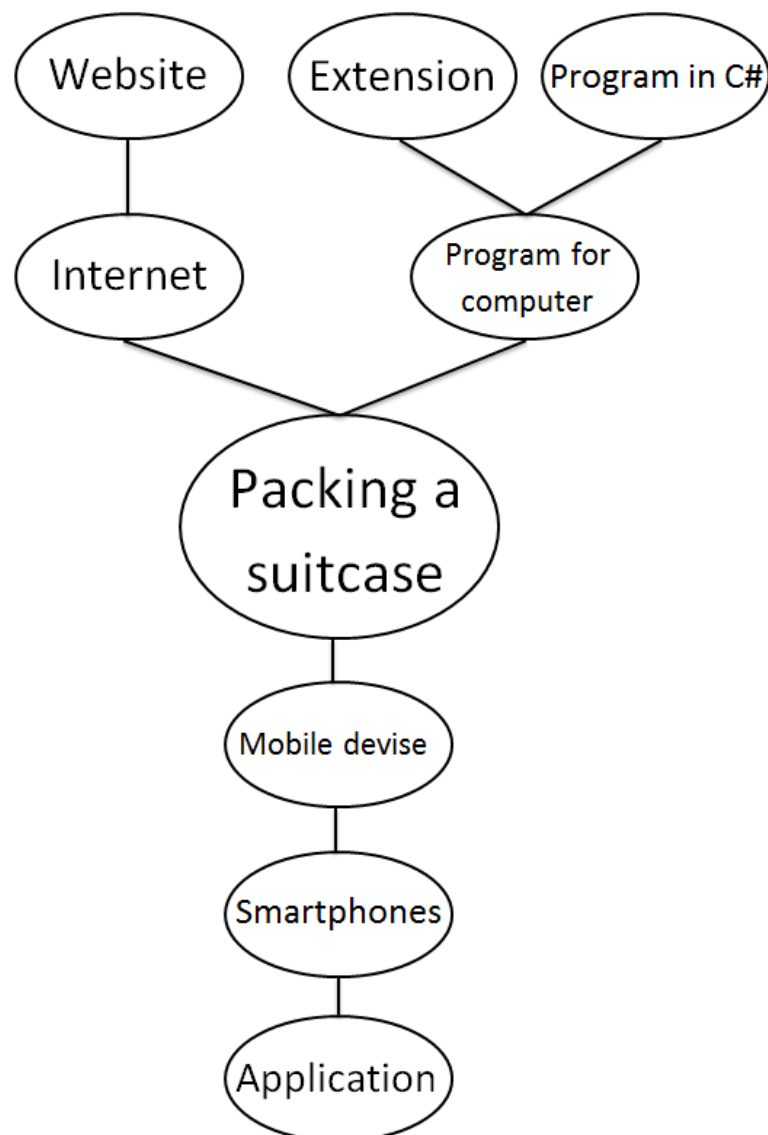


Figure B.1: Mindmap containing solution suggestions

Questionnaire

1. Were there any problems finding out how the program worked?
 2. Were there any technical problems using the program?
 3. Other problems?
 4. Was the program easy to use?
 5. How was the design of the program?
 6. Did you find the program helpful?
 7. Would you use a similar program?
 8. Suggestions for improvements?
 9. Other comments?