The design evolution of the zipper: a patent review

The Design Evolution of the Zipper: A Patent Review

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ABSTRACT
Cliff is a project which aims to develop an automatized zipper for the zipping and unzipping process. The focus of this study is to visualize the evolution trends of the zipper (slide fastener) since its first invention back in 1851 to 2017. The patent analysis was performed to develop the evolution map based in advance invention. The search has been limited to approved patents in the United States of America and Japan (US & JP) database using the search terms "zipper" and the Cooperative Patent Classification (CPC) of "A44B". Total of 940 patent reports were extracted from the Google Patents. The finding shows that the zipper's design has evolved from the conventional type to the removable, rollable, adjustable, and currently, the inventions are moving towards designing an automatic slider or even a robotic zipper. This situation is aligned with our direction, mission, and vision to design and develop Cliff as an automatized zipper.

CCS Concepts
• General and reference - General literature

Keywords
Patent analysis, technology evolution, zipper, slide fastener.

1. INTRODUCTION
Predicting the future is extremely important for any designer or companies. Developing a brand-new product always has a high risk and uncertainty [1]. Forecasting the technology or product development progress through the patent analysis is significant to ensure that the direction is aligned with the latest development in the field. A patent is a document which contains details information on the developed technology and its usage rights [2].

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The Theory of Inventive Problem-Solving (TRIZ, in its Russian abbreviation) is able to predict future image and compose future patents systematically [3]. The TRIZ evolution theory is known as one of the tools used in the product and technology prediction, to read the evolution path, and estimate the future trajectory [4]–[6].

The zipper was invented in 1851 [7]. A zipper or slide fastener is a commonly used device to join or bind the edges of an opening fabric or other flexible material. Figure 1 shows the principal parts of the zipper and standard terminology of the subassemblies of the zipper based on the ASTM D2050-04 standard [8]. The chronology of the zipper invention begins back in 1851, when Elias Howe, the sewing machine inventor, received a patent for an automatic, continuous clothing closure [7]. Forty years later, Whitcomb L. Judson invented and conceived the idea of the slide fastener, and develop a working zipper [9]. The development continues when in 1913, Gideon Sunback, an electrical engineer designed the modern zipper and patented a design entitled 'separable fastener' in 1917 [10]. Twenty years later, the B.F Goodrich company decided to use Gideon's fastener on a rubber boot and named the device 'zipper' [11].

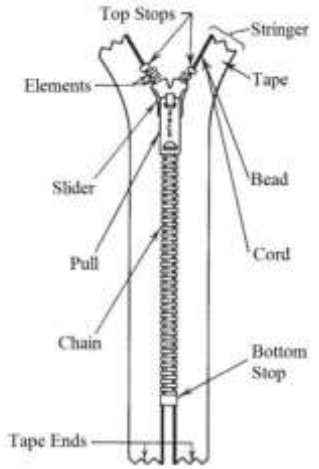

Figure 1. Standard terminology of the zipper [8]

Currently, it is difficult to find related publications (conference or journal article) written about the zippers development progress. Analyzing the patents report is another way to perform an extensive literature review on the progress of the zipper's development. The patent analysis can assist the inventor or the designer throughout this process to create a clear overview of the patent landscape. Besides that, the patent data (originality, technical feasibility, and commercial worth) provides both the technical and market attributes [12]. It also contains variety of other informations such as the problems to be solved and the potential applications [2]. This paper reports the patent analysis conducted to visualize the development progress and the design evolution of the zipper since it was invented in 1851 [7]. The study also aims to investigate the common problems mentioned by the inventors related to zippers and determine the other potential applications of the zippers mentioned by the inventors. The findings will be used as the input for our current project to develop an automatized zipper, named Cliff. It is true that the zipper is a simple device to be operated, but not everybody can perform the zipping and unzipping process independently. Therefore, this project is a response to the struggle faced by the elderly, handicapped, and ladies who have problems zipping a back-zipper dress. These groups of people will require assistance from others to perform the task.

2. CLIFF'S PROJECT

Cliff, an automatized zipper, is a project which is aimed to ease the zipping and unzipping process. This project was inspired by Adam Whiton, who build the first robotic zipper recognized as the Zipperbot [13] and an article written on actuating movement in refined wearables [14]. This newly-designed automatized zipper keeps the zipper structure as it is and develops a generic and universal type of zipper robot. Cliff could be the "future of fashion and wearables technology" [15]. It was developed using an iterative research through design process [16]. Four different prototypes were successfully developed through the design iterations. Figure 2 shows the construction of Cliff's latest prototype. It used two gear sprockets as traction mechanism on both sides of the tape to establish the uniform distribution of normal force acting towards the zipper tape as shown in Figure 3 [17]. The gear tooth grabs the zipper tape.

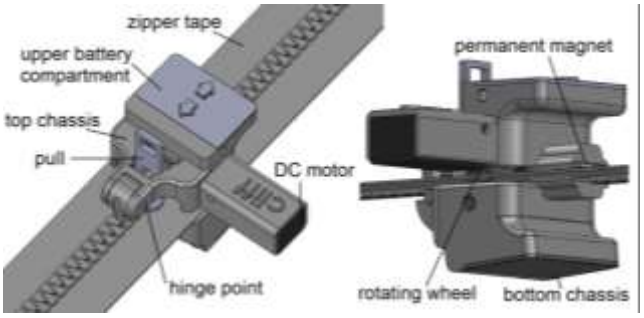

Figure 2. Cliff's prototype

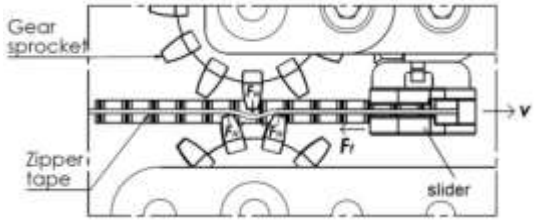

Figure 3. Cliff's traction mechanism

3. METHODOLOGY

3.1 The Patent analysis flow

The patent analysis can be performed using the manual or automated methods [3], [4]. For this study, the manual method was chosen by utilizing the search function of the Google Patents [18]. Each patent report will be read in detail to understand what is going on with the zipper's invention progress. The findings will be recorded in the Excel spreadsheet.

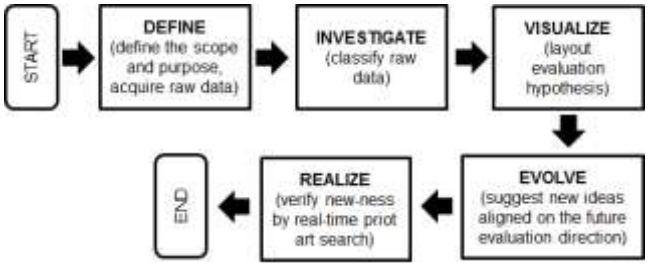

Figure 4. the procedure of the evolution map based in advance evolution [3]

Figure 4 explains the whole procedure of the evolution map construction which is based on the advance invention [3]. Firstly, the scope and purpose of the study were defined and the raw data (the patent report) was acquired. Then, the raw data will be classified and divided into nine categories as summarized in Table 1. Each of the category is marked using the different colour as shown in Figure 5(a). The evolution map was constructed as shown in Figure 5(b) based on the classified information of the patent. The fourth step, which is 'evolve', is to suggest new ideas aligned with the future evolution direction. The suggestions are based on the result obtained from the evolution map. A few patent reports have been identified which potentially could give promising ideas in the future direction aligned with the development of the automatized zipper. Figure 5(b) illustrates the visualization of the patent. Lastly, the findings will be transformed for a better presentation, and the promising ideas identified into a prototype and make a plan for the realization.

Table 1 The categories for the classification process

Colour code	Category	Description
Red	Zipper	The whole construction of a zipper
Green	Tape	The zipper tape
Yellow	Slider	The slider of the zipper
Purple	Manufacturing	Manufacturing/production/ assembly process
Orange	Elements	The zipper teeth
Grey	Pull tab	The puller of the zipper slider
Brown	Bottom stop	The bottom end of the zipper
Black	Top stop	The top end of the zipper
Blue	Application	The applications, bag, suitcase, garments, robotics etc.

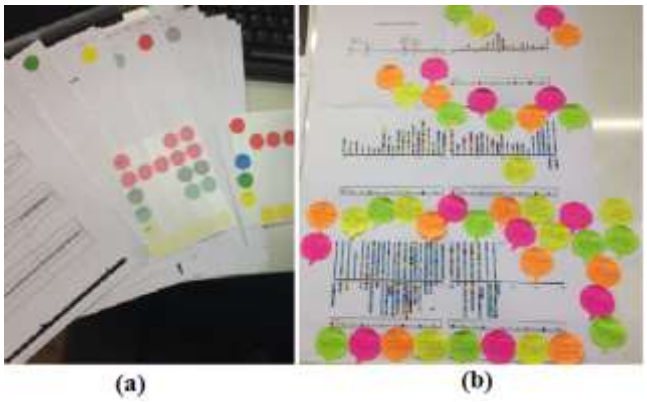

Figure 5. The (a) classification and (b) visualization of the patent

3.2 The Patent Search Scope

The manual patent search utilizes the advanced search function in the Google Patents web to find the relevant patents [18]. The search has been limited to only granted patents in the United States of America (US) and Japan (JP) database, which were written in English (for readability), and published after 01st January 1840. It is due to the most extensive patent database is the US database and considering the origin of YKK company (the largest zipper manufacturer) is from Japan. The search terms are the 'zipper' and 'A44B'. The 'A44B' is the Cooperative Patent Classification (CPC) for the buttons, pins, buckles, slide fasteners, or the like [19]. CPC represents a more detailed technology classification compared to the international patent classification (IPC) [20]. The search engine provides 940 approved patent reports based on the search terms and filters applied.

4. RESULTS AND DISCUSSIONS

There are 940 patents approved in the US and JP database of the zipper from 1851 until 2017. On average, about 5 patents are granted each year and every patent required about 2.3 years to be approved. Eddie Howe patented the first zipper or slide fastener back in 1851 to be used as the fastening for garments [7]. It is followed by the invention of shoe fastening by Judson about 42 years later [9]. Then, Sundback developed a vital invention which is recognized as the modern zipper and granted two patents in 1913 and 1917 [10], [21]. Then, in 1927, Hesse patented a zipper rubber shoe [22]. Overall, between 1851 and 1930, there are only four patents approved for zippers and the slide fasteners. There is an increment in the number of patents granted between 1931 and 1950. Most of the patents are related to the design of zipper parts such as the slider, elements, and the bottom stop. Between 1951 and 1970, a huge increment of the number of granted patents is recorded (four times higher than the same duration from 1931 to 1950). Most of the patents are classified in the 'manufacturing' category. The manufacturing company began to patent the manufacturing or assembly process for producing the zipper or the slide fastener. Meanwhile, from 1971 to 1990, about 42% of the total number of patents approved fall under the 'application' category. Most of the patents are related to the recloseable plastic zipper, bag locks, latching devices, protective enclosures, and alarms for unfastened garments. Moreover, the number of patents approved between 1991 and 2010 almost doubles the amount of patent approved between 1971 and 1990. The 'application' category is still dominating the patents approved. Lastly, in 2011 to 2017 (last date accessed is 19th September 2017), there are about 177 patents granted. During this period, a few patents presented thea new concept of the slider. In average, about 25 patents were patented each year during the last 7 years. The following sections will discuss few interesting patents in detail for each of the categories. However, the zipper, tape, and elements category will not be discussed further since there is only small amount of patents granted for these particular categories.

4.1 Manufacturing and Applications

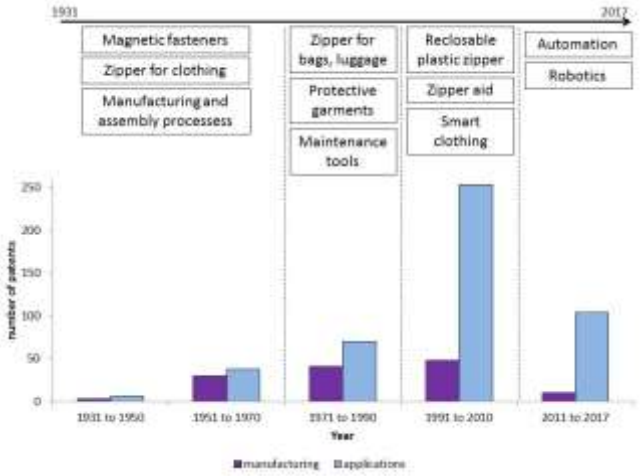

Figure 6. The number of patents approved in the category of manufacturing and applications

Figure 6 shows the number of patents granted in manufacturing and application category. The manufacturing companies actively began to patent their manufacturing or assembly processes in producing the zipper or the fastener after 1950's. For instance, the process to attach the slider to the zipper tape, cutting the zipper tape, and punching and arrange the elements. From 1931 to 1970, the granted patents is also about the zippers application for clothing. There are also two patents invented the magnetic fasteners [23], [24]. About 42% of the total number of patents approved between 1971 and 1990 fall under the 'application' category. The patents are related to the recloseable plastic zipper, the bag locks, latching devices, adjustable buckle, etc. Most of the patents granted during this period are related to the reclosable plastic zippers which is used for the packaging purpose. Two patents will be discussed the application of the zipper on the elastic stockings. Myers (1970) used the zipper to provide an adjustable fastening device for securing elastic stockings [25]. Seven years later, Malick invented an elastic stocking provided with the closing means and easy removal, particularly for an artificial leg. The elastic stocking includes a zipper with two synthetic plastic material engaging portions and a magnetic material closing means [26]. Besides that, there is also an invention of the aid device for the disabled person to use the zipper [27]. Entering the 20th century, the inventors started to design and explore wearable electronic devices. In 2004, the NOKIA corporation patented a system and method for the smart clothing and wearable electronic devices. Group of inventors from NOKIA realized that the need exists for a method of activating smart garments, providing status information of different parts of clothing to an electronic device integrated or attached to the clothing [28]. The system integrates an electronic circuit into one or more fastening devices on a piece of garments. For the zipper, it includes the zipper itself, one or more conductive cables, sensors, and controllers. The conductive cable has been sewn into the fabric of the clothing, which consists of the wires composed of a conductive metal such as the copper. This kind of system could

provide status information regarding the state of the clothing such as to determine whether the fastener is entirely fastened or not.

Another two patents were identified which discussed the fasteners indication and the alert apparatus. In 2008, Farhadian patented an open fastener indicator to notify the wearer of a clothing item of an open status of the fastener [29]. Sometimes, the user forgets to fasten the zipper, or the zipper is unfastened unintentionally. The fastener indicator comprises of electrical couplings connecting the fastener to an electrical circuit which contains the alert mechanism [29]. The following year, Michida patented an invention which is also associated with alert apparatus [30]. Michida noticed that small articles carried around being lost or dropped due to the user forget to close the fastener. The user might be labelled as a sloppy or careless person, and become more susceptible to being pickpocketed. Therefore, there is a need to have an alert apparatus for use with fasteners.

In 2017, Adam Whiton from MIT was granted a patent on the methods and apparatus for the robotic zipper, named as Zipperbot [13]. The Zipperbot used two rotating wheels which moved in between the gap of the elements on the zipper tape. The mechanism of the Zipperbot did not use the existing slider on the zipper to do the zipping and unzipping process. Thus, the Zipperbot is not generic for all kind of zippers. However, this robot marks the beginning of the development of the robotic zippers.

4.2 The Slider and the Pull

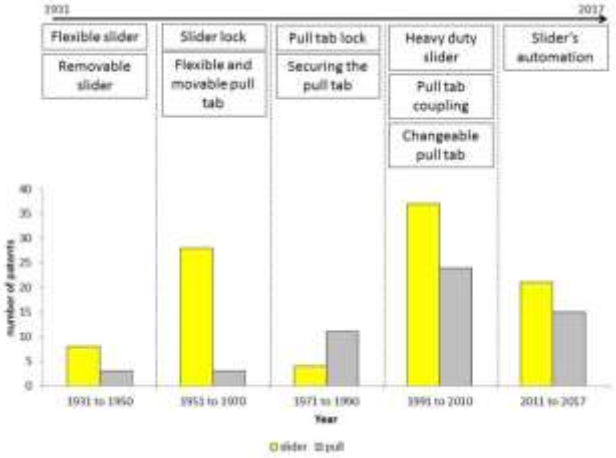

Figure 7 The number of patents approved in the category of the slider and the pull

Figure 7 shows the number of patents approved for the slider and the pull. These two parts are considered as the "engine" of the zipper's system to complete the zipping and unzipping processes. The invention of these two parts of the zipper was a bit slow from 1851 to 1950's. The focus is more on developing the flexible and removable slider. Mucci invented the first removable slider in 1938 [31]. The slider can be opened upward to be easily removed if the zipper is jammed. Twelve years later, Nissen patented the reversible slider in 1950 [32]. Both designs indicate the beginning of making a flexible or removable slider for the zipper to overcome a few problems such as when the garments get caught between the slider and the tape, or sand gets in the zipper tape of for instance a bathing suit. This invention allows users to remove the slider without tearing anything. It can be seen that the invention of the slider was very active during 1951 to 1970 (focus: slider lock, flexbile and movable pull tab) and from 1991 to 2010 (focus: heavy duty slider, pull tab mounting, changeable pull tab). There are two types of the slider lock designed during this period which are the semi-automatic and automatic lock. In 1999, Chung patented a pull tab mounting arrangement for a zipper [33]. It is a response to a problem that the slider and the pull tab are not detachable, which the user cannot replace the pull tab with other design. This patent triggered an idea for us to design a separate device to mount the pull tab on the top chassis of Cliff.

Meanwhile, in 1967, Younger invented a magnetized zipper pull tab to provide a zipper closure element having both magnetic and mechanical locking features [34]. Besides that, the inventors also developed a heavy duty zipper for the tent and canopy [35]. There are extensive developments on the slider design between 2011 and 2017. There are four patents which focused on the slider's automation during this period. In 2013, Wang patented a roller zipper slide [36]. In his invention, Wang mentioned a few drawbacks with the conventional slider. One of it is the resistance produced if the protruding upper faces of the left series of elements are stopped against the protruding upper faces of the right series of the elements during its operation. The situation will interfere with the sliding mobility. Besides that, different zipper's manufacturer's provides various specifications of the zipper parts. It makes commercial zippers not interchangeable. There is tolerance control on the slider and the elements specifications. Therefore, Wang designed a slider having a longitudinal slot on a top slider body in communication with an internal chamber thereof, and two coupling grooves located at the two opposite lateral sides of the slot. The slider employs a rolling contact technique to replace the conventional surface friction designs. Thus, it will improve the sliding mobility, reduce the elements wear, and prolongs the slider lifespan [36].

In the same year, the wheeled slider was patented by the UNDER ARMOUR company [37]. The design is a reflection of the difficulty to quickly couple the insertion pin and the retainer box, especially with the bulky garment. Moreover, the users with mobility-limiting medical conditions, such as arthritis or poor eyesight, could face the same problem. A smooth, freely moving feel usually indicated that the zipper is functioning correctly, while a rough or high friction feel may indicate an issue with the zipper. The movement of the slider along the elements is a kind of feedback to the user [37]. The snagging of the garment is also another problem addressed in this patent as it can be frustrating for the user as well as cause damage to the garment. Therefore, the company came out with a wheeled slider design where two wheels slided on the side of the element. This invention is to provide a zipper arrangement where the components may be more easily accessed and assembled by the wearer. Besides that, it could also improve the tactile feel while also reducing the chance of the garment to get snagged within the slider. However, from the construction of the wheeled slider, it is only suitable for a zipper with a flat side surface of the plastic elements, and not ideal for the coil zipper.

The Genmore Zipper Corporation from New Taipei patented another design of roller-loaded slider [38]. The patent discussed few problems related to the slider. If the pulling direction of the pull-tab and the slider is not kept in parallel, a downward pressure will be generated to the slider against the tape [38]. This situation will cause the front bottom edge of the top slider to rub against the stitches. After a long use, the stitches can break, thus spreading apart the elements. To overcome the problems mentioned, the Genmore Zipper company designed a roller-loaded slider which comprises at least one roller bracket each carrying a front roller.

Three years later, an inventor from Argentina, Alberto, invented an adjustable slider [39]. With the design, the inventor tries to solve the difficulty to replace a damaged slider without changing the original seams. The adjustable slider can be pivotally opened and closed horizontally, and it can be locked in the appropriate size of the zipper.

4.3 The Bottom and Top Stop

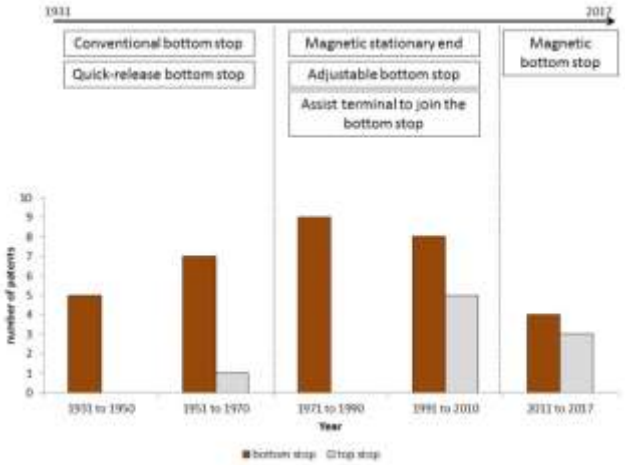

Figure 8. The number of patents approved in the category of the bottom and top stop

Figure 8 shows the number of the bottom and top stop patents approved from 1851 to 2017. It can be seen that there are not so many inventions related to this category with an average of 1 patent each year for the bottom stop. There are only a few patents related to the top stop since the part is not as important as the bottom stop. In the early years (1931 to 1970), the patents are mostly about the conventional design of the bottom stop. After 1970's, the design of the bottom stop is more focused on the use of magnetic materials [23], creating an adjustable bottom stop [40], [41], and designing terminal to ease the joining of the bottom stop [42], [43]. The current method of joining the two halves of the zipper tape is using the bottom pin and the retainer box. However, many individuals encountered difficulty to join the bottom pin and the slider such as small children, people wearing gloves for protection, elderly, and people with physical disabilities. Therefore, Peters designed a new mechanism (using the permanent magnet) for easier alignment and closure, and practical for one-handed operation.

4.4 The Zipper's Evolution Summary

It has been 166 years since the first zipper was invented by Eddie Howe. The evolution map constructed and discussed in the previous section explains how the zipper evolved since 1851. Although the zipper offers an easy closure to be operated, there are still many individuals encounter problems while using it. Some of the issues highlighted by the inventors are the difficulty of joining the bottom pin and hard to grasp the small slider body or pulling it along the zipper's elements. The other problems addressed are the zipper jamming and fouling [33], [34], the difficulty to reach areas of garments such as at the back zipper of a lady's dress [44], and non-existence of the positive lock for zippers in garments (mainly the ladies' dresses) [34]. Examples of individuals who often faced these problems are the children, elderly, people with poor vision, people with disabilities such as arthritis, multiple sclerosis, and much more. The patent issued by Dierks in 1966 shows that there is a need for an assistive device to use the zipper at the difficult-to-reach areas of garments such as the back zipper [44].

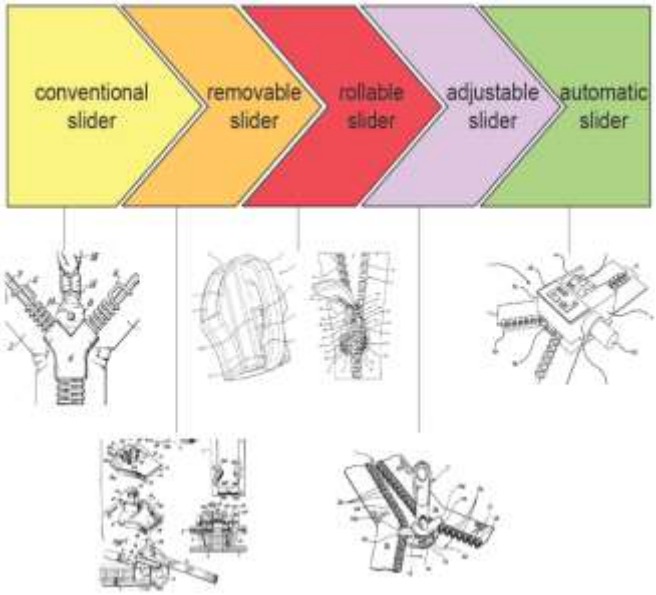

Figure 9. The evolution of the slider [10], [13], [31], [36], [38], [39]

Figure 9 visualizes the design evolution of the slider, which we considered as the engine of the zipper's system. The design of the zipper's slider has evolved from the conventional type to the removable, rollable, adjustable, and currently, the inventors are moving towards developing an automatic slider or even a robotic zipper. It proves the existence of some efforts in designing a new kind of the zipper. The advancement in the design and developments related to the zipper is really happening out there. This situation is aligned with our intention to design and develop Cliff as an automatized zipper.

4.5 The Potential Applications

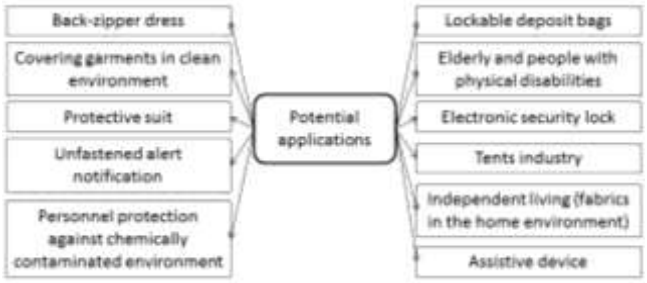

Figure 10. Potential applications, functions and features for Cliff

Figure 10 summarizes the potential applications, functions, or features for Cliff, which was extracted from the patent analysis. The patent analysis revealed a lot of potential applications, functions, or even new features of the zipper and the possibility of combining the primary function of the zipper with more advanced features. It is not only limited to the main purpose of the zipper on the garments alone, which is to complete the zipping and unzipping task. Cliff is not only beneficial for the elderly and people with the physical disabilities only. For instance, the automatized zipper could help the supervisor in clean room or

controlled environments workplace to monitor the employees. The problem addressed by Leonard is the issue of opening the garment in a controlled-environment [45]. Opening the garment used in a controlled-environment may contaminate the environment, damaging the product, and possibly subjecting the employer to fines by health inspectors [45]. An example of a controlled-environment is the food industry. It is not uncommon for workers to partially unzip their garment for various reasons, although it is prohibited. In the dairy milk industry, for instance, protective clothing is required in areas where cows are being milked. Therefore, the supervisor needs to continually watch the employees as it is not easy to detect a partially opened protective garment. This is a time-consuming task for the supervisor. Therefore, Leonard invented a garment provided for detecting when the fasteners or closure means of a garment is not fully closed [45]. Besides that, Cliff also has potentials to be used in the tents industry, the protective garments, or the personnel protection against a contaminated environment. From these possible ideas, we can conduct further brainstorming to choose which applications for robotic zipper, functions, or features to be embedded in Cliff.

5. CONCLUSION

The patent analysis performed managed to investigate the evolution trend of the zipper or the slide fasteners from the first invention back in 1851. Performing a patent analysis is another option to have an extensive review of the design and development progress of a particular product or system. The study revealed the common problems mentioned and discussed by inventors related to the zipper. The evolution map has been successfully constructed to visualize the evolution of the design and development of the zipper for the past 166 years. Besides that, a few potential applications, functions or features also have been identified which might be applicable for Cliff. The findings of this review are useful as an extensive literature about how the zipper's and the fasteners design evolved. A brainstorming session should be conducted to finalize the potential application for Cliff and improve the design of the automatized zipper.

6. ACKNOWLEDGMENTS

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