April 6, 2021

Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S6

Re: ENSC 405 Project Proposal for Rise's Roll24

Dear Dr. Scratchley,

Please find our ENSC 405W/ENSC 440 project proposal for Rise's *Roll24*, an automated process of rotating a bed-bound patient to their side, attached to this document. This product will use machine learning to recognize a patient's posture and position on the bed and to periodically rotate them using software and a microcontroller. *Roll24* is a low-cost and simple solution to improve a patient's wellbeing.

The purpose of this document is to provide the background, purpose, and scope of *Roll24*. This document will also introduce the company members, present the company's processes and milestones for this project, and the expected timeline for *Roll24*. Lastly, our company will need to address the risks and benefits, the target market, the possible competition, and the estimated costs for this project.

Our team consists of five senior engineering students in the SFU program – Jonathan Choy, Joon Kwon, Wilson Liu, Tyler Rasmussen, and Himson Chick. Our diverse team is made up of students in Computer Engineering, Systems Engineering and Electronics Engineering.

Thank you for reviewing this project proposal document. If you have any questions or concerns, please contact our Chief Communications Officer, Wilson Liu, through Canvas, Company 4's Gitlab, or through email at yla361@sfu.ca.

Sincerely,

Himson Chick

Himson Chick
Chief Executive Officer
Rise

Project Proposal

For

Roll24

Team Members	Himson Chick	CEO
	Jonathan Choy	CTO
	Joon Kwon	COO
	Wilson Liu	CCO
	Tyler Rasmussen	CFO
Submitted To	DR. CRAIG SCRATCHLEY	ENSC405W
	DR. ANDREW RAWICZ	ENSC440
	SCHOOL OF ENGINEERING SCIENCE	
	SIMON FRASER UNIVERSITY	
Contact Person	Wilson Liu	
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Executive Summary

 An aging population causes an increasing number of health problems and one ongoing concern is the increase in the number of people who suffer from bedsores every day. Our product will save many lives by preventing bedbound patients at home. This solution will also reduce the burden for family members, healthcare workers, volunteers, and other care givers by reassuring that the patient will be comfortably repositioned during the night.

Bedsores develops when there is too much pressure on the body and is a common problem for bed-bounded patients. *Roll24* is a product designed to autonomously rotate and change positions as a solution to development of pressure ulcers for these patients. Other solutions to this problem include using pillows to reduce pressure on specific areas of the body, helping the patient to manually change positions, and for the patient to move their arms, for example, to help with their blood flow.

Roll24 will use 4 stepper motors and 4 stepper motor drivers to control the rotation process. There will be two stepper motors secured horizontally to the side of the bed and one stepper motor placed vertically on each of the two horizontally placed motors. The sling will be attached to the corners at the top of the motors and will be dragged by the motors to mimic rotating a bedbound patient manually. As a safety mechanism, the Kinect V2 camera will be secured on the ceiling to ensure that patient is within the boundaries of the bed.

Our strategy for promoting our product is to form partnerships with residential care homes and assisted living homes and will require funding for marketing and for mass producing the final product. To fund the expenses of *Roll24,* we will apply to the Engineering Science Student Endowment Fund (ESSEF) and the Wighton Development Fund.

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Glossary

UPS < Uninterruptible Power Supply >

AI < Artificial Intelligence >

1 Introduction

1.1 Background

Bed bound patients in hospitals have access to nursing staffs that can help reposition them to prevent bed sores and bed sores related complications around the clock. This is not true for those in a residential setting. Throughout the night it may be difficult for those in residential setting to find help to reposition as their caretaker may not be around.

Rise recognizes this problem and believes it needs to be solved. To address this, Rise came up with *Roll24*. It is a device aimed to bring an affordable solution for automatic repositioning of patients while a caretaker is not present. The method of repositioning a person used by nurses involves utilizing the bed sheets. It is pulled across the patient by the nurse in the direction the patient is to be rolled onto. The goal of *Roll24* is to simulate a nurse or a caretaker repositioning the patient while they are not present to help the patient. The automation of *Roll24* will be using camera sensors to determine the safety of the patient in relation to their location on the bed. It will also recognize the skeletal structure of the patient and determine the movement of the apparatus that will do the repositioning of the patient.

There are similar devices that have achieved automatic repositioning that does not require intervention of another person during the process, but they are prohibitively expensive. The aim for *Roll24* is to devise a product with affordability in mind. In doing so, we hope to provide a solution to those whose only barrier was cost.

1.2 Scope

The main scope for this project is to design, assemble, test and deliver a working prototype for the *Roll24* product. The goal for this device is to create an affordable solution for simulating the repositioning of a patient done by a nurse.

In the scope of this project there are two primary focus. It is to physically be able to roll a patient up to 250lbs on to their side, and to have a machine vision component to ensure the safety of the patient during the process of repositioning.

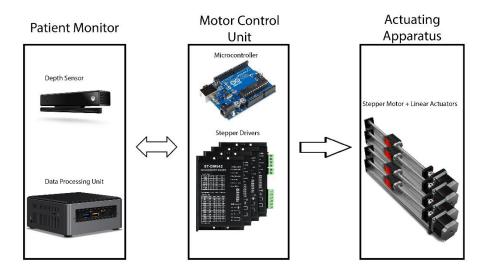The figure below describes the high-level architecture of *Roll24*.

Figure 1.2.1: Overview of *Roll24's* Components

The three main components of *Roll24* are:

1. **Patient Monitor**

   The camera sensors and data processing unit that is responsible for analyzing the patient's location and skeletal position for safety purpose.

2. **Motor Control Unit**

   Microcontroller and stepper driver responsible for movement of the Actuating Apparatus according to the signal from the Patient Monitor.

3. **Actuating Apparatus**

   The physical actuators, chassis and sling that will be used to reposition the patient according to the signal from the Motor Control Unit.

The important design objectives that *Roll24* must fulfill to be successful are:

1. Be able to roll a patient of up to 250lbs to their side.
2. Be able to reposition a patient at set interval.
3. Be able to process the transmitted raw image data in real-time.
4. Be able to send a halt signal in cases defined to be dangerous that will stop the repositioning process.

A proof-of-concept prototype for *Roll24* will be delivered at the end of the 4-month development phase. The main focus for this prototype is to implement the Motor Control Unit and Actuating Apparatus that is capable of moving 13.5kg vertically and horizontally and basic unsafe case recognition by the Patient Monitor. The integration between the Patient Monitor and the Motor Control Unit will not be implemented, thus the control of the apparatus will be semi-automatic. The software development kit that comes with the Kinect V2 is the reason why it was chosen for the camera module. This choice will

aid us immensely when trying to get skeletal structure data but also limits us to certain platforms for data processing. We will be using an Intel CPU that is running Windows 8 or higher for both development and operation of the necessary programs. The transmission of image data will also only be possible through a USB connection.

In the following 4-months after the proof-of-concept prototype, the development of the engineering prototype of *Roll24* will begin. In this phase the Patient Monitor and the Motor Control Unit will be integrated. Unsafe cases defined by using the skeletal structure of the patient and the automation of the repositioning will be achieved.

2 Product Justification

Aging population is an inevitable reality in the world for the next couple decades. More people are entering into their senior years. Many elders unfortunately will become bed bound and require long term care. When a patient become bed bound, the number one priority of care is to avoid pressure ulcers. Research shows the prevalence of pressure ulcer in various Canadian healthcare setting are estimated at 26%, although more studies are needed, the data suggest pressure ulcers are even more prevalent in all healthcare setting [1]. Another research reports "The estimated cost of managing a single full thickness pressure ulcer is as high as $70,000, and the total cost for treatment of pressure ulcer in the U.S. is estimated at $11 billion per year"[2]. Using the general rule of thumb, US stats numbers are ten times of Canadian numbers; we could estimate pressure ulcer cost Canadian tax payers in around one billion dollars a year. However, commercially available products to solve this emerging health crisis, are either heavily relying on manual labours or simply too expensive for middle to low income house hold to afford. To meet this ever-growing demand, Roll24 is designed to meet this need. After the initial product release, we will refine our designs and partner up with OEM components factory to further decrease our production cost, increase our competitiveness even more, monopolizing the market.
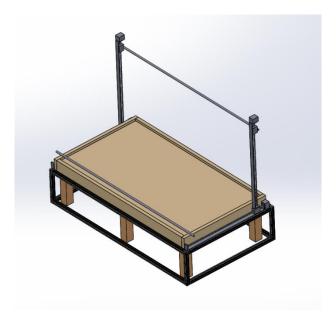

Figure 2.0.1Figure 1: 3D modeling of Roll24 without the sling

2.1 Benefits

Pressure ulcer kills. Our products safe lives. *Roll24* offers a solution to a problem that affects the most vulnerable population. And it tapes into a growing market that is undervalue and underdeveloped. Our goal at *RISE* is to create great value with our product that will benefits all the stakeholder.

Patients

Roll24 helps relief chronic pressure injury for bedbound patients at comfort of their homes. Even when the patients become bedbound, they can still enjoy their days surrounded by their lovely grandchildren at the convenient of their own home. Spending time with family and friends will dramatically improve the well-being of bedbound patients. Affordability is another a key benefit of our product. At one tenth of the leading brand competitor's cost, *Roll24* provides a great alternative for those patients want quality in home care without being bankrupt.

Caregivers

Repositioning of a pressure ulcer patient is mandatory in every 2 hours. For chronic bedbound patients, this is required 24/7. It is a physically demanding and tedious task if done with the traditional way. *Roll24* releases caregivers for more important works and free them from the back-breaking task. There is old saying in Chinese goes like this: there are no good sons in front of a chronically sicken parent's bed. It summarizes the harsh reality of taking care sick bedbound elderly parents at home. The time and efforts spend on taking care with bedbound family member are enormous. One of *Roll24*'s key features is automatic repositioning patient during night time. This will tremendously improve caregiver's quality of life, levitates the heavy burden from their shoulders by giving them the much need rest they deserve.

Societal benefit

Pressure ulcer is painful and heals slowly, the social cost and emotion toll on the family are hard to measure. *Roll24* can help bedbound patients recover faster from existing pressure injuries and prevents new pressure ulcer from developing. There will be less sicker patients at hospital because *Roll24* take care of them at home, potentially saving millions of dollars for Canadian healthcare system. It will also free up already scarce hospital resource for other patients who need more critical cares.

2.2 Risks

Engineers at *RISE* hold the highest engineering standards for their products and will always put their customers' safety as first priority. However, we realize nothing is perfect. Since *Roll24* is a unique and novel solution in the market, there may still be risks while using *Roll24* due to lack of user data. Some of the foreseeable risk can be mechanical, electrical, or software wise. As our product increase its market share and become more popular, some unforeseeable risks could become apparent as well.

Mechanical

Potential risks such as mechanical failure may happen due to prolong operation of the device. To prevent this, *RISE* will offer maintenance service with a small month subscription fee to guarantee safe operations of the device when the product is outside of the warranty period. Our commercial version *Roll24* shrouds all mechanical components from the user, no moving parts should catch anything. However, there is always the concern for misuse, warning labels should be applied at critical areas.

Electrical

Because our devices are made of electronic components, they are prone to risks due to electrical failure. For example, when there is a power outage during usage, the machine will cease to response without power. Our solution is to suggest the user to get an uninterruptible power supply (UPS) and connect it between the wall outlet and the device, so in the case of power outage, *Roll24* will maintain basic functionalities for the remainder duration. Another possible risk is caused by electrical power surge, a sudden increase of current to the device due to power grid switch or nearby lightning strike. The simple solution here is to partner up with power supply companies to get the best rated power supply for our product. After initial product launch, we will have an intensive customer feedback review to further refine the design of *Roll24* into a better product. In the future version, we could partner up with battery companies to integrate the UPS component in the system itself. *Roll24* shrouds all electrical components from the user, a possible water spill may still cause short circuit, again warning labels should be applied at critical areas.

Software

Lastly, *Roll24* has a "smart" element incorporated into the design, which uses the some of the latest Artificial Intelligence (AI) /machine learning technologies. This, however, comes with the issue of training quality. The algorithm needs to be properly trained with large amount of representative data images in order to have an accurate detection. It is also crucial take into account the environment surrounds the device, since it could give faulty readings for the AI system. For these risks, we plan to gather more user data with patients' permission to further improve our AI system.

2.3 Market Analysis
Canadian Market
The Government of Canada provides the 2019 financial statistics for the Nursing and Residential Care Facilities industry and is shown in the tables below [3]. As shown, there were 4476 businesses in the industry with the smallest companies earning $30,000 in revenue and the largest companies earning $5,000,000 [3]. Of note, 79.7% of Canadian businesses in the nursing industry are generating an average profit gain of $102,600 in 2019 [3].

Report by revenue in thousand of dollars						
	Whole industry (reliability)	Bottom quartile (25%)	Lower middle (25%)	Upper middle (25%)	Top quartile (25%)	Percentage of businesses reporting
Number of businesses	4,476					
Revenue range:						
Low ($000)	30	30	75	290	846	
High ($000)	5,000	75	290	846	5,000	
REVENUES AND EXPENSES	(thousands of dollars) - Averages					
Total revenue	693.0[B]	47.3	161.2	510.6	2,053.0	100.0
Sales of goods and services	N/A	N/A	N/A	N/A	N/A	N/A
All other revenues	N/A	N/A	N/A	N/A	N/A	N/A
Cost of sales (direct expenses)	79.2[B]	2.8	14.7	51.9	247.1	29.4
Wages and benefits	50.7[B]	0.3	5.5	30.6	166.2	10.9
Purchases, materials and sub-contracts	28.0[C]	2.5	9.2	21.3	79.1	27.8
Opening Inventory	0.7[B]	0.1	0.2	0.4	2.3	3.4
Closing inventory	0.3[C]	0.1	0.2	0.3	0.5	2.8
Operating expenses (indirect expenses)	559.5[C]	23.5	136.8	411.1	1,666.6	97.0
Labour and commissions	277.9[B]	4.0	40.3	208.6	858.5	62.7
Amortization and depletion	36.6[C]	1.7	8.2	25.3	111.2	75.3
Repairs and maintenance	26.7[C]	0.6	7.0	24.5	74.4	68.1
Utilities and telephone/telecommunication	28.3[B]	1.7	7.9	25.1	78.3	82.9
Rent	27.3[B]	2.1	6.6	14.3	86.4	39.8
Interest and bank charges	39.5[C]	1.0	18.7	20.7	117.7	60.5
Professional and business fees	21.8[E]	1.4	14.9	13.2	57.7	86.2
Advertising and promotion	5.1[E]	0.5	1.3	3.0	15.4	58.8
Delivery, shipping and warehouse expenses	0.3[E]	0.0	0.1	0.3	0.7	8.0
Insurance	7.7[C]	0.7	3.3	8.4	18.3	73.3
Other expenses	88.5[C]	9.8	28.5	67.6	247.9	96.3
Total expenses	638.7[B]	26.3	151.5	463.0	1,913.7	97.0
Net profit/loss	54.4[A]	20.9	9.6	47.6	139.3	99.7

Table 2.3.1: Financial Performance for Care Facilities in Canada [3]

PROFITABLE vs NON-PROFITABLE BUSINESSES	(thousands of dollars)				
Profitable					
Percentage of businesses (%)	79.7	N/A	N/A	N/A	N/A
Total revenue	669.4[B]	47.0	158.7	510.6	2,079.8
Total expenses	566.8[B]	19.3	108.6	423.6	1,820.1
Net profit	102.6[B]	27.8	50.1	87.0	259.7
Non-Profitable					
Percentage of businesses (%)	20.3	N/A	N/A	N/A	N/A
Total revenue	785.8[C]	49.2	169.8	510.7	1,968.3
Total expenses	921.0[C]	82.0	303.1	589.4	2,209.3
Net loss	-135.3[E]	-32.8	-133.3	-78.7	-241.0

Table 2.3.2: Profitable vs Non-Profitable Businesses [3]

As of May 2020, according to the Canadian Institute for Health Information, there are 2039 long-term care homes in Canada which consists of 24-hour nursing care homes and retirement homes [4]. The figure below presents the distribution within the country and provides the proportion of publicly owned homes vs privately owned homes [4]. The population size of each province is in proportion with the number of care-homes in each province and, thus, highlights the bigger markets. In Canada alone, there are over 86000 people who suffer from spinal cord injury and for individuals who suffer from this injury, it can cost "an estimated average lifetime cost of $2 million Canadian dollars per individual" [5]. These injuries affect patients by causing additional strain and pressure on the body and cause added difficulty on performing everyday activities which can lead to fatigue [5]. For our product, we aim to target this market and to reduce the cost for rehabilitation by offering a low-cost solution for a one-time purchase.
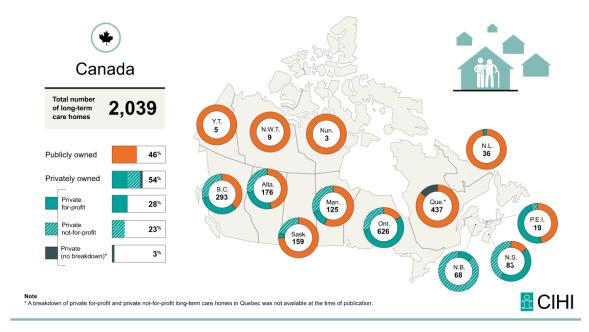
Figure 2.3.1: Number of Long-Term Care Homes in Canada [4]

2.4 Competition

On the market, there are other products that share the same solution as the *Roll24.* These products are designed to be a solution for bedbound patients who suffer from bedsores and can alleviate pain by physically moving the bed or the user to different sleeping postures. However, some of these products lack automation functions or the safety features provided by *Roll24*. *Roll24* will be able to use an image sensor to detect if a patient is oriented properly and to stop operations if the patient is not within the bounded operation area. The following subsections below detail competitors to our product.

Freedom Bed

The *Freedom Bed,* designed by ProBed Medical Technology Incorporated, has been designed to allow the patient to choose between manual and automatic operation for a configurable operation duration [6]. This product lifts certain areas of the mattress to move the patient from left to right and can also raise the patient's back to a sitting position [6]. For safety features, the *Freedom Bed* uses voice control and safety rails installed the sides of the bed [6]. The difference between the *Roll24* and the *Freedom Bed* is that Roll24 rotates the patient on a fixed level mattress and has a camera to detect the patient's location on the bed as a safety feature.

Figure 2.4.1: Left Rotation of Freedom Bed [6]

Repo Sheet

The *RepoSheet Lift Aid*, designed by Hillrom, uses a sheet attached to an apparatus over the patient's bed to manually lift the patient off the mattress, turn the patient, and reposition the patient [7]. The sling on the *Reposheet* is accredited, complies with all requirements for MDD Class I products, can be attached and detached for cleaning, and can be changed to support various patient weights [7]. The difference between the *Roll24* and the *RepoSheet Lift Aid* is that the *Roll24* is fully automated and has machine learning as a safety feature unlike the *RepoSheet* which relies on the caregivers for the patient's safety [7].
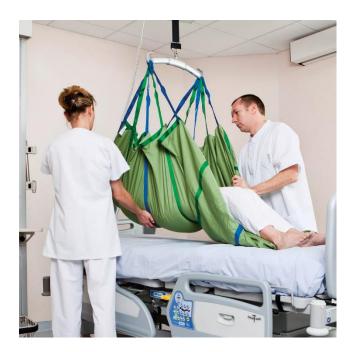

Figure 2.4.2: Image of the Reposheet [7]

3 Finances

3.1 Cost Analysis

Prototype cost breakdown listing all components for the Roll24.

Part	Part Number	Unit Price	Quantity	Subtotal ($)
Rolling Sub System				
600mm CNC Linear Actuator + Nema23 Motor	FSL40-600	271.01	2	542.02
900mm CNC Linear Actuator + Nema23 Motor	FSL40-900	327.315	2	654.63
Digital Stepper Driver	DM542	102.36	4	409.44
DC Power Supply 24V 13.6A 350.4W	LRS-350-24	59.37	1	59.37
Arduino Mega	EL-CB-003	22.99	1	22.99
Chassis				
1515 Lite T-Slots	1515-Lite	0.6075	75.59	45.92
1515 Lite T-Slots	1515-Lite	0.6075	78.74	47.83
1515 Lite T-Slots	1515-Lite	0.6075	23.62	14.35
1515 Lite T-Slots	1515-Lite	0.6075	38.19	23.20
15 Series 2 hole Gussetted Inside Corner Bracket	4332	5.81	16	92.96
15 Series Hidden Corner Connector Inside-Inside	33450	6.95	16	111.20
8020 Economy Tnuts + Bolt	3320	0.81	32	25.92
Detection Sub System				
Kinect V2	GT3-00002	175.72	1	175.72
Kinect V2 Adapter		40.99	1	40.99
Subtotal				$ 2,266.55
Tax (12%)				$ 271.99
Total				$ 2,538.53

Table 3.1.1: Bill of Material for Roll24

3.2 Potential Funding

3.2.1 Engineering Science Student Endowment Fund

The Engineering Science Student Endowment Fund (ESSEF) run by the SFU Engineering Science Student Society (ESSS) provides funding for student projects which meet specific criteria falling under four categories: Competition, Entrepreneurial, Class and Miscellaneous. Our product would satisfy the requirements for both the Entrepreneurial and Class categories. This allows us to compete for 55% of the total funding available [8].

3.2.2 Wighton Engineering Development Fund

The Wighton Development Fund organized by Dr. Rawicz in another potential source of funding for our project. This program states that "projects benefiting society, (for example, biomedical developments or aids for the elderly and physically or mentally disadvantaged) will be treated preferentially" which clearly favours our project since the *Roll24* is an aid for the elderly and physically disadvantaged [9].

4 Project Scheduling

4.1 Gantt Chart

The figures below illustrate the team's scheduling, in the design and documentation of *Roll24,* for the duration of the alpha phase (ENSC405W) and the beta phase (ENSC 440).
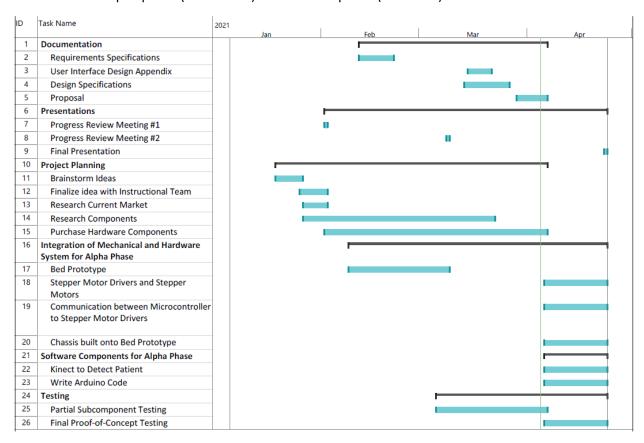

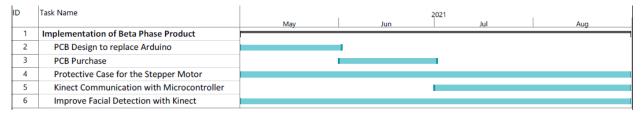**Figure 4.1.1: Gantt Chart for Alpha Phase Product (ENSC 405W)**

Figure 4.1.2: Gantt Chart for Beta Phase Product (ENSC 440)

5 Company Overview

Rise was founded in January 2021 by a group of 5 senior engineering student at SFU who wanted to create a product that will help those around us. Our objective is to create cost-effective and innovative technology that will help improve the daily lives of the people. Our first product, *Roll24*, aims to bring an affordable solution to bed bound patients who do not have access to staffs that can reposition them 24/7 by automating the process for the times their caretakers are not around.

5.1 Meeting the Team

Himson Chick
hchick@sfu.ca
Chief Executive Officer

Himson is a fifth-year Electronics Engineering student with an interest in electronics and circuit design. His previous co-op work experiences include working as a hardware engineer at FLIR Systems and working as an electromagnetic compatibility (EMC) technical assistant at LabTest Certification. Himson will apply his knowledge of microcontrollers and hardware design to ensure that the hardware component of *Roll24* is implemented and functioning as expected.

Jonathan Choy
jychoy@sfu.ca
Chief Technology Officer

Jonathan is a senior electronics engineering student with an interest in signal and power integrity for audio electronics. He has completed co-op experience at Nvidia and Adara Systems which has helped in developing his skills in hardware development, circuit design, and PCB layout. Jonathan will be making use of these skills for the hardware design of the *Roll24*.

Joon Kwon
joonk@sfu.ca
Chief Operating Officer

Joon is a senior computer engineering student with co-op experience in DevOps and system integration. His previous co-op experience at CORVUM has given him expertise in automating data collection of key performance indicators and performing extract, transform, and load.

Yu Liu (Wilson)
yla361@sfu.ca
Chief Communication Officer

Wilson is a proud dad of two and a senior system engineering student at SFU. He has experience working in the aviation industry. His expertise in mechanical design has proven valuable to the development of *Roll24*. Further integration efforts will be applied to this project in the coming months.

Tyler Rasmussen
trasmuss@sfu.ca
Chief Financial Officer

Tyler is a senior computer engineering student with experience in software design and web application development at both BCAA and SFU Faculty of Health Sciences. He will be applying his knowledge to the development of the patient monitor algorithm.

6 Conclusion

The *Roll24* is an affordable, automated solution to bedsores for bed bound patients. Using a frame that attaches to the patient's bed, the *Roll24* is easily adaptable to many living conditions and provides a solution for almost any living conditions. The automated patient repositioning process reduces dependence on a caretaker, while the patient monitoring system guarantees that the patient is safe. With the *Roll24,* patients will require less attention from caretakers, and will still be tended to even if a caretaker is not available, ensuring that they never develop bedsores. This will drastically increase the quality of the bed bound patient's life, as well as ease pressure on caretakers.

This document was written to address the background, justification, and project details for the *Roll24* including our initial design, finances, scheduling, and team. We outlined how we can solve the problem; we also described how the *Roll24* will be produced with lower costs than our competitors by attaching to the consumers existing bed and by using a unique rotational apparatus. Our team believes we can combine our varied technological experiences to develop the *Roll24* as a unique solution to bedsores that will tangibly improve the lives of many bedbound patients.

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[3]   "Nursing and Residential Care Facilities - 623 - Financial performance - Canadian Industry Statistics - Innovation, Science and Economic Development Canada", *Ic.gc.ca*, 2019. [Online]. Available: https://www.ic.gc.ca/app/scr/app/cis/performance/rev/623;jsessionid=0001I6CbxsmXBchBlG4zKtG5aKj:-OI4TRJ. [Accessed: 06- Apr- 2021].

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[7]   "Repo Sheet®", *Hillrom.com*, 2021. [Online]. Available: https://www.hillrom.com/en/products/reposheet-lift-aid/. [Accessed: 06- Apr- 2021].

[8]   "ESSEF", *ESSS*. [Online]. Available: https://www.esss.ca/essef. [Accessed: 06- Apr- 2021].

[9]   A. Rawicz, "FUNDING AVAILABLE FOR STUDENT PROJECTS - WIGHTON ENGINEERING DEVELOPMENT FUND", *Www2.ensc.sfu.ca*. [Online]. Available: http://www2.ensc.sfu.ca/~whitmore/courses/ensc305/pdf%20files/Wighton_Fund.pdf. [Accessed: 06-Apr- 2021].