Tracking system for a safety harness system

Tracking system for a Safety Harness System

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Abstract

The Toronto Rehabilitation Institute (TRI) in combination with the university of Toronto are developing the challenging Environment Asset Laboratory (CEAL) as part of a large research infrastructure upgrade program. The CEAL-simulator consist out of a six-degrees-of-freedom (six-DOF) simulation platform. On this platform researchers are able to investigate stability and balance of normal and disabled persons. Subjects will be placed on this platform and the simulation/motion system will cause the platform to move. These motions may vary from slow movements, steady state tilting of the platform and rapid movements.

Since the subjects will be performing their tasks on the moving platform, safety is a critical issue in this program. The subjects are generally older and impaired people who have suffered a stroke or an injury. Their safety is the critical aspect in the project. To prevent the subjects to become injured, a safety harness system is required to protect the subjects against the hazards of falling.

During this internship there is searched for the optimal solution for tracking a person on the platform. The current concept for the safety harness system is a XY-guidance mounted onto the platform. The safety system must track the motion of the subjects onto the platform. Goal of this internship is to find the optimal solution for this tracking problem. This is achieved by chronological treating the following aspects:

- **Requirements**, setting up a list with al the relevant requirements.
- **Possible solutions**, There is searched for commercial available measurement equipment en technologies which are capable to solve the tracking problem.
- **Concepts**, from the found solutions one is worked out in two concepts of which one is chosen.

This report is mend as a guidance document for The CEAL project and its subcontractors. It provides the necessary information for the subcontractors to make a package of detailed drawings and calculations, based on the stated requirements and concept drawings.

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Chapter 1

Introduction

1.1 Background

The Toronto Rehabilitation Institute (TRI) in combination with the university of Toronto are developing the challenging Environment Asset Laboratory (CEAL) as part of a large research infrastructure upgrade program. The CEAL-simulator will enable researchers to investigate stability and balance of normal and disabled persons. To develop techniques for the prevention of falls, to evaluate rehabilitation processes, the improvement and new development of assistant devices.

The experiments will be conducted in a controlled, repeatable manner using a six-degrees-of-freedom (six-DOF) simulation platform (figure1.1). Subjects will be placed on the simulation platform and the simulation/motion system will cause the platform to move. These motions may vary from slow movements, steady state tilting of the platform and rapid movements. With these controlled motions, it is possible for the TRI researchers to induce neuro-muscular reactions similar to those prior to a fall. To make the simulations more reality like it is possible to recreate realistic surroundings. In some simulations there will be a visual environment completely surrounding the subject on the platform.

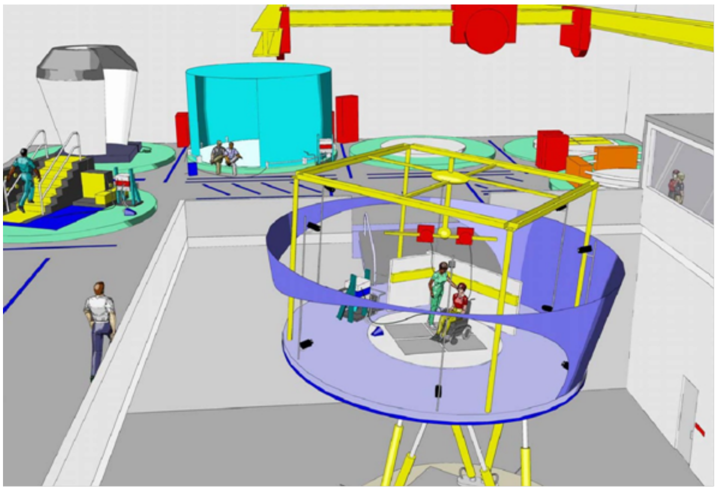

Figure 1.1: Artist impression of the CEAL complex

1.2 Safety

Since the subjects will be performing their tasks on the (rapidly) moving platform, safety is a critical issue in this program. The subjects are generally older and impaired people who have suffered a stroke or an injury. Their safety is the critical aspect in the project. The subjects should be remain unharmed during the experiments but also when failure of the motion system occurring.

In order to prevent falling, subjects are secured to a safety harness fall arrest system. This system makes sure that there is an anchorage point right above the subjects. The current concept for the safety harness fall arrest system is a XY-guidance mechanism which is mounted onto the platform and is actively driven to follow the movement of the subjects on the platform. On the anchorage point for the lanyards will be placed an passive Z-guidance system (retractable pulley). The safety system will be monitored by the motion tracking system. This system will monitor the movements of the subjects. The position measurements plus the absolute platform angel will be used to drive the XY-guidance mechanism.

1.3 IDT

IDT (International Department of Technology) is an independent and unaffiliated company that specializes in specifying and developing flight and vehicle simulators, and in managing complex multiplayer international programs. IDT operates with a small core of specialists with the availability of a broad range of resources. These external experts provide support to the backbone of core capabilities, allowing IDT to take on projects up to large sizes.

- Analysis of Research, Engineering or Training Needs
- Creating and participating in program teams within the customer's environment
- Systems Engineering for design specification and clear requirements management
- Compliance Verification of with international standards
- Simulator Systems Development
- Project Execution

Within CEAL, IDT functions as a covering institute, which is responsible for the simulator hardware and corresponding subsystems. IDT takes care of the specifications and additional requirements of the individual systems as well as the overall system. The realization, regulations and the overall responsibility of the subsystems will be kept with the subcontractors.

1.4 Problem definition and goal

Within the CEAL simulator, subjects will be performing experiments on the simulator platform in which they are subjected to situations with a great risk of falls. Since subjects will be walking freely over the platform, ensuring their safety is the most critical aspect in the entire project. Therefore a safety harness system is designed to protect the subjects against the hazards of a falling. To obtain a minimal risk the XY-mechanism of the safety harness system must follow the subjects movements on the platform. For that a form of tracking is necessary that the subjects position on the platform is measured and fed back to the controller of the XY-mechanism.

The main goal of this study is to define the requirements at which the tracking system must satisfy and choosing a measuring method. These two items are of great importance for the project as the individual systems like the safety Harness System will be realized by subcontractors.

1.5 Approach

At the start of the internship there has been looked to the demands and wishes of the total system an some specific subsystems. This analysis has led to the formulation of a list with requirements regarding the global use of the system and some specific requirements of the tracking system. These requirements are presented in chapter two. In chapter three there is searched, using the requirements, for possible solutions for measuring the position of the subject(s) on the platform. By comparing the differed measuring methods and using value judgment it is possible to choose the most suitable measuring method. In chapter four the chosen measuring method is worked out in another two concept of which one is chosen. And finally in chapter five there are presented some conclusions and recommendations.

Chapter 2

Requirements

In this chapter the requirements for the fall arrest system are formulated. This is done with in mind that the main function of the fall arrest system is to protect people participating in CEAL experiments from injuries during a possible fall. And providing full freedom of movement (or as much as possible within the boundaries of the system) without practicing any disturbing forces on the test subjects.

2.1 Global requirements

The global requirements refer tot the "normal use" of the entire system. These requirements are not specific for a single part of the CEAL, or specific for the tracking system. They describe the startup, operation, maintenance and environmental conditions of the CEAL. [6] [1] [4] [3]

2.1.1 Required environmental Conditions

An important component of the simulations performed on the CEAL, is the possibility of imitating the effects of different environment circumstances. The use of these effects like rain, mist or a varying temperature range, leads to a specific set of environmental requirements which differ from the usual requirements for an indoor facility. The functionality of the CEAL may not suffer due to the consequences of these environmental effects, and the system must be resistant against;

1. Temperature range of -10 deg C to + 40 degC
2. 0 to 99 % relative humidity
3. Pressures between 998 and 1025 hPA
4. Snow or rain
5. Adjustable wind velocity (using a ventilator)
6. Decreasing visibility (using a smoke machine)
7. Variation in luminosity (varying from total darkness to bright sunlight)
8. Surrounding noise (created by the simulation software)

2.1.2 Maintenance and service

Although maintenance and service are not necessarily mechatronic issues, they directly relate to the used sensors and actuators and therefore influence the design of the tracking system. Following requirements are an indication for the maintenance level and are sufficient for now, describing the service for the Safety Harness System with corresponding parts. It may be clear that these requirements are nothing but complete, and do not cover the maintenance for the complete system.

1. Regular maintenance shall be done by competent persons at Toronto Rehabilitation Institute (TRI). Extensive maintenance should be done by mechanics with support or supplier/ manufacturer consult.
2. The supplier or manufacturer of the safety harness system shall provide documentation on how to maintain and check the safety harness system.
3. Defective components shall be replaced only by original parts or parts prescribed by or in consultation with the manufacturer.
4. The mean time to repair (MTTR) of the safety harness system shall be less than 4 hrs (estimated value), depending on the broken component.
5. The mean time between failures (MTBF) shall be more than 50.000 hrs (estimated value).
6. Two persons should be able to do the maintenance on the safety harness system.
7. After each repair, a competent person shall test the safety harness system real time to verify that the system is working correctly and that there is enough clearance to walls or objects. A redundant lifeline should be used for the tester.
8. It should be possible to use a (small) ladder for maintenance instead of climbing on the supporting structure. For extended maintenance, the safety harness system shall be removed from the platform.
9. Different environments and surfaces may cause the platform and the safety harness system to become dirty. The safety harness system must therefore be easy to clean.

2.1.3 Preparation

The preparations needed to perform simulations on the CEAL should be kept to a minimum and should be easy to perform. With this said, the time needed to put on the safety harness or attach it to the equipment should be kept in the order of minutes. Also the time to install, time from attaching to the safety Harness System till simulation start, must be kept to an minimum.

1. It shall be possible to wear part of the safety harness before entering the platform and then attach the safety harness to the suspension structure.
2. The safety harness system shall provide individual protection to maximum 2 human subjects.
3. Before each simulation session, a test person shall inspect and test the safety harness system real time to verify that the system is working correctly and that there is enough clearance to walls or objects. A redundant lifeline should be used for the tester.
4. Before each simulation session, all equipment on the platform must be checked whether they are properly placed and secured.

2.2 Specific requirements

Items discussed in this paragraph treat the requirements for the Safety Harness System and more specific the requirements for the tracking system and the accompanying subsystems. [6] [1] [4] [3]

2.2.1 Loads

Since the safety harness System is a mechanical system, it is important to know something about the velocities, accelerations and loads which work on the system. Not only the mechanics have limitations, CEAL works with human users, which have their own limitations concerning accelerations and descending rates. It is only reason there is a Safety system anyway. These considerations are taken into account and are implemented into the load requirements.

1. The fall arrest block shall be able to handle a vertical load of 300 kg (two subjects of 150 kg each) or an vertical load of 450 kg (one subject of 150 kg walking and one subject in a powered wheelchair with a total mass of 300 kg).
2. The fall arrest block shall be able to handle with subjects with a minimal body weight of 40kg.
3. Although platform tilts of maximum 15 degrees will be used, the hardware limitation of the platform is a tilt of 40 degrees. Therefore, the safety harness will be designed to be operated safely when motion occurs at these angle.
4. Normal accelerations and decelerations of the motion platform will be maximum 1 g in translational directions. For extreme motion system failures (like sudden valve closure), the safety harness system should be designed to be operated safely to maximum decelerations of 2.5 g for about 350 ms.
5. The safety harness system should be designed to be operated safely to velocities the motion platform of up to 1.5 m/s.

2.2.2 Operational requirements

When using the CEAL a number of different items may attract the attention. These can be small items, like giving a light signal in a certain situation. But some operational demands can highly influence the design of the Safety Harness and its tracking system.

1. When the safety harness system intervenes, an indication light or sound shall be visible or audible both in the simulator and in the control room.
2. The researchers on the platform and the operator in the control room shall be trained or instructed on how to use the safety harness system.
3. The safety harness should only be released (manually) when the motion platform is completely settled.
4. The safety harness system should have an independent motion tracking system to monitor subject movement.
5. The subjects must be able to walk around freely without being restrained by the safety harness system. The safety harness system should only intervene when a subject falls and when he is not able to recover.
6. It should be possible to use the Fall arrest system for powered wheelchairs and/or other mobile medical equipment.
7. When a subject is wearing the safety harness, it must still be possible to connect him to medical equipment. Large medical equipment shall be secured to the platform, preferably at the edge. Compact medical devices can be attached to the subject's harness.

8. When using a descent device, the subject will slowly be lowered to the ground after a fall arrest.
9. It must be possible, either by the assistant or by an operator in the control room, to manually activate and reset the safety harness system.
10. It should also be possible for the assistant to manually activate the fall arrest block of the patient.
11. Connecting lines between the subject and medical equipment shall not interfere with the movements of the subjects.
12. Lanyards shall be kept straight and under a certain tension by means of a self-retracting mechanism or an equivalent mechanism. The lanyard tension shall be such that the subjects do not experience any inconvenience of the fall arrest system.
13. The subject shall not be disturbed by noise of the tracking system. Above all, the subject shall not be able to perceive the operations of the tracking system by its noise.
14. The subject must not be disturbed visually by the tracking system. The control room shall not be visible to the simulator occupants during experiments.

2.2.3 Mechatronics

1. During a fall arrest, the arrest force may be dependent on the subject's condition and shall be 4000 N maximum.
2. The planar range of the tracking system shall be an area of 6000 by 6000 mm. As an extra safety measure, only an area of 5000 by 5000 mm shall be used for experiments to create a buffer zone between subjects and the edge of the platform.
3. The tracking system shall not drift away due to gravity or inertia effects.
4. The suspension point of the safety harness must remain above the subjects within a reasonably range (about 0.2 m), even when the motion platform tilts (up to 40 degrees) or translates (with maximum decelerations of 2.5 g).
5. When subjects are moving too fast in horizontal direction and/or the tracking system is not capable of tracking them, the tracking system shall brake and as a response the fall arrest mechanism shall hold the subject.
6. The tracking system shall be self-locking. It will be locked by brakes when no power is supplied to the drive system. Only when the drives system is powered, the brakes shall release.
7. It is preferable (or maybe wishful) to connect the safety system with the simulation software, to make active steering of the fall arrest system possible. The fall arrest system may adapt to or prepare to extreme platform motions (high accelerations or maximum tilt). However this connection may not override safety protocols and endanger the subject's safety!

2.2.4 Production and regulation

To guarantee the operation and safety of the individual parts as well as the entire system, some requirements are made to the suppliers. The main idea is that it is possible to have a fast and reliable production of the system, without spending too much time with individual specifications and regulations. Each supplier is responsible for its own part of the program.

1. The fall arrest system is preferably constructed out of standard parts and/or products to minimize manufacture and testing time.
2. The responsibility for the functioning and regulation of the individual parts and/or systems is preferable kept by the supplier.
3. The supplier should be qualified to CE and CSA norms, as well as their product.

2.3 Failure modes

System failures can occur when the motion system receives false or receives no commands from the host computer. This may occur during a hardware failure (broken sensor) or during power fall-out. Although system failures can occur, the safety of the subjects on and around the platform may never be endangered. The following subsections describe the appropriate actions which should take place when errors occur. The failure modes are divided into motion system failures, concerning the systems motion system and Safety harness system failures, specific for the safety harness system. [6] [1] [4] [3]

2.3.1 Motion system failures

1. When malfunctions are recognized in the motion system, the tracking system should brake. Even when no abnormal platform movements occur. This can only be triggered by a signal send by a computer or manually by the operator.

2. The tracking system should brake and the fall arrest system should remain functional whenever abnormal platform movements at high accelerations occur. This would be the case when a motion system failure has not been recognized in time or at all (failure alert not send by computer or by operator).

3. Measures through redundant systems shall be taken to limit extreme platform movements. The safety harness system however should be functional even when these redundant systems fail.

2.3.2 Safety harness system failures

1. The safety harness system should remain functional when the tracking system fails. Experiments should be stopped until the tracking system is operational again.

2. Before the experiment starts, TRI researchers shall make sure no object or obstacle can be reached when a test person sways sideways due to a sudden stop of the motion base. The safety harness system prevents contact with the sidewalls but cannot prevent currently unforeseen contact with high obstacles. Sometimes it should be possible to touch certain obstacles to hold on to it.

Chapter 3

Solutions

To guarantee a correct operation of the safety harness system, the subjects position on the platform is an important parameter. In this chapter two measuring methods are discussed;

- Tracking the safety line, where the cable orientation is an direct measure for the position error of the XY-mechanism. (Relative position measurement.)
- Measuring the position of the subject with respect to a fixed known point on the platform and compare it with the absolute XY-sled position. The error signal can be generated out of these two position measurements. (Absolute position measurement.)

These two measuring method are discussed as well as their operating principle, hardware/sensor usage and its suitability for this specific application.

3.1 Cable tracking

One method to track a subject moving on the platform, is by using the safety line. The safety line is always connected to the subject and it is therefore possible to use it for determing the relative position of the subject with respect to the connection point of the safety line. The z-position (height) of the subject is not relevant for the tracking system, for it is taken care by the descending device.

To minimize the influence of the safety system on the freedom of movement, and in case of falling, keep the deadzone as small as possible, the safety line is kept under a small tension. Due to these tension the line between the harness and the anchorage point is kept in a straight line and can be used as a sort of position vector for the subject with respect to the xy-guidance system.

3.1.1 Platform angle

One disadvantage of this method of tracking is that it does not take into account the platform angle. Test subjects should always be perpendicular to the suspension point of the safety harness system, even when the platform is tilted. This effect can be canceled out by takeing along the platform tilt angle into the controller of the XY-mechanism. The tilt angle can be measured by some form of gyroscope, or can be calculated by the simulation software. Using simulation data is only possible when the autonomy of the safety harness system can be guaranteed, and will not be dependent from the platform hard- and software. The possibility of platform soft- and/or hardware failures is precisely one of the reasons a safety system is needed.

3.1.2 Measuring methods

There are roughly two ways to use the safety line to track the position of the subject on the platform, and determine the desired position of the xy-mechanism. It is possible to create an reference plane under the xy-mechanism in which an xy-position measurement can be made. The measured distances can be used to determine the tracking error. It is also possible to measure the angle the safety line makes round the x- and y-axis. The deviation from the perpendicular (with correction for platform tilt) is an direct measure for the tracking error.

The use and type of measuring sensor can be discussed. When accuracy is examined, just two simple switches could be sufficient. The switches only sense the touching of the cable, when the translation exceeds a certain tolerated area. This is sufficient for the cable orientation and therefor the direction of the position error. This could create a form of system damping (but also play!) preventing the system to reacting on oscillations in the safety line and jumpy movements of the subjects. When using more accurate measurements methods, measuring rod, protractor or force element it is possible to realize a more accurate tracking and more progressive control actions.

3.1.3 Summary

It can be said that this is an reliable and simple method to realize tracking. It is expected that satisfying the required tracking error is not a problem and a more accurate tracking is also possible. There are not many parts needed and that there is no demand for enormous calculating power, which results in a fast and reliable system with simple and cheap sensors. In operation this system will demand less maintenance. Also starting up simulations will not cost a lot of time since there are no sensors attached to subjects and there is no need to initialize. Points of interests are for now;

- The external sensor which measures the platform orientation.
- The safety line, which could suffer uncontrolled movements like wobbles and waves.

It is expected that the costs for the orientation sensor would not be that high. And due to the high stiffness and short length, the cable will be rigid enough to function as a measurement resource. A rough estimation for the cost lie in the order of €1.500. The major part of this is due to the cost of the mechanical construction because the estimated costs for the sensor part is estimated to be less than €100.

3.2 Person tracking

The second option to realize tracking is following the subject itself. The subject should not encounter any inconvenience of the tracking system, so it is not possible to connect him directly to a ruler. A wireless measuring system could be a solution. In this paragraph a number of such wireless measuring methods are discussed.

3.2.1 Triangulation

Although triangulation is not a measuring system, most measuring systems are using triangulation in some form. For this the principle of triangulation is briefly discussed. In most systems where it isn't possible to directly measure a distance, displacement or height using a ruler, triangulation is used. Most generally known examples are GPS or naval navigation. Triangulation is based on the characteristic of a triangle that it is completely determined when one side (base) and the neighboring angles are known. The sides of the triangle are proportional with the sine of the opposite angle. Using this property for the objective of length or position determination, angles are measured to determine distances or distances are measured to determine the angles.

In the Safety Harness System the base of the triangle is formed by two defined points on the platform. The tip of the triangle is moving, the subject on the platform. The subject's position is now determined with the help of a location algorithm based on triangulation. This is known as forward incision, at which two ore more coordinates are known and the position of the subject with respect to these coordinates can be calculated.

Although in theory, two defined points are sufficient to determine the position of a third point, several circumstances can bring on the need for more defined points. The number op reference points are defined by the type of sensor and it's surrounding. The network of sensors can be obstructed due to working principle, optical barriers, radio interference or sensor sensitivity.

3.2.2 GPS Systems

The Global Positioning System (GPS) is a world wide triangulation based positioning system, which has its origins in military outdoor position determination. Some civil applications are naval navigation, satellite navigation on motor vehicles and hand held units for hiking and camping purposes. The GPS principle can also be used for indoor purposes. There must be a number of local GPS transmitters also known as pseudolites. This system is mentioned once again because of the fact that this type of indoor GPS are commercial available products. Their operation principle can vary depending on the application from radio based to optical (laser or infrared). [7] [5]

For use in CEAL this type of positioning system could be used. The most commercial available products are more aiming on large scale indoor positioning with less accuracy. One example can be the tracking of a fork-lift truck in a machine factory. When using this system for CEAL prices for the GPS soft and hardware will start at about €10000 (order of magnitude).

3.2.3 Network based systems

Network based positioning systems are a specific sort of position determination. Instead of using sensors which measure distance or orientation, a network is used. This can be commercial available (means relatively simple and cheap) network applications such as an already existing WLAN or bluetooth system. At the same time an advantage is that these network systems maybe already available and there is no need for specialized knowledge (or is maybe already available with the network supervisors). Commonly used methods for determing the position of a transmitter within a wireless network are;

- **Cell of origine** (COO),method which determines which transmitter is the closest one delivering signal to the receiver.
- **Time of arrival** (TOA),network based positioning method that measures the time it takes for radio signals to arrive at and from multiple acces points.
- **Received Signal Strength**,(RSS)determines the distance from the measured signal strength. For most situations the signal strength is inverse quadratic related to the distance between transmitter and receiver. on its own a reliable method, but in practice the send signal is not homogeneously spread due to antenna position and construction.
- **Time difference Of Arrival** (TDA),The difference in time between departure and receiving of the network signal is measured. Measure for positioning accuracy with this method is the degree in which the signals differ, and is therefore less suitable for small scale position determination, as is required in CEAL.
- **Fingerprint methods**, The network properties like signal strength, COO are mapped over the area in which position determination is taking place. The receiver compares these parameters with the measured values and determines using a sort of lookup table it's position within the mapped area.

The choice for one or more positioning methods depends on the application. Important parameters are, the size of the area to track, required accuracy, required speed, required signal/transmittor strength and (already present) signal type. Depending on above mentioned properties a choice can be made for one or a combination of the mentioned measuring methods. [2]

For use in CEAL WLAN could be an option. A propagation (signal spreading) model can be made, in which the signal strength and the different access points are use up (COO en RSS method). The mobile client measures signal strength of all surrounding access points and delivers these data to the positioning engine which can calculate the position by solving a maximum likelihood problem. With the advantage that the system is not affected by the fact that several access points transmit at the same frequency because it uses the integrated signals (receiver "knows" which signal is sent by which transmitter).

3.2.4 Vision systems

When using a vision system, an objects position and displacement can be determined using image recognition. The object is scanned (filmed) using a CCD or an digital videocamera using visible or ir light. The images are converted into digital pattern using a image-processor and compared with stored pattern to identify objects and movements.

The refreshing rate of most vision systems is quite high, in the order of magnitude of 1000 to 500 images per second. This high refreshing rate makes it possible to track subjects real time with a high level of accuracy. One of the disadvantages of this type of system is that it compares images with known stored data, which makes it in practise rather unstable when using it on objects without a unambiguous defined shape (such as an human person). For these unstable objects, markers should be placed which cancels out the advantage of a vision based system.

Vision systems are extremely flexible, nevertheless the subject or more specific, the suspension point should always be visible. This viability can not be guaranteed in the highly changeable environment of CEAL, where objects and fog can decrease the viability to zero. Combined with the high costs makes a vision based tracking system not the most obvious choice.

3.2.5 Motion capture systems

Motion Capture Systems are highly specialized systems which are especially mend for register person movements. Common applications for these type of systems ar into the course of the biomechanical industry, sports analysis and revalidation. It can also be used for generating large scale and difficult animations as used in the film industry. In the most used scenario, subjects are hanged with radio sensors or optical markers. The movement of these independent sensors is translated using a extern computer into a rigid body model of the subject and can be used to analyze the subjects movements.

In CEAL the tracking system should track the movement of the subject in a horizontal XY-plane, while a motion capture system registers movements in a 3D environment. For use in tracking system these difficult registrations are not necessary and can financially not be justified for use as tracking system only. When TRI-investigators decide to obtain a motion capture system for medical purposes, it could be considered to use it in collaboration with another stand alone safety system for a more intelligent safety system (predict when a subject is going to fall, depending on previous actions). Nevertheless the autonomy of the safety system should always be guaranteed.

3.2.6 Magnetic trackers

Magnetic trackers can be used to capture translations and rotations in 6 Degrees of freedom (6-DOF) surrounding. This technique is most commonly used as an interface to a virtual world, for instance, by tracking head, hand, or input device motion. Therefore magnetic tracking technology is a viable option for (full-body) motion capture. This information can be used in real-time, for simulation uses or as input for a mechanically driven system. A typical set-up contains the following components:

- A transmitter, usually permanently installed on a workspace ceiling
- One or more sensors, often attached to special helmets or gloves
- An interface device and a controller/computer.

The magnetic trackers could be compared with the motion capture system mentioned above, but differ at a few points due to their operating principle. Some important differences (positive as well as negative) are mentioned;

- No line-of-sight issues, electromagnetic fields can travel through minor obstructions like human beings. Therefore, a sensor that is facing away from the transmitter, occluded by a body, can still yield valid data.
- Magnetic trackers are on the lower end of the spectrum, and can be much cheaper than optical solutions. A key portion is that the processing is not complex compared to other solutions, so the computational equipment demands are slight.
- Electronic devices, and conductive or ferrous metals, can distort the projected electromagnetic field. When the field is inaccurate, readings are similarly inaccurate. This can be neutralized by mapping the electromagnetic field, but must redone with every change of the surrounding in which the subject is tracked.
- Since the field falls off with the square of the distance, readings at the edge of the field are much less accurate, so distance diminishes accuracy.

- Minor fluctuations in current and the surrounding can cause a tracker to report motion when none is occurring. Even if this motion is quickly corrected for, the rapid small-range motion gives the jitter effect. With the highly moveable simulation platform this could be a major disadvantage.

For the use in CEAL magnetic tracing is one of the sensible possibilities, with a price varying in the range between €3000 and €6000. Due to the highly variable surroundings on the platform, the system would be rather labor-intensive. This combined with lesser accuracy, makes magnetic tracking a possible but not the most obvious solution.

3.2.7 Other commercial available tracking systems

In the above paragraphs a number of the most occurring wireless measuring/positionig systems. It will often happen that commercial available systems slightly differ from the described working principles or combine one ore more. A well known example are vision like systems with a acoustic working principle (sonar), canceling the demand for visible objects. Or radio beacons with the same working principles as described in the subsection Network based systems. For the reason of readably and the fact that this chapter is just a global overview, is chosen not to name all these small individual systems and products as they do not contribute to a better overview and understanding of the substance.

3.3 Comparison

The measuring methods discussed in the above paragraphs are all more or less capable to reach the required accuracy. To determine which variant is the most suitable option for applying in CEAL they are compared on a number of points. In table 3.3 an overview of the discussed systems is given.

Technology	**Measuring method**	**Hardware**	**Sensor type**	**reliability and stability**	**price**
Cable tracking	Direct with platform angle compensation	cable tracker	Angular or linear displacement sensor Load cell	Stable	€1.500
Indoor GPS	Triangulation	Trackers Satalites	laser Ir Radio based	Stable	€10.000
Network based	Signal strength Time of arrival Angle of arrival Cell of origine (triangulation methods)	WLAN Bluetooth Transmitters and receivers	WLAN	Stable but inaccurate	€2.000
vision	Computer generated	Camera	Optical (visible/IR) with or without markers	Quite accurate but instable	€10.000
Motion capture	Computer generated	Camera Radio Based Independent motion sensors	Optical (visible/IR) with or without markers Radio markers Gyroscopes Accelometers	Stable and sufficiently accurate	€30.000 - €50.000
Magnetic tracking	Field orientation	Receiver	Electro magnetic coils	Stable but labour-intensive	€3000 - €6000

Points as Used technology, Measuring method,Needed hardware and sensor type speak for themselves. The points Price, Reliability and stability need some explanation.

- **Reliability**, As the Safety Harness System, protects subjects in case of falling, this one of the most important points at which the systems are examined. The measuring system must be redundant and always be operative. Technologies which have a higher reliability due to lack of failure sensitive parts or measuring method have an intrinsic advantage in comparison with other techniques.
- **Price**, Although safety is a key issue, on which may not be cut down budget limits the some of the solutions. For the Safety Harness System the budget is set on approximately €150.000 with more specific€10.000 as a target for the measuring part as described in this report. Price estimations are made based on a single piece fabrication and should be seen as a indication as real prices depend on specifications like build in dimensions, signal type and peripheral devices.

Of the six mentioned methods already three can be excluded based on the poor reliability and stability or lack of accuracy. The remaining three; Cable tracking, indoor GPS and magnetic tracking can be sorted out based on their suitability For the specific use in CEAL.

Some of the measuring methods demand for a specific sensor use. Subjects performing experiments in CEAL should not be obstructed in their performance by sensors or markers used by the tracking system. Or be harassed by long preparation and initialization procedures. Measuring methods which require such implementation are considered as not suitable for this specific application. For these reasons the use of magnetic tracking is not considered the best method for this application.

With cablet racking and Indoor GPS both remaining as feasible solutions, the low cost price, easy maintainability and most important the simple design tip the scale in advantage of cablet racking. This is probably the most simple solution with the smallest chance for disturbances and hardware failure.

Chapter 4

Concept

In the previous chapters some possible solutions for the following of a person on the platform are discussed. Out of this discussion the option of cable tracking as a measurement for the subjects displacement on the platform is chosen. In this chapter some points of interest, two measuring concepts specific elements of this solution are discussed.

4.1 Points of interest

As mentioned in chapter three there were some points of interest concerning this type of tracking solution;

- The sensor which measures the platform orientation.
- Wobble and waves in the safety line.

Concerning the external sensor no further problems are expected. Industrial gyroscopes or even more simple versions as used in model helicopters are available which can measure angles in three dimensions (Although only two would be sufficient!). They are also quite insensible for drift on the angular position measurement. It could also be well possible to use superfluous rotational axis as a measurement for the drift of the gyroscope.
This said, the angular position should always be set to zero before starting a new experiment. And before implementing a gyroscope into the control loop of the safety harness system, the angular drift must be examined.

When the safety line is used in the tracking system, wobble and waves could jeopardize the accuracy of the position measurement. Or in extreme cases could lead to instabilities in the safety harness's motion system. For these reasons the absent of these effects are of the most importance.
User tests performed with the North Safety decent controller gave no reason for expecting cable wobble. Due to the relative high cable stiffness, short span of the cable (typical less than two meters during an simulation) and a preset tension, movement of the attached subjects does not cause wobble in the cable.

4.2 Joystick measuring

With Joystick measuring the safety line is followed by a joystick like pyramid, in which the cable is fed through, as can be seen in figure4.1. There are two axis in which two bodies are rotating. These rotations are direct measures for the deflection of the safety line in X and Y direction. The rotations can be measured by two rotational potentiometer resistance. These sensors can be, when placed in a Weedstone bridge, directly as a input signal for the motion system.

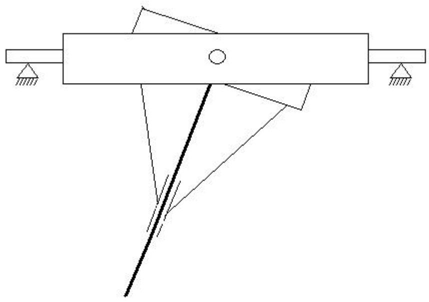

Figure 4.1: Schematic view of the joystick

Within the motion system a compensation for the platform angle should be made as the Joystick does not take take into account this angle.

4.3 Tension ring

Another possibility for measuring the deflection of the safety line is using a simple ring like in figure4.2. This ring is suspended in a statically determined way, so that the only possible movements of the ring lie in the horizontal (XY)plane. The springs will give the ring a resistance against displacement. By choosing a sufficient high spring stiffness the system becomes more robust, and therefore less sensible for small perturbations of the safety line. The stiffness of the springs is depending on the thickness and stiffness of the safety line and the hight the ring is placed. The displacement of the ring in the horizontal plane can be measured using load cells. Doing this, the output signal of the load cells is a direct measurement for the deflection of the safety cable.[8]

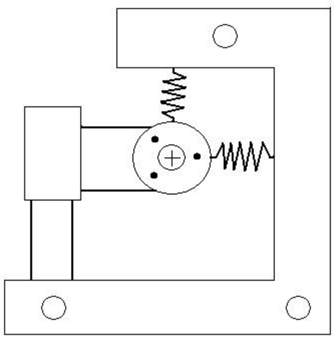

Figure 4.2: Schematic view of tension ring

Even as in the previous case of the joystick measurement system a compensation must be made for the platform angle. As the tension ring can only sense displacements in the horizontal plane parallel tot the platform floor.

4.4 Comparison

When one wants to choose the best solution out of before given concepts a number of points should be taken into account. Although the second concept of the tension ring looks mechanically more simple than the first one, there are two things that make it a more complicated solution.
The load cells that are used would be more expensive than the rotational potentiometer used in the joystick concept. Also the rotational potentiometer can be directly read out (with the help of a cheap Weedstone bridge) in contrast to the load cells which require more sophisticated electronics. An option would be to replace the load cells with a linear resistance. But the sensitivity of such a linear resistance for wear and dust would make it not suitable for use in CEAL.

The other point is that the Joystick is constructively a more simple solution. All the mechanical moving parts are rotating, which can easily be supported by rotational bearings. And the joystick itself can be made out of low grade steel which is welded into the desired shape. This in contrast to the tension ring in which more high grade steel or even leaf springs have to be used.

The comments mentioned above and the expectation that both concept will work with the same accuracy leads to the conclusion that the joystick measuring method is the most suitable solution for the problem of person tracking on the platform.

Chapter 5

Conclusions and Recommendations

During this internship several parts of the safety harness system are studied. This resulted in in a list with a number of global and more specific requirements for the total system or for the safety harness. Out of these requirements seven possible solutions were presented, which could all track a person walking on the simulation platform. The chosen solution, cable tracking using a joystick like measurement device gives the desired accuracy and stability which is required for the use in the CEAL project. It is the most suitable solution based on;

- Simple construction
- Simple and reliable sensors
- Insensible for environmental conditions
- Easy maintainability
- Easy in daily use
- Total cost estimation well within the budget

Summarizing it can be said that the chosen solution is the most suitable because it is based on simple, cheap and proven technology.

This report is mend as a guidance document for The CEAL project and its subcontractors. It will therefore not be complete but should be seen as a guidance for further implementation of the safety harness system. In the future specific components and calculations have to be performed before implementing the chosen solution into the CEAL simulation platform.

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