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Development and testing of a concept for analyzing kinematics in show jumping

An analysis tool for riders and trainers

Master's thesis in Product Development and Production Engineering

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MASTER'S THESIS 2020

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Cover: Louise and Saltiz flying over fences.

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Abstract

Equestrian sports have been a research area for Chalmers for the last eight years. The general aim of this venture has been to incorporate technological solutions and generate new knowledge connected to equestrian science.
The aim of this project was to develop a concept using technology in order to bring new possibilities of analyzing kinematics for practitioners of equestrian sports. Within the field of equestrian sports, show jumping was targeted as a first area of focus.
A market analysis including interviews and a survey was performed in order to capture the voice of the customer (VOC). This analysis was used as input for concept selection. The selected concept was tested in order to generate new knowledge about kinematics in show jumping.
Video analysis was assessed to be the best suited technology for the product concept developed in this project. Concept testing showed that the point of take-off for loose jumping and low heights are consistent with the Distance formula. Further, the tests showed that the distance from the fence to the point of landing in most cases exceeds the distance from the point of take-off to the fence.
We conclude that the distances to fences are perceived as a difficult parameter to consider as a rider. Therefore, a function measuring the point of take-off and landing is a suitable first tool of the product concept. Further, video analysis is considered the best option for providing a flexible product for users.
In addition, collected data from tests suggested that increasing the distance between fences make the point of take-off less dependent of fence height. These tests had a low sample size and should therefore be interpreted with caution.

Keywords: Product development, voice of the customer, equestrian sports, show jumping, kinematics.

Dictionary

KPI	key performance indicator
Lead change	the change of leading leg (left or right) in canter
L-class	competition class within show jumping (100-120 cm)
M-class	competition class within show jumping (120-145 cm)
S-class	competition class within show jumping (145-160 cm)
Stride	The canter consists of one stride followed by a flying part. Each stride is triple time where the horse first it places one of the hind legs, second the other hind leg together with the diagonal front leg, third the last front leg. One stride is considered from the first hind leg to the last front leg
Vertical fence	a type of fence consisting of a single row of jumping poles
VOC	voice of the customer

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Elin Lorin and Niklas Westman, Gothenburg, June 2020

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1
Introduction

This chapter presents a background for the thesis along with the purpose, research questions and delimitation.

1.1 Background

Technology is a common feature in many sports today. Chalmers has during the last eight years had a venture into Equestrian sports [1], [2] where a technical fence has been present at Gothenburg Horse Show (GHS) for the last five years. The aim of the technical fence projects has been to increase the knowledge of physics in connection to show jumping and get a wider audience interested in related subjects. This enterprise has been successful and resulted in new knowledge such as the Distance formula [3], [4], [5].

Until now the technical fence has been only used in a limited environment at the Gothenburg Horse Show and the data has not been readily accessible for the riders. Therefore, there exist a possibility to use previous gained knowledge to advance the Chalmers technical fence into a product.

Another aspect concerns the issue of documentation of information and knowledge. Riders and trainers undoubtedly possess large amount of knowledge of equestrian sports and show jumping. This knowledge seems to seldom be formalized or published which suggests the knowledge can be viewed as tacit knowledge. Tacit knowledge is categorized as informal and can be difficult to communicate explicitly [6]. A digital product could help information gathering that can be transformed into knowledge that is accessible for different stakeholders. Furthermore, a digital tool could help to easier provide an overview in addition to documentation of a horse's performance.

A device to detect and measure the stride of the horse when moving towards, over and after the fence could provide valuable insight for the rider, trainer and other stakeholders in order to achieving a desired outcome. This could help to analyze the kinematics of the horse to improve its performance.

1.1.1 Purpose

The purpose of this project is to produce a concept for a product that incorporates technology in order to bring new tools of analysis for practitioners of equestrian sports. This firstly entails an investigative part where a market analysis is to be performed in order to map out different customer interests and needs. Secondly the information from the market analysis is used in order to generate a specification which concepts are evaluated against. Thirdly, the selected concept is tested in order to generate new knowledge about the distances in relation to the fence and the accuracy of the concept is evaluated. Lastly, the thesis aims at presenting a way in how data gathered by the concept can be visualized in an informative and intuitive manner.

1.1.2 Research questions

Four research questions are formulated and are to be answered in the thesis. The first two questions are case specific and aims at developing a product concept. The third and fourth question is of scientific nature which can help formalize knowledge making it more accessible.
RQ1: *What kinematic factors would potential users be interested in?*
RQ2: *What type of technology would be suitable for a concept measuring kinematic factors in show jumping?*
RQ3: *How accurate is the distance formula when applied to loose jumping and lower heights?*
RQ4: *How does the distance between two fences affect the take-off and landing distances?*

1.1.3 Delimitations

The thesis aims at resulting in a product concept that can be further developed into a finished product. Focus will be placed on the early stages of product development, including market analysis, creation of an initial requirement specification, concept selection and concept testing. Therefore, areas such as user experience and implementation will not be covered. A schematic overview of the areas focused on can be seen in figure 1.1. Further, the concept testing aims at also generating new knowledge of kinematics in show jumping and ideas for future research.

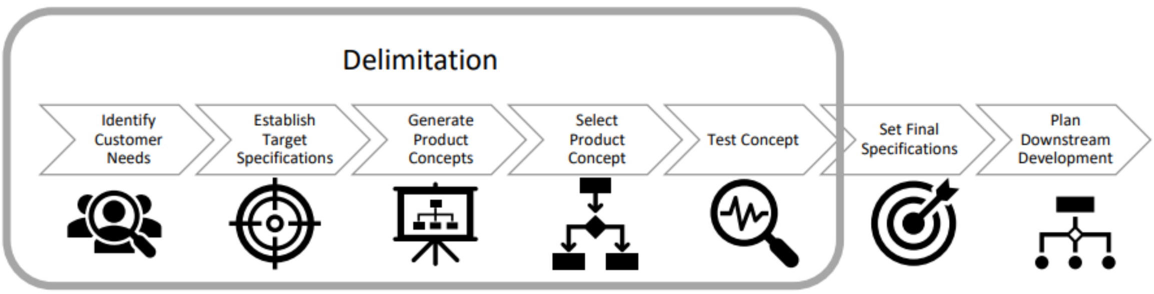


Figure 1.1: An illustration of the delimitations regarding the concept development process.

2
Theory

Expanding the knowledge of physical aspects connected to equestrian sports can provide a foundation for new products utilizing technical tools. A better understanding of the kinematics behind what makes a good jump could also act as a basis for riders and trainers to analyze training sessions or competitions in order to improve the performance.
This chapter provides a theoretical framework on which the thesis is based upon.

2.1 Product Development

This project has followed steps from Ulrich & Eppinger's [7] product development strategy, where the voice of the customer has been of the greatest importance. This project consists of three main parts; mapping of the voice of the customer, concept development and testing.

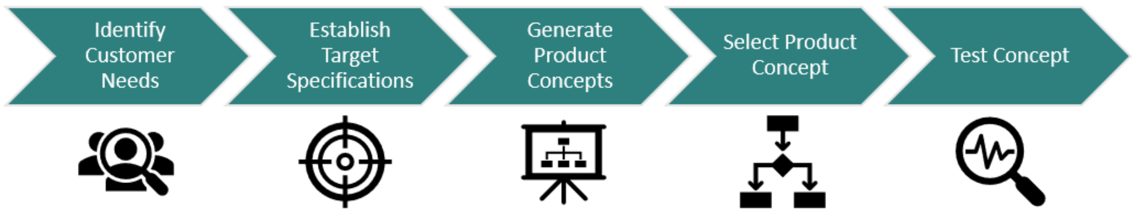


Figure 2.1: An overview of the main steps in this project.

2.2 Identification of Customer Needs

A large part of this project has been to capture the voice of the customer, both the customer's unspoken and out-spoken needs [8]. The voice of the customer (VOC) can be defined as a customers outspoken and unspoken needs [9], [10]. These needs are what the customer defines as value in a product or service and should therefore be aimed to achieved in product development. Özdağoğlu *et al.* [11] describes the importance of the VOC in product development. In addition, Melander [12] states that customer involvement can be particularly useful in early stages of product development. Therefore, capturing the VOC has been of focus throughout this project. Cooper *et al.* [9] states that VOC is a fairly new approach for companies and that there is no standard methodology. Therefore, the project has utilized classical methods such as a survey and interviews in order to investigate the VOC.

Further, the growing product segment of smart products does not only expand products abilities, but also places needs on organizational capabilities [13]. It is therefore important to bare these aspects in mind in today's product development. Digital products also offer companies to utilize data in terms of customer feedback [14], which offers possibility for utilizing customer data for development of new product versions.

2.3 Research regarding show jumping

Equestrian sports have been the focus of much previous research. This research often has a veterinarian angle and focuses on how to reduce and detect injuries. Egenvall *et al.* [15] suggests variation in training as a measure to reduce injuries in show jumping horses. However, Rogers *et al.* [16] states that no clear method exists for reducing musculoskeletal injury types. Therefore, to gain kinematic data could contribute to future research into the veterinarian field of injury prevention.
Previous research done on loose jumping horses found that poor horses had a higher mean horizontal velocity of the center of gravity (CG) than the good one had. What was also significant between the two groups was that good horses have a greater flexion in the carpus joint, good horses bend their forelimbs more than poor horses [17]. This indicates that measuring horizontal velocity could be one of the first functions to develop in a product concept.
A section in [18] discusses the point of take-off and landing. Further, [18] suggests that the leap curve is parabola-like and that the point off take-off and landing should be at an equal distance from the fence for a vertical fence. Moreover, [18] also includes a discussion of where the point of take-off and landing is located in relation to fences and how the height of fences affect those distances. Further, [18] states that the point of landing is located at a distance further from the fence than the point of take-off in most cases. However, no numbers are given to these distances which indicates that this could be possible aspect to research.

2.3.1 Defining the leap over a fence

In the following section a short discussion follows in how to define start and end points for the leap over the fence. Also, how to define the stride.
Previous research at Chalmers have generated the new distance formula [3], [4], [5] which can be seen in equation 2.1

$$l = 1.3 \cdot h + 0.2 \tag{2.1}$$

The formula gives the distance l in meters from the point of take-off to the fence where h is the height of the fence. This formula was developed by using data measured at GHS. However, the formula may be inaccurate for heights below 1.2 m since it was derived using a minimum value of h at 1.2 m [5].
Perhaps the easiest way of defining the leap would be to follow one hoof from take-off to landing. This definition is simple and would only require data acquisition for one hoof.

Another way of defining the point of take-off (and landing) is to use the mean value of the hoofs. A common pattern in the data is that one front hoof take-off earlier than the other front hoof and the back hoofs which have roughly the same point for take-off. This is visualized as M_{avg} in figure 2.2. A distinct advantage with this definition compared to following one hoof is that it will give the same output if the horse performs a lead change (change from e.g. left canter to right canter) over the fence.

The research done in regards to generating the Distance formula used a third definition. This definition is described as the hoof closest to the fence act as the point of take-off, while the first hoof to hit the ground after the fence is said to be the point of landing [3]. Figure 2.2 shows this method as M_{closest} This method may be the best option to use in future test since it means tests results can be compared with the formula shown in equation 2.1. This method will hence be called the min-method (since its definition evolves around the minimum distance to the fence from either side).

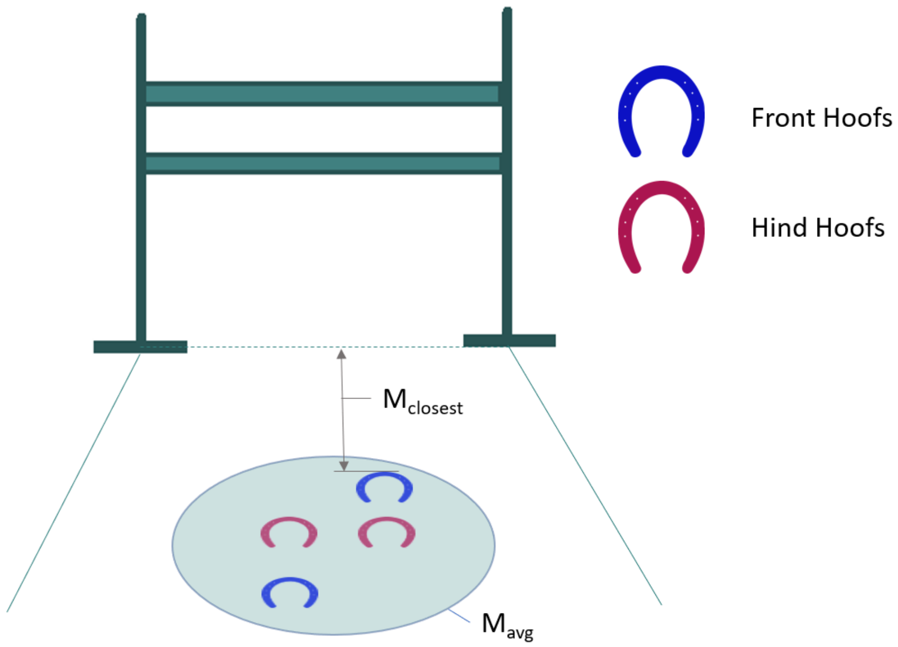


Figure 2.2: Visualization of the different methods for measuring distance of take-off and landing in relation to a fence. The circle represents the usage of all hoofs in the M_{avg} method.

2.3.2 Currently used tables

In show jumping, one of the difficulties are the distances between fences, called related distances. Related distances are usually defined as the number of non-jumping strides between two fences. The literature study showed that the three most commonly used tables are "Strömsholmsmetoden" [19], "Tävlingsreglementet"

[20], [21] (hence reefed to as TR) and "Ridhandboken" [22], see tabular 2.1 for exact distance for number of strides. The tables present a range for recommended distances which could be used for training.
TR is used by course designers at competitions and can therefore be viewed as the official related distances [20]. The distances provided in TR are used in competitions up to S-class, where course designers can increase the course difficulty by deviate from the table [20]. Furthermore, it is hard to find where the different tables originate from. The authors' best guess is that they originate from experienced trainers/riders/course designers whom undoubtedly possess a great deal of knowledge. The trouble may occur that this knowledge is not always, perhaps even seldom, documented and formalized. Hence the authors have not been able to find data that act as a basis for the described tables.

Table 2.1: The distance between two fences for different number of strides from Strömsholmsmodellen, TR and Ridhandboken.

No. strides		Stömsholms-metoden	Avg	TR	Avg	Ridhand-boken	Avg
1	min	6.5	6.8	7.4	7.6	7	7.5
	max	7		7.8		8	
2	min	9.75	10.0	9.75	10.0	10	10.5
	max	10.25		10.25		11	
3	min	13.5	13.8	14	14.5	14	14.5
	max	14		15		15	
4	min	17	17.3	17.5	18.0	17.5	18.0
	max	17.5		18.5		18.5	
5	min	20.5	20.8	21	21.8	21	21.5
	max	21		22.5		22	
6	min	24	24.3	24	25.0	24.5	25.0
	max	24.5		26		25.5	
7	min	27.5	27.8	28	28.8	not given	
	max	28		29.5			

There are three main theories of where the take-off point is:
• the take-off point is as far from the fence as its height [23].
• the take-off point is half the length of a stride [24].
• the take-off point follows the Chalmers formula: $l = 1.3 \cdot h + 0.2$, where h is the height of the fence [5].

Table 2.1 shows a comparison of the three different models where the minimum and maximal distance is shown together with the number of strides between two fences. It turned out that distances vary in a relatively large range. By more careful comparison and taking into account the three theories mentioned above, it became clear that the distances between the fences do not increase linearly with the increased number of strides at related distances.
Although the literature both discusses the point of take-off [18] and also presents values for distances between fences [18], [19], [20], no effort is done to connect these two. If the distance between fences are varied the horse may have to adapt to the

new distance. This could be done in a variety of ways, imagine that the distance between two fences are decreased, how will the horse adapt? Either the horse could use the same point of take-off as before, but in order to clear the fence, it may have to increase the angle of take-off. Another possibility could be that the horse shortens the stride between the fences (or increasing the frequency of the stride) and thereby has created enough distance to the fence that a similar point of take-off can be used as before. Therefore, this project aims at investigating how the point of take-off is altered by varying the distance between two fences.

2.4 Technology

Different technologies are available in order to capture data such as position and velocity that can be used for analysis. This section gives a theoretical perspective on three types of technologies available.

2.4.1 Video analysis

Video analysis revolves around the idea to analyze video footage in order to acquire data of desired parameters. Multiple previous studies have been done using video analysis. A study by Mousavi *et al.* [25] concludes that video analysis via an app can be done for evaluation of certain lower limb movements on a treadmill. Similarly, a study by Bradley *et al.*, [26] also concludes that caution is needed in using 2D video analysis. Hence there seems to be doubts in how exact video analysis are in different situations. It is therefore of importance to investigate error estimation in this thesis, should video analysis (or any other technology) be used.

2.4.2 LIDAR & RADAR

LIDAR (Light detection and range) and RADAR (Radio Detection and Ranging) units are similar, except that LIDAR uses a light wave from a laser while the RADAR uses radio waves. When the waves are then reflected on a surface or object, the distance can be calculated.

A common area of use for LIDAR units today is the automotive industry. Several manufacturers are currently developing vehicles utilizing LIDAR in order for applications such as autonomous driving [27], where the LIDAR unit function detects the distance and velocity of objects surrounding the user vehicle.

Previous research from Chalmers technical fence have been using both RADAR and LIDAR. When LIDAR was used, a prototype was built and placed in the center of the obstacle. This can affect both the horse by scaring it and the measurement data becomes poor as the horse changes gallop across the obstacle or it splashes sand. From a user perspective, LIDAR is also quite complex and high precision units are expensive, while external effects such as weather can reduce the LIDAR performance [28]. RADAR could be a better option in this context due to RADARS being less expensive in general and less sensitive to weather effects.

2.4.3 Motion Sensors

Motions sensors are units such as accelerometers and gyroscopes. These sensors are present in many smartphones today [29] and can be used in software analysing the data the sensors provide. Inertial motion sensors often use a combination of gyroscopes and accelerometers in order to generate data. According to Adesida *et al.* [30], inertial motions sensors are the most common type of sensors used in sports equipment today. Further, Adesida *et al.* [30] describes how one of the main advantages of motion sensors is the possibility to capture data form sports being performed in their natural environment rather than in a test setup. Therefore, motion sensors could be a type of technology that offers flexibility for its users.

3
Methodology

This chapter will provide an overview of the work method. How data was collected how the tests were conducted. It also includes a market analysis with competing products and stakeholders needs.
The research done in this project can be viewed as mix-type, containing both qualitative and quantitative methods. While this approach is beneficial for its flexibility, it can also be problematic in terms of the knowledge needed in both methods. It is therefore of importance to ensure transparency in order for the results to reviewed efficiently.

3.1 Research approach

The qualitative research areas in this project include the literature study, interviews and the survey. The quantitative parts include the observations performed and analysis of these results. Further, a string search was used to quantify common phrases in question 9-13 of the survey (see Appendix A).
Quality in qualitative studies is an important part of ensuring trustworthiness and transparency. Tracy presents several important focus areas for maintaining high qualitative quality in research which includes sincerity, credibility and ethics (among others) [31]. These areas have acted as guidance for the quality of this thesis.

3.2 Literature

The material used in the literature review was sourced from various sources such as Chalmers library, Science direct and EBSCO. In regards to the theory connected to rules and regulation of show jumping, the material was found on The Swedish Equestrian Association's website.

3.3 Identification of customer needs and competing products

The initial phase of this project has focused on identifying customer needs and competing products. The aim of the mapping phase is to build a foundation on which to base an initial specification that can then be used to verify concepts against.

3.3.1 Data collection

Since the project is based on open-ended problems different stakeholders were interviewed and a survey was performed. The interviews tried to cover different stakeholders' interest in a technological aid that can present interesting parameters connected to show jumping.
The survey targeted a larger audience where the result could be analysed for patterns using simple quantitative methods.

3.3.1.1 Interviews

The interviews were conducted using a semi-structured approach in order to let the interviewees answer openly while trying to keep to a manuscript of formulated questions. The questions were in some cases altered slightly in order to fit the interviewees role.
The different interviewees can be categorized as amateur and professional riders, trainers, test judge, course builder, horse owners and breeders. All interviews (with one exception) were done via phone.

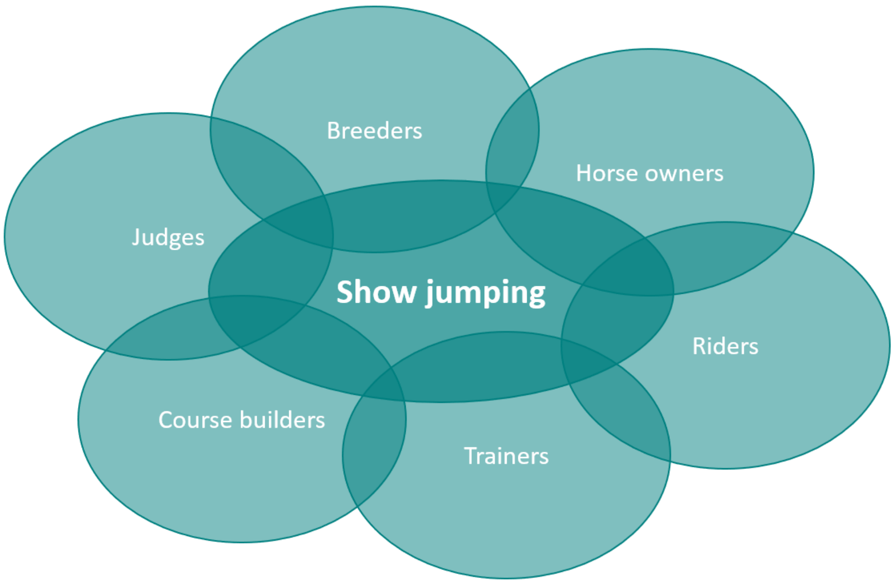


Figure 3.1: The different potential users and stakeholders.

3.3.1.2 Survey

A survey was created for information gathering in order to determine who the target group where and what factors they were interested in.
The survey was created in google docs and was published 24th of February. Several information channels where used to spread the survey and included spreading on social media by the authors and a link in an article published on the website Hippson [32].

The purpose of the survey was two-fold. Firstly, the purpose of the survey was to identify what factors connected to show jumping riders found difficult or wanted to explore more. Secondly, the survey provided information about who the respondent was.
The survey contained thirteen questions and was aimed at the greater mass of athletes within horse riding. Predominantly those who responded were amateurs who rides L-class (beginner level). Questions and summery of the answers can be found in Appendix A.
The questions where of different types, where multiple choice questions where used in order to identify on what level the person answering the survey is competing. Other questions such as "What" was open-ended where the respondent could freely write an answer. The theme for the open-ended questions where developed from Cooper *et al.* [9] suggestion into how approach feedback of new products. This means (in this project) that instead of asking for specific kinematic that could be of interest, questions could be focused on getting a general idea of what the potential customer experience as troublesome.
The number of respondents were 108 in total, 92 of those respondents answered the final version of the survey. No sampling was used in order to choose the respondents.

3.3.2 Competing products

A scan of the existing market was done by web-searches and other information gathering activities such as question during the interviews. "Competing products" where defined as technological products tailored for equestrian sports or a product that could easily be adopted to equestrian sports. This provided a filter which narrowed down the number of products.

3.4 Concept development

The results from the survey and interviews acted as a base for the following concept development phase. Each step of the concept development phase is discussed in the following sections.

3.4.1 Creating a specification

The specification was created using the results from the survey foremost. From the survey, information about who the users potentially are and what factors they would be interested in was obtained. This information was then translated into an initial requirement specification, see Appendix B.

3.4.2 Concept generation

The concept generation was done primarily by brainstorming around different possible technological solutions that can be used for measuring basic physical properties in show jumping.

3.4.3 Concept selection

The concept selection was done in a first step by comparing each concept to the specification. Concepts that passed this stage were then evaluated in a Pugh-matrix in order to rank them. The concept rated highest was then evaluated in terms of time creating a prototype within the projects time constraints.

3.5 Observations

To answer RQ3 and RQ4 two tests were done. The first test contained of three horses jumping a test track. In the second test a rider rode the same track. The test design and test setup were influenced by the concept selection and is hence presented in section 6.1.

4

Market Analysis

This chapter includes the results from the market analysis performed including interviews, a survey and investigation into competing products.
The final section presents the specification created from the results of input from the interviews, survey and competing products.

4.1 Interviews

All interviewees expressed an interest in a concept that can show physical aspects of show jumping. However, the interviewees also had difficulty narrowing the expressed interest down to factors such as position or velocity.
The interviewed course designer did say that the Swedish Equestrian Association had plans on reviewing the distances for jumping combinations, but that there was "...uncertainty in what to change them to".
The main outcome of the interviews was that there seem to be a genuine interest in a product that can present kinematic factors to a user. Several of the interviewees welcomed the authors to perform testing at facilities where they operate.

4.2 Survey

The conducted survey showed 76 % of the respondents competed in L-class and 23 % in M-class which can be seen in Appendix A. Further, almost 42 % stated that they practice and compete on more than one horse. The respondents have generally been riding for a long period of time, over 80 % stated that they have been riding for over 10 years.
By using a string-search for quantifying common keywords in the open-ended questions 23 % stated distances as one of the hardest parts of show jumping. In addition, the approach and tempo were perceived difficult parts of show jumping.
The results of the survey do therefore indicate that providing a function that can analyze distances to fences can be a first item to develop.

4.3 Competing products

The main customer are amateurs and professionals within show jumping. In addition, trainers, breeders and judges have shown a big interest in this project. Having

a tool helping them analyze the horse's technique could provide valuable information and a better foundation for an argument.
From a global perspective, there are a few companies developing measuring equipment for riders to analyse the movement of the horse. Four competitive products are described in the following section and includes a short description of each product. Three products are specifically targeting equestrian sports and are fairly similar in the way they work. The Fourth product is an app that targets practitioners in multiple sports. Although that product does not advertise to riders, it could potentially be in the future. The market for using technology within the equestrian sport is growing rapidly and there could be several companies emerging with new technology that is not currently available on the market.

4.3.1 Equisense

Equisense is a French company, working mainly in European market. Their most developed product - Equisense Motion S - is attached to the girth. It measures symmetry, time on each lead, determine gait and duration and can also determine the number of jumps. Further it has features as heart rate, transitions and GPS-tracking [33].
The advantage with this product is that is can be removed and then put on another girth and used on many horses.

4.3.2 Voltaire Design

Voltaire Design is a French company, working mainly in France, Germany, United Kingdom and USA. The saddle *Blue Infinite* has integrated electrical components that makes it possible for the rider to connect via Bluetooth to the Voltaire Design app. It measures strides/minute, symmetry, number of jumps, speed, height over fence and angle of the jump. It also has, in similarity to Equisense, heart rate and GPS-tracking [34].
An advantage with this product is that it, very similarly to Equisense, gives the user a good holistic view, summery and statistics (need/demand from the interviews). Disadvantage is that the sensors are integrated in the saddle making it to no use when the saddle don't fit the horse and also making reparation/maintenance difficult.

4.3.3 Equinosis

Equinosis is a diagnostic system for veterinaries to measure, objectively, the movement or asymmetry of the horse. The product consists of three parts that are placed on the horse head, one front leg and on the back, it collects data which is then transmitted to the veterinarian's computer [35].

4.3.4 Coach's Eye

Coach's Eye is an app available for Android and iOS that allows users to analyze video [36]. The app allows its users to draw on the video, measure angles and compare video side by side. Example images are presented for a variety of sports such as golf, baseball, soccer and football.

4.4 Creating an initial specification

The results from the survey performed (as can be seen in Appendix A) shows that most of the respondents compete in L-class and M-class. Therefore, it can be deducted that these persons are not professional riders and thereby and may have a more limited budget at spending at equine equipment. Furthermore, 43 % answered that they have more than one horse which they train and compete with. This indicates that flexibility could be an important factor for a product to be used in multiple horses. In addition, the most common answers to the open-ended questions 9 and 10, where "distances", "approach" and "tempo". This gave a first idea to what kinematic factors the concept should be able to measure.
Other constraints present in the specification comes from the regulatory document provided by Swedish Equestrians Association's rule book. For example, it is not allowed to alter the appearance of the fences in an uncontrolled manner [20]. Therefore, any concept that is a part of the fence must "fit" the rest of the fence in terms of design and colour.

5
Concept generation and selection

This chapter details how the concept generation was done and how the concept selection was performed.

5.1 Concept generation

During the concept generation three main concepts were produced, each with their own technical platform.
The first concept is based on using LIDAR and/or RADAR in order to measure hoof positions in relation to a fence. One way of doing this is to place the LIDAR/RADAR unit in connection with the fence for the unit to acquire data. This type of solution has been previously tested during the 2017 rendition of Chalmers technical fence at Gothenburg Horse Show [3], [4]. This type of solution would require a form of housing in order to protect the LIDAR/RADAR equipment in case a beam on the fence would fall for instance. As previously mentioned, this puts design requirements for the protective casing, such as matching coloring.
The second concept idea revolves around using motion sensors in order to capture data. According to our market analysis, this is the most commonly used method by competing products. Sensors could be attached to different equipment used while riding in order blend in without disturbing the horse or the rider.
Video analysis is a third concept that uses a camera (e.g. on smartphones) that the user can record film with. This film is then imported into a software that generates position by following desired points on the horse. This would mean that the measurements would be performed from the side or from the front in order to capture video.

5.2 Concept Selection

From comparing the concepts with the initial specification seen in Appendix C the video analysis concept is the winning idea. Compared to the other concepts it offers the ability to measure all desired and wanted factors. Further, although LIDAR/RADAR and motion sensors could potentially also measure most of the desired factors, they are assessed to require more advanced analysis in order to present relevant information.
Video analysis also offers the best flexibility which is considered to be of importance for the targeted users. A LIDAR/RADAR solution would most likely be limited to a fence and would require different housings for different fences for it to be used at a

competition. Motion sensors are flexible in that they could capture data over several obstacles, but the concept does require hardware that may have to be integrated into a girth or saddle. Hence this concept is less suitable for collecting data from multiple horses. From a production and distribution perspective the video analysis method also has an advantage in that most of the hardware needed is already owned by most potential users. Therefore, only software needs to be distributed which would keep distribution costs to a minimum. Appendix C contains each concept's score in a weighted Pugh-matrix.

5.3 Ethical aspects

User privacy is a factor that has to be taken into account in terms of storing data and potentially video files in a correct manner. Using a software to analyze video footage may not be ethically questionable. However, if users were to upload video footage to a server it is of the greatest importance to follow legal requirements and user privacy.

6

Observations and concept testing

The test design, method for analysis and results are presented in this chapter. A total of 4 tests were conducted. The function of the first two tests was to develop and improve the test design and procedure itself. Modifications were made in order to ensure the camera had a clear line of sight of the objects that are followed. The effect of lighting was considered after the first test in order to ensure sufficient quality of the video footage. Different types of markers were used on the horses for easy tracking in the analysis software.

The observations are based on using video analysis in order to follow different points on the horses. Previous thesis has been done at Chalmers with the use of LIDAR and RADAR which have their own advantages and disadvantages to video analysis. An overview of the observations and test design can be seen in figure 6.1.

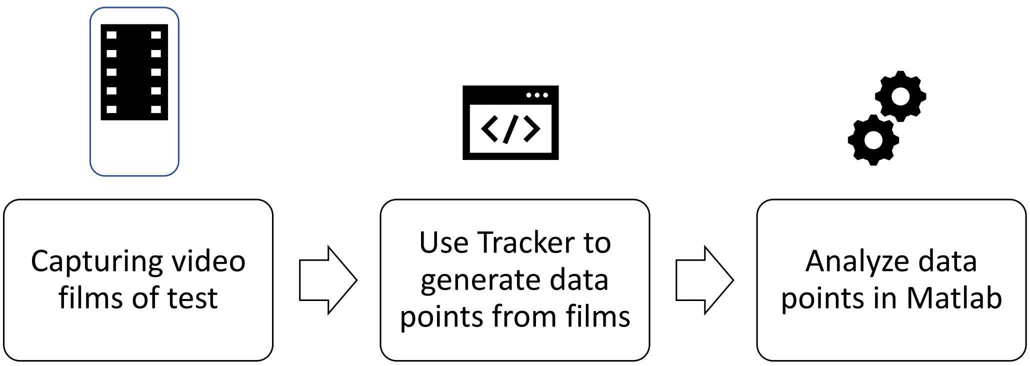
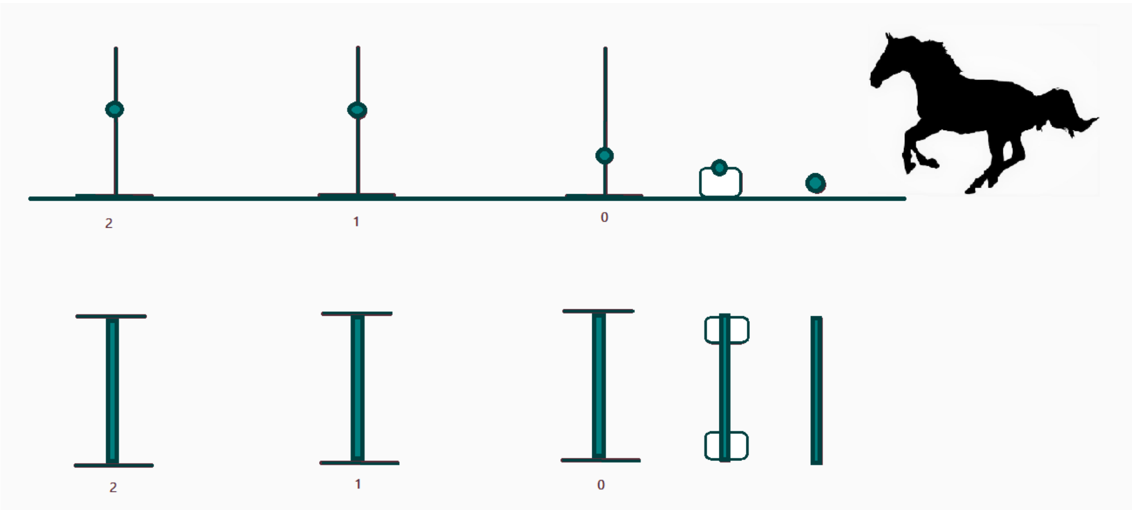


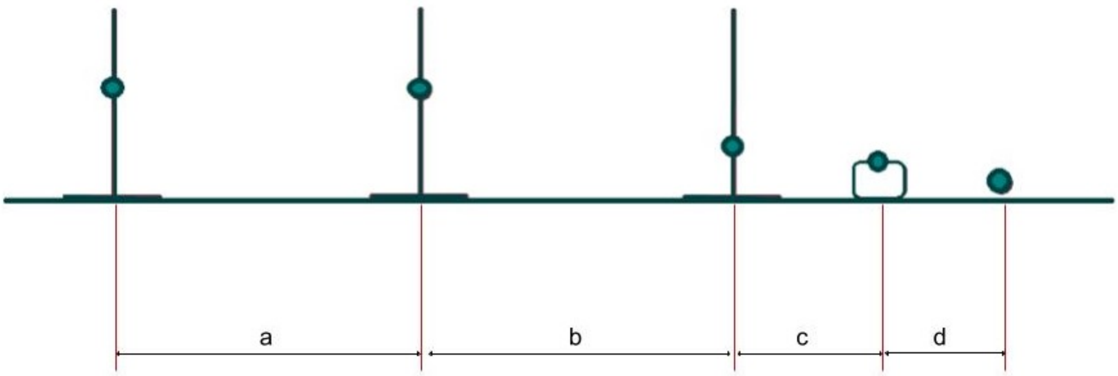
Figure 6.1: Overview how the tests generates data that can be analyzed.

6.1 Test design

The conducted tests are based on the free-jumping course design used for assessing three and four-year-old horses in the show jumping category [37]. A modification to the designed was introduced in the form of one extra fence. The course consists of two areas, the test area (fence 1 & 2) where measurements were made and the guidance area (up to fence 0). The guidance area is present to help the horse into the right rhythm and speed. The fence setup can be seen in figure 6.2.



(a) Showing direction and setup of the test. Data is collected from take-off at fence 1 to landing after fence 2.



(b) showing distance, a-d, between fences. Distance c and d were never changed though-out the test.

Figure 6.2: Test setup, showing direction and distance.

The test included a single jump per horse on each height and distance combination. The heights varied between 1 m and 1.3 m with 10 cm increments, and the distances between fence 1 and 2 was 7.5 m and 8.0 m at each height resulting in 8 combinations in total for each horse. The settings for a were determined by values currently used in competition [21] (see table 2.1). For practical reasons, the values where shifted from $a_{\text{min}} = 7.4\,\text{m}$, $a_{\text{max}} = 7.8\,\text{m}$ to $a_{\text{min}} = 7.5\,\text{m}$ and $a_{\text{max}} = 8.0\,\text{m}$. Further, table 6.1 shows the different height settings and distances used. Due to using live animals as participants in the test, the number of runs was limited, but they could redo the test if an attempt failed. Because of the circumstances regarding covid-19, all tests were done at one location.

Table 6.1: Distances and height variation for tests.

Loose jumping, fence x, mean ± standard deviation [m]				
Distance [m]	a = 7.5	a = 7.5	a = 8.0	a = 8.0
Distance [m]	b = 7.0	b = 7.0	b = 7.0	b = 7.0
Height [m]	Take-off	Landing	Take-off	Landing
1.0				
1.1				
1.2				
1.3				

6.2 Test setup

The test was done by using cameras in smartphones placed perpendicular to the test track. An overview of the setup can be seen in figure 6.3.

One camera was used for the primary data capture during all tests. This camera was mounted on a tripod at a height of 1.5 m.

The positioning of the camera can be seen in figure 6.3. The reason for the positioning was to capture the relevant parts of the test track while minimizing measurement errors caused by perspective.

The smartphones used where Samsung S9 models which has the possibility to film in 60 frames per second (FPS) [38]. Different settings of FPS (30 and 60) were used during the test. The resolution used were 1920x1080 for all tests.

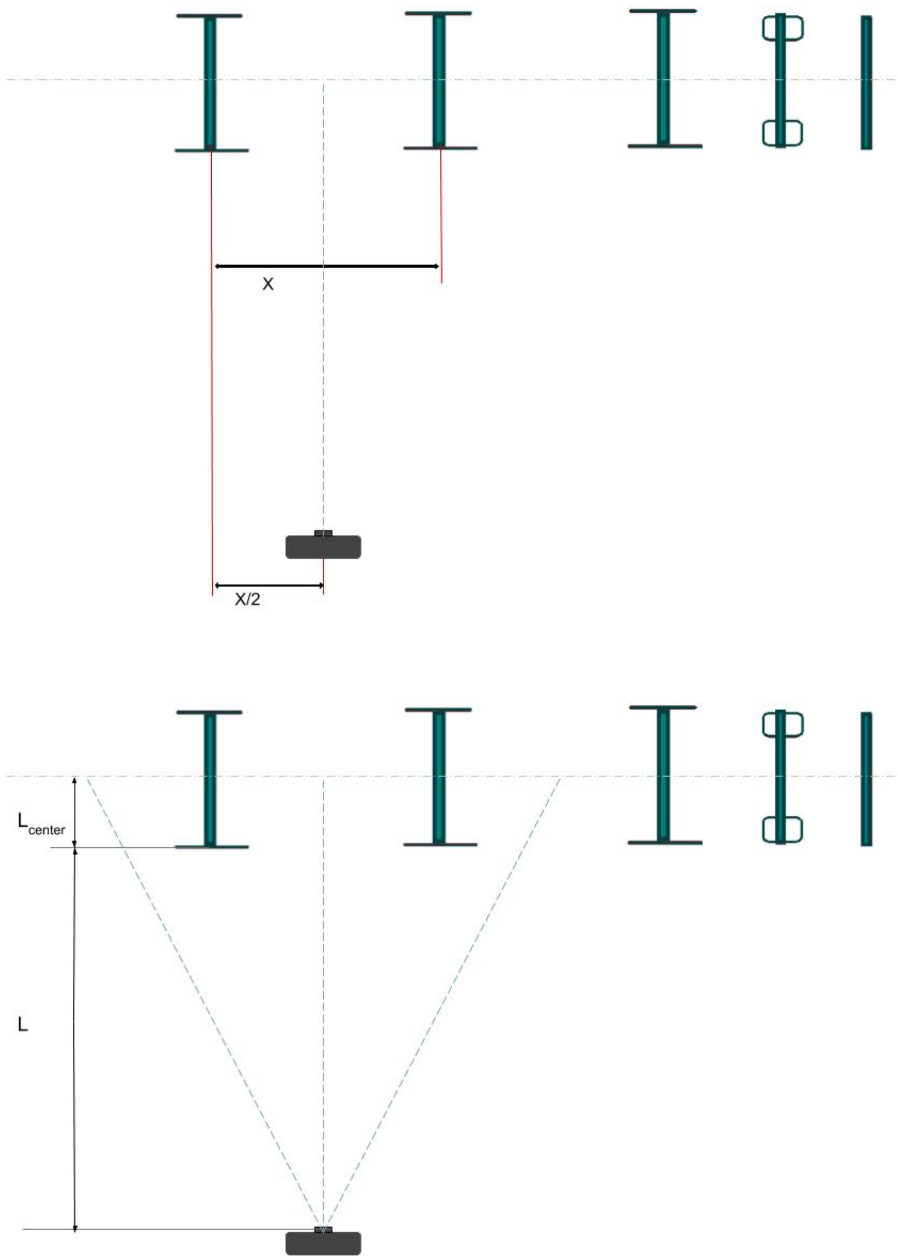


Figure 6.3: Test setup, showing camera placement.

6.3 Observation analysis

The first step of the observation analysis was done in creating data points using Tracker. Tracker is an open source software build on Open Source Physics [39].
The software first needs to be calibrated in order to set the correct scale for the data points. This is done by using the built-in tool Calibration Stick where points of the video are marked and the distance between them is entered. For the test

these points were chosen to be the middle of each upper beam on the two fences. The real distance was measured using a laser rangefinder and the measurement was entered into the Calibration Stick software to set the scale.

The software also uses an origin point that all other positions are related to. The position of the origin was set at ground level, in the middle of the first fence (Fence 1). All positions in Tracker are hence related to this position.

Further, points were marked on each of the horses used in the tests. The markings were made with tape of different colour in order to be able to track the points in the Software. Points of Mass were created (in Tracker) that correspond to markings on each horse. The points of mass are objects that can be tracked (using the function Autotracker in Tracker or manually) and thereby position data can be generated. Autotracker is a function in Tracker which tries to find a specified point in the next frame. Point Masses where created for each hoof, a point 10 cm below the withers and a position on the side of the head. These points can be seen in Tracker in figure 6.4.

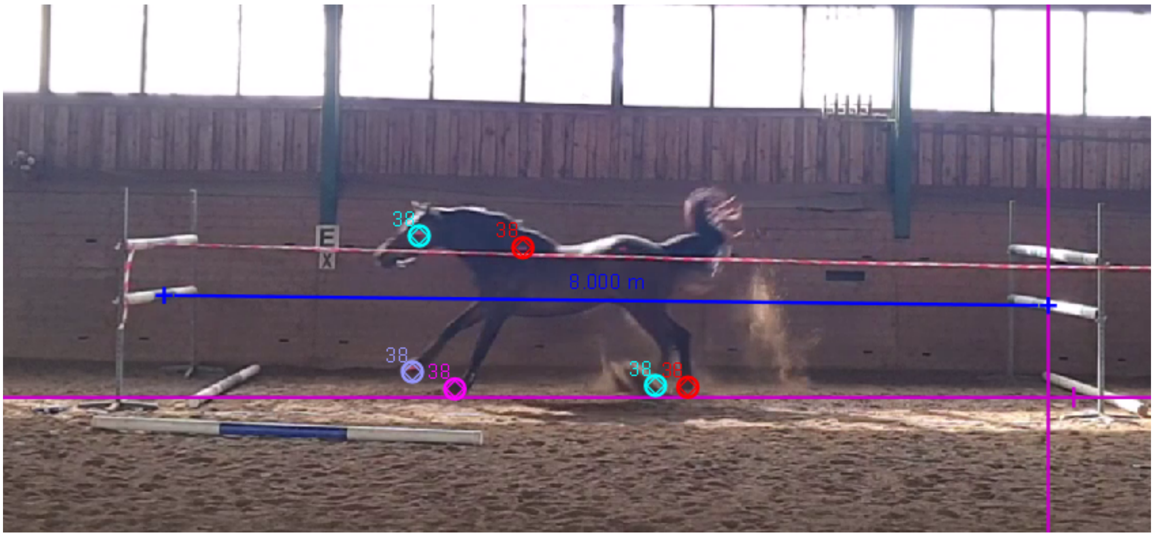


Figure 6.4: Point masses at each hoof, withers and head in Tracker.

The final step using Tracker is to export the data points, that in our case, contained x-position for each hoof.

6.3.1 Analysis in Matlab

The analysis of the collected data was done in Matlab. A program was written that read the data from the text files generated from Tracker. A function was developed that extracted steps from the imported data file containing the hoofs x-position. The hoof positions could then be used in different plots and further analysis.

Using the definition of jump length and stride length discussed in section 2.3.1 and 2.3.2, values for these factors could be obtained.

6.3.2 Error estimation

Two types of error estimation were done. The first error estimation was done by comparing points x-position (horizontal displacement) assigned in Tracker with lengths measured while doing the tests. These points were taken at the edge of the view from the camera while the object measured was positioned at the center line of the test setup. This resulted in an approximate horizontal error of 5 %. Another source of error could be if the object tracked is moving closer or further away from the camera. This has the effect that objects closer to the camera appear larger (larger values of x-position) while objects further way experience the opposite effect and appear smaller. As mentioned in section 6.3 the origin was placed at the center of the first fence which means that the best data would be acquired when the horses move along the center line of the test track.

The tool Calibration tape has been used in order to assess the perspective error present in the tests. The tool measures distance between two points assigned by the user in Tracker. By measuring the distance of the fence supports (shown in figure 6.5) a minimum and maximum boundary is created in order which dines the track where the horse can move. By using the function Calibration tape and comparing with the distance measured at the test, the error is estimated to be ±1 0% from the center line.

Figure 6.5: Calibration tapes were placed in order to get an error estimation.

6.4 The length of the stride over the fence

As presented in section 2.3.1, the equation for the Distance formula 2.1 is given by $l = 1.3 \cdot h + 0.2$. Using equation (2.1), the following values were obtained for each height shown in table 6.2.

Table 6.2: Theoretical values from the Distance formula.

Height [m]	l
1.0	1.50
1.1	1.63
1.2	1.76
1.3	1.89

In order to be able to compare the data gathered from the tests the same method of defining the point of take-off and landing was used as in the research resulting in the Distance formula (see section 2.3.1).

The results from the conducted test are presented as the mean μ from test result for each height along with the standard deviation σ.

6.5 Loose jumping tests

The test where loose jumping was investigated contained three horses where each horse jumped the test course for each height. The age of the horses was 5, 7 and 13 year old, all breed for jumping. This test was performed without rider where the horse has to use its natural technique without the impact from the rider.

Table 6.3 contains the results for fence 1, and table 6.4 shows the results for the second fence in the combination.

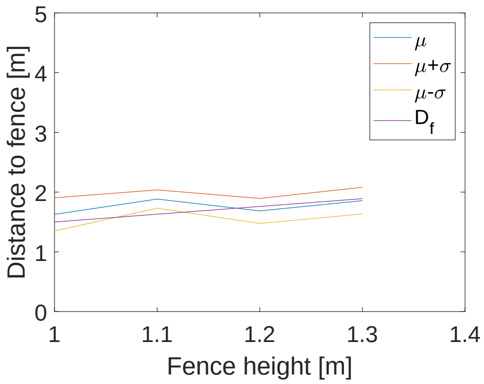
Table 6.3: The table shows the take-off and landing distance to fence 1 for the loose jumping test.

Loose jumping, fence 1, mean ± standard deviation [m]				
Distance [m]	a = 7.5	a = 7.5	a = 8.0	a = 8.0
Distance [m]	b = 7.0	b = 7.0	b = 7.0	b = 7.0
Height [m]	Take-off	Landing	Take-off	Landing
1.0	1.63±0.28	1.90±0.34	1.94±0.24	2.34±0.12
1.1	1.88±0.15	1.62±0.55	1.80±0.19	1.94±0.16
1.2	1.69±0.21	2.05±0.30	1.81±0.29	2.13±0.15
1.3	1.86±0.22	1.90±0.38	1.89±0.20	2.48±0.17

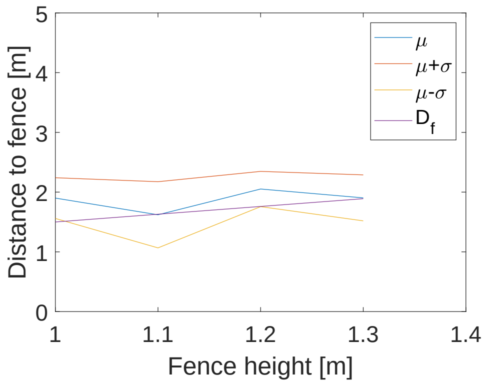
Table 6.4: The table shows the take-off and landing distance to fence 2 for the loose jumping test.

Loose jumping, fence 2, mean ± standard deviation [m]				
Distance [m]	a = 7.5	a = 7.5	a = 8.0	a = 8.0
Distance [m]	b = 7.0	b = 7.0	b = 7.0	b = 7.0
Height [m]	Take-off	Landing	Take-off	Landing
1.0	1.48±0.30	2.61±0.56	1.81±0.38	2.34±0.12
1.1	1.63±0.18	2.21±0.69	1.71±0.18	2.54±0.30
1.2	1.56±0.29	2.47±0.74	1.72±0.29	2.89±0.15
1.3	1.91±0.19	3.00±0.10	1.88±0.10	2.86±0.26

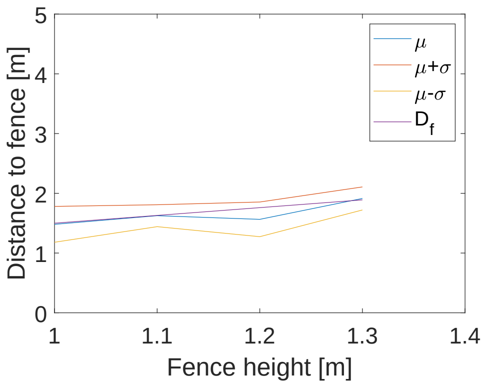
The plots visualize how the results compare with equation (2.1) by plotting the equation in the figures. The first four plots show the loose jumping test for $a = 7.5\,\mathrm{m}$ in figure 6.6.



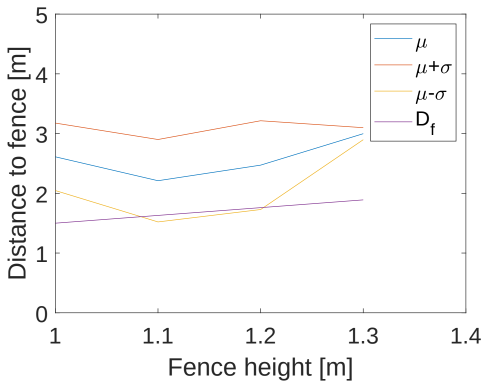
(a) Take-off, fence 1.



(b) Landing, fence 1.



(c) Take-off, fence 2.

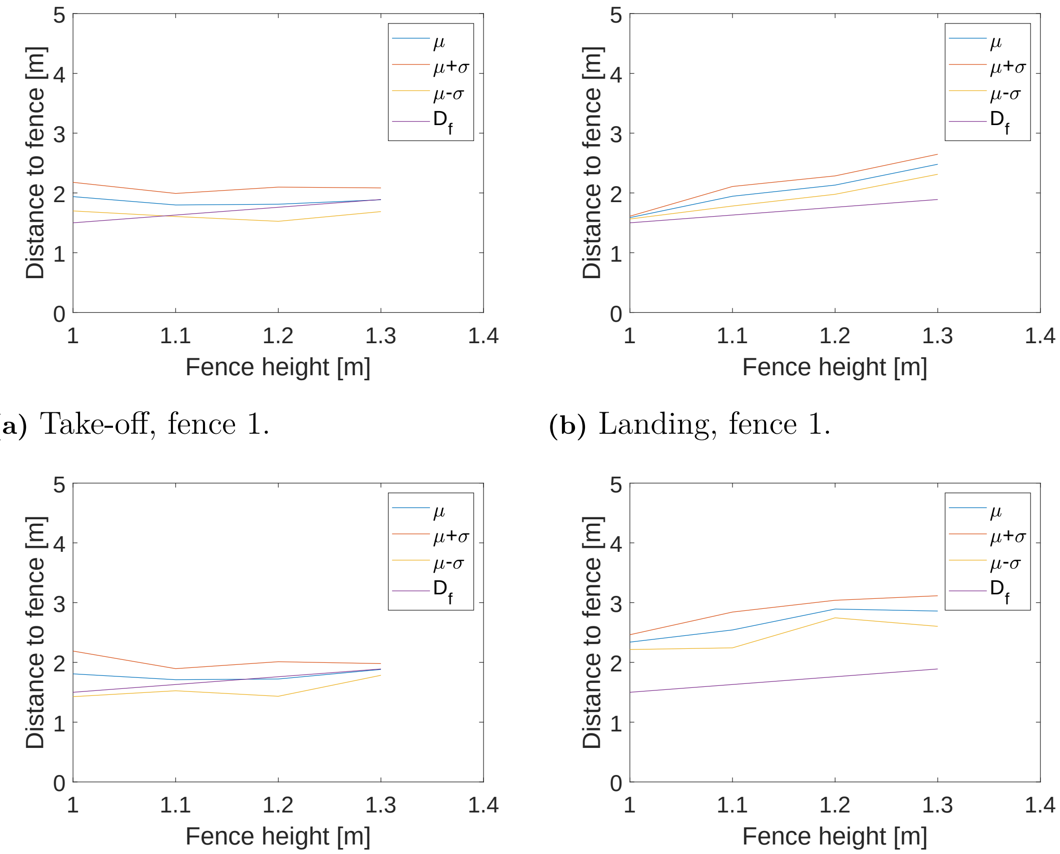


(d) Landing, fence 2.

Figure 6.6: Plots of the loose jumping test ($a = 7.5\,\mathrm{m}$), showing take-off and landing distance for different heights compared with the Distance formula (D_f).

By examining the plots, it can be seen that the data collected of the take-off distances fits the distance formula well. The landing patterns seen in fig 2 and fig 4 are more spread than the take-off points and although the Distance formula fit the landing

data for fence 1, it is outside of the landing data from fence 2. This is expected since the Distance formula was developed for take-off distances and the theory stated that the landing point is normally further away from the fence [18].
Further, the plots for the loose jumping test ($a = 8\,\text{m}$) are shown in figure 6.7.



(a) Take-off, fence 1. **(b)** Landing, fence 1. **(c)** Take-off, fence 2. **(d)** Landing, fence 2.

Figure 6.7: Plots of the loose jumping test ($a = 8.0\,\text{m}$), showing how take-off and landing distance for different heights compare with the Distance formula (D_f).

When increasing the distance between the fences to $a = 8\,\text{m}$, similar results regarding the fit versus the Distance formula are obtained compared with the take-off distance $a = 7.5\,\text{m}$. However, for the landing distances, the data is placed above the line representing the Distance formula.

6.6 Tests with rider

The Distance formula was developed using data from riders jumping a single obstacle. Therefore, a test was performed with a rider in order to show how the rider data from this projects test setup relates to the Distance formula. The test with rider were done with two horses (down from three in the loose jumping test).
Table 6.5 shows results from fence 1 where data is presented as the average from the two horse along with the standard deviation.

Table 6.5: The table shows the point of distance of take-off and landing for fence 1 in the test with rider.

Rider, fence 1, mean ± standard deviation [m]				
Distance [m]	a = 7.5	a = 7.5	a = 8.0	a = 8.0
Distance [m]	b = 7.0	b = 7.0	b = 7.0	b = 7.0
Height [m]	Take-off	Landing	Take-off	Landing
1.0	1.73 ± 0.27	2.09 ± 0.91	1.64 ± 0.23	2.09 ± 0.95
1.1	1.72 ± 0.16	2.30 ± 0.92	1.75 ± 0.07	2.04 ± 0.73
1.2	1.76 ± 0.06	2.37 ± 0.58	1.81 ± 0.10	2.20 ± 0.58
1.3	1.94 ± 0.28	2.24 ± 0.51	-	-

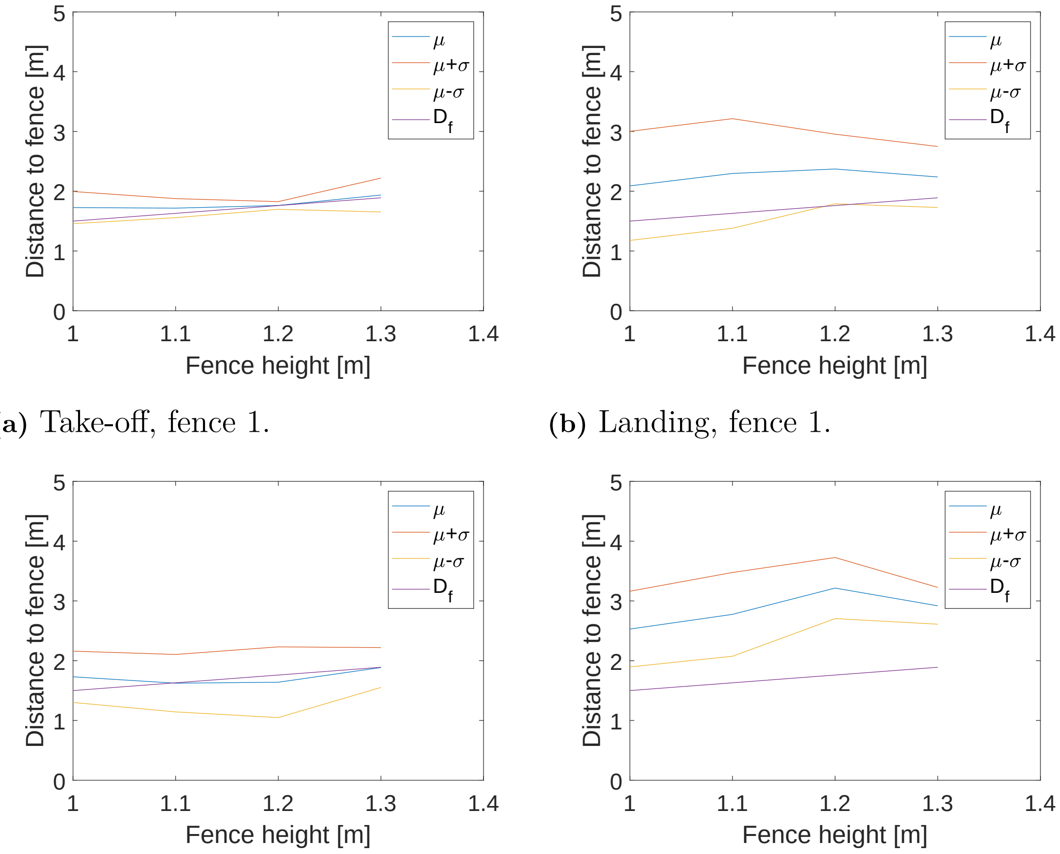
As can be seen in table 6.5 no data was acquired for $a = 8\,\mathrm{m}$. This was due to the horse's stopping before obstacle number 2.

Further, data for fence 2 is shown in table 6.6.

Table 6.6: The table shows the point of distance of take-off and landing for fence 2 in the test with rider.

Rider, fence 2, mean ± standard deviation [m]				
Distance [m]	a = 7.5	a = 7.5	a = 8.0	a = 8.0
Distance [m]	b = 7.0	b = 7.0	b = 7.0	b = 7.0
Height [m]	Take-off	Landing	Take-off	Landing
1.0	1.73 ± 0.43	2.53 ± 0.63	1.95 ± 0.58	2.43 ± 1.33
1.1	1.62 ± 0.48	2.78 ± 0.70	2.06 ± 0.67	2.62 ± 1.27
1.2	1.64 ± 0.59	3.22 ± 0.51	2.20 ± 0.48	1.87 ± 1.98
1.3	1.89 ± 0.33	2.92 ± 0.31	-	-

Plots showing results for $a = 7.5\,\mathrm{m}$ are presented in figure 6.8. Note that the number of horses used is $n = 2$, down from $n = 3$ in the loose jumping test.



(a) Take-off, fence 1.

(b) Landing, fence 1.

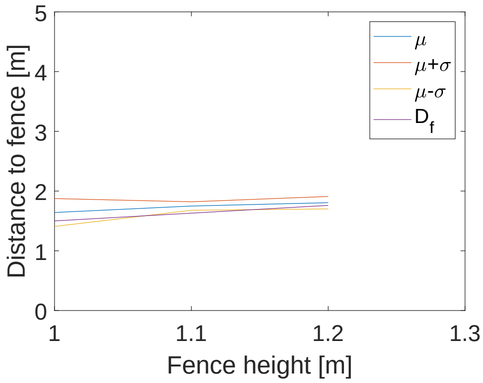
(c) Take-off, fence 2.

(d) Landing, fence 2.

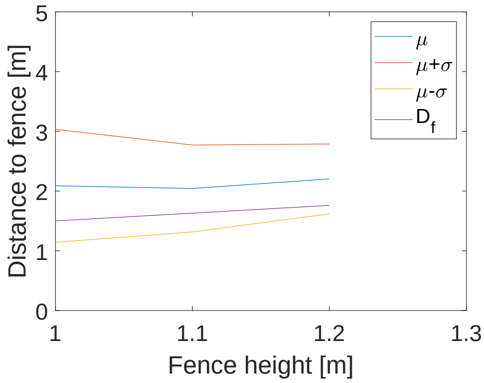
Figure 6.8: Plots showing test with rider ($a = 7.5\,\mathrm{m}$), visualizing how take-off and landing for different heights compared with the Distance formula (D_f).

A similar pattern appears in the plots shown in figure 6.8 compared to the plots from the loose jumping test. The data for take-off points are fairly close to the theoretical values from the Distance formula. The landing point data is shifted upwards in the plot, showing that landing takes place further away from the fence.

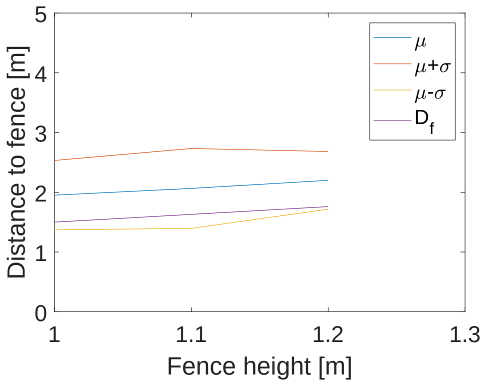
Plots showing results when $a = 8\,\mathrm{m}$ can be seen in figure 6.9.



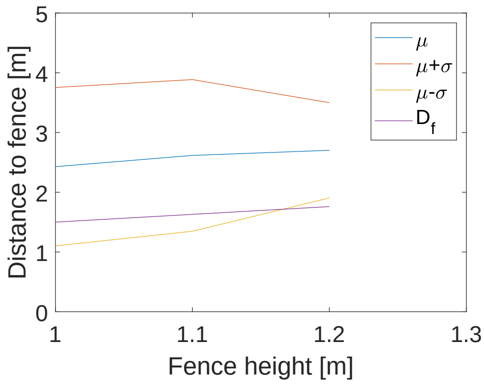
(a) Take-off, fence 1.



(b) Landing, fence 1.



(c) Take-off, fence 2.



(d) Landing, fence 2.

Figure 6.9: Plots of the test with rider ($a = 8.0\,\mathrm{m}$), showing how take-off and landing for different heights compared with the Distance formula (D_f).

When increasing the distance between the fences to 8.0 m the theoretical distance is within one standard deviation of the take-off data. However, the standard deviation is higher in general for take-off at fence 2 and in both plots showing landing data.

7
Discussion

The following chapter contains discussions regarding the results from interviews, the conducted survey and physical testing. It also contains a discussion regarding the methodology used.

7.1 Interviews and survey

The interviews were successful in that all interviewees answered all questions asked and seemed willing to participate. The partial lack of clear answers in terms of what factors to investigate is likely because the interviewees have not thought of the topic extensively before. And thus, it would rather come as a surprise if clear and exact answers were the result of the open-ended nature of some of the questions.

Although the majority of respondents in the survey compete in L-class, some similar answers were obtained during the interviews with professional riders and a course builder. This suggests that factors such as distances and speed are of interest independent of the competitive level of the user.

A difficulty in designing a survey is to balance the level of how specific the questions are. The questions should not be leading but at the same time preferably be focused on a desired area.

Another problem can be the length of the survey itself. When developing the survey, the number of questions where always considered in order to ensure that respondents would not stop answering in the middle of the survey.

The survey answers show a wide variety of answers to the more open-ended questions as expected. Although those answers might not have given exact results in specific KPIs to measure, they gave an initial area of interest, namely difficulties regarding distances and point of take-off.

7.2 Concept development

The developed concept does have some distinct advantages as well as areas that can be improved. One of the strongest properties the video analysis concept possess is its flexibility. The data collected during the tests could be analyzed further where velocities and accelerations could be analyzed. Further, another dimension of flexibility is related to being able to measure on different horses with one test setup. Another advantage of the video analysis concept is its property of being non-invasive. This means that it can be used on all types of obstacles (given that room exist to do so) where no casing or outer appearance needs to be changed.

By utilizing smartphones (or other digital cameras), most potential users probably have access to the necessary hardware which could reduce the barrier of trying the concept out.
There are however limitations to the concept as well. Since no translation of the data points is currently done, the camera positioning needs to be done in a correct manner. This puts requirements on the user in order to generate film that can be analyzed.
The lighting of the test area is a factor in the Tracker software's ability to use the function Autotracker. Although there is a possibility to apply filters on the video files in Tracker, there is a risk of reaching the programs memory capacity if the videos are long.
Further, points can be obscured at certain times which causes the Autotracker function to lose track of the point. This can happen when one leg is placed in front of another or when surface material whirls up when a hoof touches the ground. At this current stage, manual tracking is then needed in order to complete the set of data points.
Lastly, an additional camera placed in front, behind or above a fence would give information if the horse is moving sideways.

7.3 Observations

The data obtained for take-off position in both tests (loose jumping and the test with a rider) was consistent with the Distance formula. A slight difference may be noticed when the distance a was set to 8.0 m and $a = 7.5$ m. In the take-off data for that set, the point of take-off seems almost independent off the fence's height.
When analyzing the landing position, it lies above the line representing the Distance formula in most cases. This could be an indication of that the apex of the leap curve is reached after the studied point has cleared it. Furthermore, the variation in the landing data was generally larger than take-off variation. That may not be surprising when looking at fence 2, since the horse probably sees that there is no more fence's ahead and might therefore jump slightly differently.
The increased standard deviation present in the last test, with rider and $d = 8$ m, could be the result of only using two horses (two data points). Decreasing the amount of data can increase the variance since if the assumption is made that the take-off and landing can be viewed as a stable process. Further, these tests were the last ones conducted in the test procedure. Effects such as fatigue may have affected the performance which resulted in increased variation.

7.3.1 The definition of the stride length

The data presented in section 6.4 have been obtain by using the M_{closest}-definition mentioned in 2.3.1. This definition was used in order to compare the results versus the Distance formula. However, this definition would result in poor results for the stride between the fences. Since the min-method uses the minimum distances, before and after a fence, the stride in between two fences would become large.

7.3.2 Measurement errors

Since the tests conducted involves live animals the number of tests available was limited. This resulted in that a decision was made to not use replications in order to maximize the data looking at different heights. From a pure test design perspective using replications would have been ideal in order to quantify the noise in the measurements. Another option could therefore have been to reduce the number of heights for each horse and use replications.
The error estimation mentioned in section 6.3.2 of $\pm 10\,\%$ gives a hard boundary to the error caused by moving outside of the frame of reference. It is unlikely however that a horse would place itself right at either edge of the test track which would mean that the actual error is less. This can be exemplified by assuming that the horse would in most cases only use the middle section of the fence which spans 2 m (down from 3.5 m). By measuring at pre-determined points in Tracker, the inner 2 m span gives an error estimation of $\pm 4\,\%$. One way of reducing the error further could be to use homography in order to reduce the perspective error caused by camera placement.

7.4 Methodology

This thesis has used both qualitative and quantitative methods which can be suitable for this type of project which has a broad perspective. This can however also be demanding in terms
The limited number of test opportunities could perhaps have been disposed differently. A first test was done to develop the test itself. However, it could be discussed whether testing should have focused more on verification of the concept rather than also trying to generate new knowledge regarding kinematics connected to show jumping.
Another realization is that the number of ideas connected to the development of the concept began to sprawl once concept testing began. If testing would have begun earlier, it would have left more time to develop more functions and also refine the existing ones.

7.5 The effects of covid-19

The spread of covid-19 has surely affected all of us to various extents. This section presents changes and adaptations that had to be made in order to mitigate the effects for this project.
Covid-19 has limited the ability for this project to collect data. Several interviewees invited us to facilities where they are active in order to collect data. Further, the data collection was planned to be done early to mid April. This was however not possible due to large events being prohibited and thus these events have been cancelled. This also becomes an ethical question where the authors should follow guidelines and recommendations made by government agencies and Chalmers. Therefore, no trips were made to any of the interviewee's facilities.

In addition, covid-19 changed the way the authors worked, switching from meeting at Chalmers to doing the vast majority by distance solutions. Although this has not halted the project completely, it did cause delays in performing the observations which had to be performed at own held tests.

8 Conclusion

The overall purpose of this thesis was to develop a concept that could be used in a future product within show jumping for showing kinematic. A first step towards a product has been taken by answering the research questions. Below each research question is presented with its corresponding answer.

RQ1: *What kinematic factors would potential users be interested?*
The result from the survey shows that distances to fences is considered a problem for riders. Hence being able to present data showing point of take-off and landing has been focused on in the initial development of the analysis part of the concept.

RQ2: *What type of technology would be suitable for a concept measuring kinematic factors in show jumping?*
From the selection done through using the specification (shown in Appendix B) and Pugh-matrix (shown in Appendix C) video analysis was considered the best option. This due to its flexibility in range of kinematic variables that can be gathered and its ability to be used on several riders/horses.

RQ3: *How accurate is the distance formula when applied to loose jumping and lower heights?*
By using the observations made in this project, the Distance formula gives a good estimation of the take-off distance in relation to a fence. However, the formula does not provide accurate estimations for landing position. The actual landing distance was proved to be greater than the estimation made by the formula.

RQ4: *How does the distance between two fences affect the take-off and landing distances?*
Increasing the distance between fences seem to make the point of take-off less dependant of the fence height. Landing distances appear unaltered by increasing the distance, while it also increases as the height of the fence increases.

This thesis has given a first glance at what kinematic factors potential users are interested in. Further, the thesis has shown that video analysis has potential in a concept measuring kinematic factors. There is however much room for future research and development. Presentation of velocity and acceleration could give further possibilities for users to analyze their performance. In addition, although the limited number of tests, the landing distances varied substantially more than take-off distance. Hence it may be interesting to delve deeper into why the landing distance has larger variation. There are also potential to investigate how the error in position can be minimized, for instance by using homography.

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A

Appendix 1

Questions and results from the survey.

Enkät för hoppryttare om användandet av teknik

Detta är en enkät för att utreda behovet av tekniska hjälpmedel i samband med hoppning.

* Required

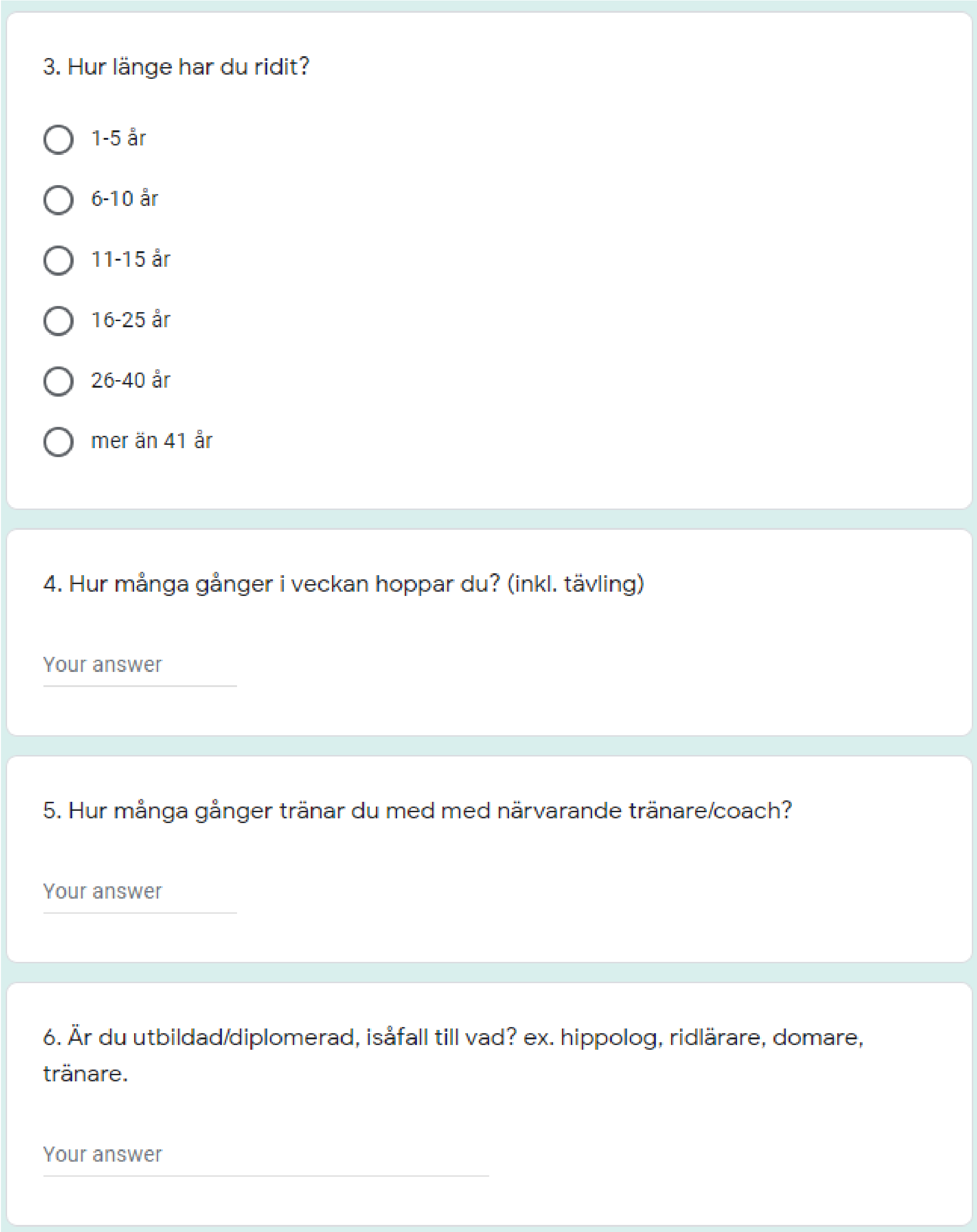
1. Vilken nivå tävlar du på? *

- Lätt klass (90-120cm)
- Medelsvår klass (130-140cm)
- Svår klass (150-160cm)

2. Hur många hästar har du som tränas och tävlas?

- 1
- 2-5
- fler än 5

Figure A.1: Survey questions 1 and 2.



3. Hur länge har du ridit?

- 1-5 år
- 6-10 år
- 11-15 år
- 16-25 år
- 26-40 år
- mer än 41 år

4. Hur många gånger i veckan hoppar du? (inkl. tävling)

Your answer

5. Hur många gånger tränar du med med närvarande tränare/coach?

Your answer

6. Är du utbildad/diplomerad, isåfall till vad? ex. hippolog, ridlärare, domare, tränare.

Your answer

Figure A.2: Survey questions 3, 4, 5 and 6.

7. Vilka hästar tränar du?

- [ ] Unghästar inför 3 och 4 årstest - mestadels löshoppning.
- [ ] Unghästar (<7år) som tränas och tävlas i utbildning.
- [ ] Hästar äldre än 7 år.

8. Hur avgör du avstånd mellan hinder/bommar?

- [ ] Ögonmått
- [ ] Stegar
- [ ] Har markeringar på väggen
- [ ] Mäter exakt mått
- [ ] Other: ______

9. Vilket eller vilka moment inom hoppning tycker du är svårast?

Your answer

10. Inom hoppning, när upplever du att det uppstår mest problem? (ex. anridning, rivningar, stop, takt, tempo m.m)

Your answer

Figure A.3: Survey questions 7, 8 ,9 and 10.

11. Har du olika avstånd mellan hinder/bommar beroende på vilken häst du rider? Om "ja", hur resonerar du kring avstånd?

Your answer

12. Hur vet du att din häst utvecklar sin hoppteknik? (ex. för statistik, analys, magkänsla)

Your answer

13. Övriga kommentarer. Tycker du att vi har missat något eller vill dela med dig av dina tankar så skriv gärna nedan

Your answer

Figure A.4: Survey questions 11, 12 and 13.

Results form the survey.

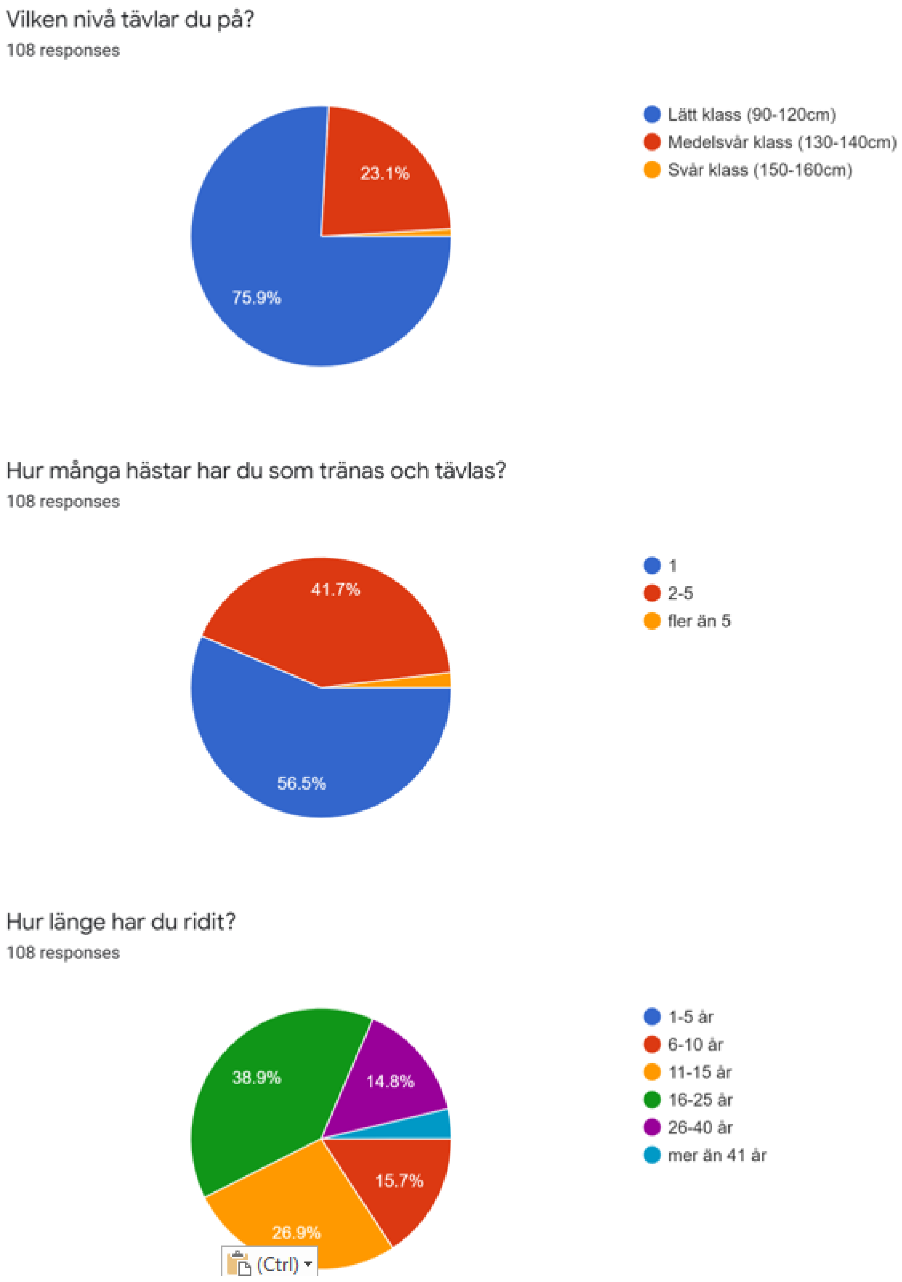


Figure A.5: Survey results for questions 1, 2 and 3.

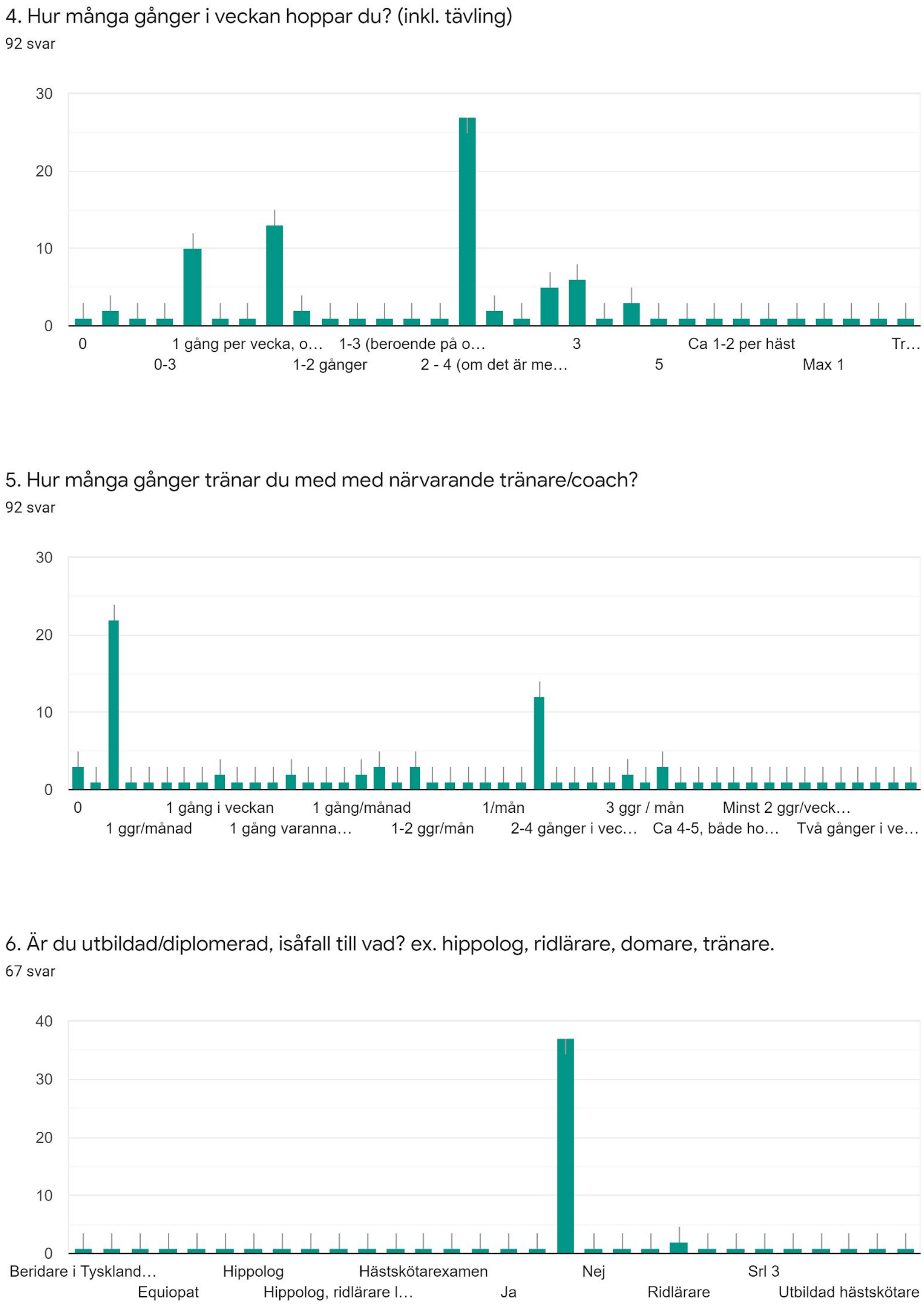
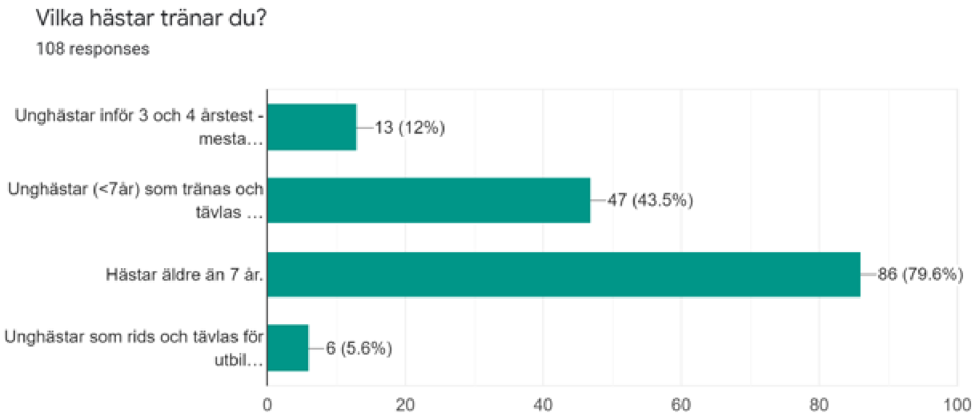


Figure A.6: Survey results for questions 4, 5 and 6.



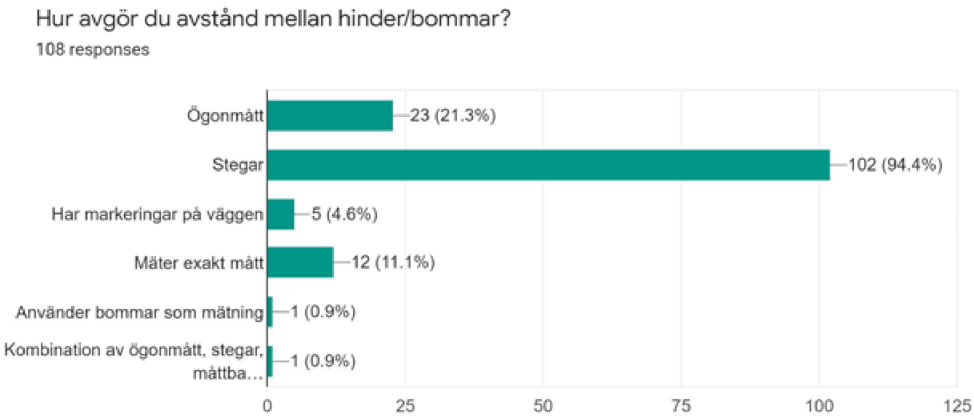


Figure A.7: Survey results for questions 7 and 8.

Vilket eller vilka moment inom hoppning tycker du är svårast?	count	percent	n
Anridning	8	9%	92
Avstånd	21	23%	
Tempo	4	4%	
Avsprångspunkt	4	4%	

Inom hoppning, när upplever du att det uppstår mest problem? (ex. anridning, rivningar, stop, takt, tempo m. m)			92
Anridning	33	36%	
Stopp	12	13%	
Takt	7	8%	
Tempo	24	26%	

Hur avgör du avstånd mellan hinder/bommar? (Multiple choice)			108
Stegar	103	95%	
Ögonmått	24	22%	
Mäter	12	11%	
Använder markeringar	5	5%	

Hur vet du att din häst utvecklar sin hoppteknik? (ex. för statistik, analys, magkänsla)			92
Film	37	40%	
Magkänsla	29	32%	
Resultat	6	7%	
Analys	15	16%	
Statistik	3	3%	

Har du olika avstånd mellan hinder/bommar beroende på vilken häst du rider? Om "ja", hur resonerar du kring avstånd?			92
Ja	36	39%	
Nej	25	27%	

Figure A.8: Survey results for questions 9, 10, 11, 12 and 13.

B

Appendix 2

The initial specification is shown below.

Chalmers	Project: Chalmer Technical Fence		Target requirement specification sheet				
Created: 2019.05.20							
	Criteri	Function	Goal	D/W	Weigh	Verification method	Demander
1.	Performance						
	1.1	Safety	Product must be safe for the user and the horse	D		Physical testing	All
	1.2	Measure velocity	measure both horisontal and vertical velocity	W	3	Comparing data with physical measurements	S.S, N.J, F.M,
	1.3	Measure length of the stride	be able to measure take-off and landing over two fences.	W	5	Comparing data with physical measurements	All
	1.4	Change in velocity/frequense/stride (regularity)		W	2		F.M, N.J, S.S, D.S
	1.5	Horse technique when jumping	measure technique (legs/back) in relatioinship to angle.	W	3		D.S
	1.6	Symetri of the movement	To measure that the horse moves symetrical both when jumping and flatwork.	W	2		D.S.
	1.7	Statistical analysis of result		W	4		S.S, N.J, F.M, D.S
	1.8	Minimal time to kalibrate the product		W	2		Developer
	1.9	Accurate data with fault <5%		D			Developer
	1.10	Non-invasive on course design or fence		W	5		All
	1.11	Flexability	Need to be work on different fences and location	W	4		Developer
2.	Enviroment						
	2.1	Product should be recycleble	the product have to be recycleble	D			Developer
3.	Life span						
	3.1	Life span without major, expensive reparation	>= 8 years	D			
4.	Maintenance						
	4.1	Maintenance free		W	2		All
5.	Cost						
	5.1	Maximum investment cost	1500 SEK	W	1		Developer
	5.2	Subscription cost	~100 SEK	W	1		Developer
6.	Modularity						
	6.1	Has to be connectable to app eg. andriod and Iphone	Connect to system	W			Developer

Figure B.1: Requirement specification.

C

Appendix 3

Appendix 3 shows the Pugh-matrix.

Wishes	Weighting (1-5)	Motion sensor	Radar/Lidar	Video Analysis
Measure distance from fence	5	-1	1	1
Measure stride length	5	1	1	1
Velocity	3	1	1	1
Symmetry of movement	2	1	-1	-1
Statistical analysis of result	4	0	0	0
Low need for regular maintenence	4	0	-1	-1
Easy to use	4	1	-1	0
Non-invasive on course design or fence	5	0	-1	1
Flexability	4	0	-1	1
Minus		1	5	2
Zero		4	1	2
Plus		4	3	5
Total		3	-2	3
Weighting score		9	-6	16
Rank		2	3	1

Figure C.1: Pugh-matrix including weights.

D
Appendix 4

This chapter provides an overview of the data analysis procedure and done in Matlab. This Appendix also provides a brief discussion of future possibilities of the concept.

D.1 Function development in Matlab

The exported data files form Tracker contained each hoofs position throughout the test track. These files where imported into Matlab where an initial preparation of the data was done. This preparation entails filling in missing points (due to different starting points of when an object appears in the frame) as NaN (not a number) in order to create arrays of the same length.

In Matlab, a function was developed that finds steps given the input of hoof positions. Further, the distance to a defined fence position is calculated for the two different definitions of the point of take-off and landing (see section 2.3.1).

Given these steps, a second program produces the plots of how where the point of take-off and landing occurs. The plots can be seen in section 6.5 and 6.6.
A minimum of built-in Matlab functions have been used in order to easily transfer the code to another programming language that may be more suitable for future development.

The step to implementing analysis of velocity and acceleration is not far away. Either velocity and acceleration can be exported from Tracker and thereby using Trackers algorithms, or given position and time, the same results can be obtained in Matlab. Therefore, the method for this could be chosen by considering what would be the most time-efficient or practical way.