Research and Design of Wearable Intelligent Umbrella to Help People in Rainy Days

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Abstract. Because the people with upper limb disability will encounter travel problems in rainy days, researchers designed and made wearable intelligent umbrellas, so as to improve the rain-shield efficiency of the disabled when traveling in rainy days. People with upper limb disabilities will suffer from poor balance and low rain-shield efficiency when holding umbrellas with one hand. This umbrella can be used as a backpack for people with upper limb disabilities. When traveling in rainy days, the umbrella will automatically adjust the orientation of the umbrella surface according to the wind speed sensor on the other side of the backpack to improve the rain-shield efficiency. The design of umbrella is based on physical experiments, and the conclusion of rain-shield efficiency is also drawn from experiments, which ensures the strong scientific nature of the research. At present, the conclusion of the experiment verifies that umbrellas can be used in daily life and can run normally under turning, walking, turning and other actions. This study can improve the travel convenience of disabled people and improve their social identity.

1. Introduction
Traveling is an important part of people's life. In rainy days, the combination of wind and rain brings many inconveniences to people's going out. In order to solve this problem, people invented umbrellas, raincoats and other rain-shield tools. You only need to open your umbrella and put on your raincoat in rainy days to travel easily. But for disabled people with upper limb defects, it will be very difficult to travel in rainy days. At the beginning of the year, researchers communicated with disabled friends on Zhihu and Baidu Post Bar, and found the problems they encountered when traveling in rainy days. The disability of one hand or both hands makes it difficult for them to hold the umbrella, because the counterweight of the body will be uneven when holding the umbrella, which often leads to wrestling. If you travel with an umbrella with the help of others, the efficiency of rain-shield may be reduced, and the reduction of space under an umbrella will bring great inconvenience to two people. At the same time, in windy weather, the movement track of raindrops will be affected by the wind, forming an oblique downward movement track. At this time, if the umbrella is not held obliquely, the rain-shield efficiency is very low. Therefore, the research question of this study is: How to improve the rain-shield efficiency of people with disabilities when traveling in rainy days?
2. Structure design

The intelligent umbrella needs to adjust the orientation of the umbrella surface according to the wind speed and direction. According to the relationship between the pitch angle (pitch axis) and the wind speed calculated theoretically, the rotation of the umbrella on the pitch axis has a certain rotation angle. At the same time, in order to achieve the highest rain-shield efficiency, the umbrella surface also needs to face the direction where the wind blows to people. Therefore, the umbrella needs to rotate in the horizontal direction of the plane (Yaw axis). At the same time, in order to ensure the stability of umbrellas, yaw and pitch rotation need to have sequence. Considering that the torque of the pitch shaft is too large, rotating the yaw shaft first is the best choice to maintain stability, so the workflow of the intelligent umbrella is as follows: put the umbrella into the rotating table; Read wind speed and direction; Rotate the yaw axis; Rotate the pitch axis; Realize rain-shield.

![Figure 1. Schematic Diagram of Umbrella Working Flow.](image)

In order to ensure the convenience of assembly, the researchers designed the intelligent umbrella modularly according to the motor module, the electronic control backpack module and the sensor module.

When explaining the design of each module separately, the researcher wants to explain the overall design idea first. First of all, the wearable intelligent umbrella is displayed in the form of a backpack with a panel in the middle, a motor module on the left shoulder and a sensor module on the right shoulder. The umbrella weighs 486.8 g and the sensor weighs 485.0 g, so it is reasonable to distribute the same weight on both shoulders. This design ensures the aesthetic feeling of the backpack while ensuring the uniform counterweight of the left and right shoulders.

The Pitch shaft rotation module consists of a motor bracket base and a motor bracket. A motor bracket is installed on the base, and the base is connected with the steering gear through screws. The motor bracket consists of four peripheral boards and a top cover. The peripheral boards are buckled together to ensure the stability of the structure; They can also be connected to the motor bracket base. The motor is connected through a small opening left in the board. Similarly, in the design of the top cover, the design of bolt and lock catch is adopted.

In the electronic control backpack module, the designer chooses to cut a backpack panel with wood boards and fix electronic components such as Arduino UNO control module on the panel. In order to ensure that the steering gear can rotate freely and is not restricted by wiring, the steering gear control module is fixed under the left shoulder and a sensor module on the right shoulder. The backpack panel also contains a bread board, a depressurizer and three batteries. The red battery is 9V and cooperates with the buck to reduce the voltage to 5V to supply power to Arduino. 4 1.5 V batteries are combined to form a 6V power supply to supply power to the steering gear control module. The blue battery on the right is 12V to supply power to the wind speed and direction sensor. There is also an aluminum profile on the backpack panel. In order to ensure the strength of the device, the researchers chose to add an aluminum profile as the load-bearing beam.
3. Programming
The design of the program uses the for loop to make continuous judgment. After reading the wind direction data of the sensor, it can be used to determine an exact wind direction angle. And through the formula in the theoretical calculation part, the pitch angle of the umbrella Pitch axis is obtained through the wind speed, and the umbrella orientation is changed to achieve the best rain-shield efficiency. At the same time, re-enter the for loop at the end, judge again and change the angle.

4. Experiment and adjustment

4.1. Relationship between umbrella steering adjustment sensitivity and human body steering
The purpose of the experimental design is to verify the actual use efficiency of umbrellas. In actual walking, the human body needs to carry out such activities as steering. At this time, because the backpack is worn on the back, the umbrella needs to rotate an angle to adapt to the new wind direction. In order to explore the relationship between the sensitivity of wind direction adjustment and human body steering, the researchers designed the following experiments.

Experimental steps:
1. Researchers put on intelligent umbrellas and reset Arduino program after facing one orientation. (The reset procedure is designed to ensure that the initial position before each rotation of the human body is due north, so as to facilitate recording the direction of the umbrella after rotation)
2. The researcher rotates 45° and uses a stopwatch to record the time required for rotation. During the experiment, Arduino will record the pointing of the umbrella base after turning.
3. The researcher connected the umbrella to the computer and wrote down the direction of the umbrella base.
4. Step 1 and 2 were repeated for 5 times; Increase the human body rotation angle by 45° and repeated 1 - 3 times.
Experimental data:

Table 1. Relationship Data between Adjustment Sensitivity of Umbrella Steering.

| Angle(°)± 0.1° | Time(s) | Position(NESW) | Average Time(s)± 0.01s | Pointing deviation probability(%) |
|---------------|---------|----------------|--------------------------|----------------------------------|
| 45°           | 1.79    | NE             |                          |                                  |
|               | 1.93    | NE             |                          |                                  |
|               | 1.78    | NE             |                          |                                  |
|               | 2.19    | NE             |                          |                                  |
|               | 2.13    | NE             |                          |                                  |
| 90°           | 2.00    | E              |                          |                                  |
|               | 2.36    | E              |                          |                                  |
|               | 2.38    | NE             |                          |                                  |
|               | 2.82    | E              |                          |                                  |
|               | 1.77    | E              |                          | 5%                               |
| 135°          | 2.68    | SE             |                          |                                  |
|               | 2.98    | SE             |                          |                                  |
|               | 2.99    | SE             |                          |                                  |
|               | 3.11    | SE             |                          |                                  |
|               | 3.17    | SE             |                          |                                  |
| 180°          | 3.23    | S              |                          |                                  |
|               | 3.79    | S              |                          |                                  |
|               | 3.29    | S              |                          |                                  |
|               | 3.34    | S              |                          |                                  |
|               | 3.57    | S              |                          |                                  |

Through data analysis, it can be concluded that the average time required for an umbrella to turn 45° is 1.96 s, the average time required for an umbrella to turn 90° is 2.67s, the average time required for an umbrella to turn 135° is 2.99s, and the average time required for an umbrella to turn 180° is 3.44s. It can be seen that by adjusting the design of the electronic control program, the time difference of umbrella adjustment has been reduced by nearly 50%. This time difference can reasonably adapt to
the steering of the human body during walking, ensure that the umbrella always points to the position of the wind direction, and ensure the highest rain-shield efficiency.

Conclusion:
Through experiments and the adjustment of the electronic control program, the umbrella can complete 180° steering within 3.44 s ± 0.2s. This conclusion verifies that the intelligent umbrella can ensure that the human body can still enjoy the maximum rain-shield efficiency under the umbrella after steering.

4.2. Windproof Ability of Intelligent Umbrella Structure
At the same time, in order to ensure that umbrellas can withstand different scales of strong winds when traveling in rainy days, it is necessary to carry out experiments on windproof scales. However, because there is only one prototype, all structures have been fixed, and large blowers are difficult to find, the actual operation is very difficult, so researchers choose to carry out theoretical calculation.

In the theoretical calculation, the conversion formula of wind speed and wind pressure and the calculation formula of torque are mainly used. The researchers first calculated the maximum stress area of the umbrella surface, then calculated the relationship between pressure and wind speed through the conversion formula of wind speed and wind pressure, and finally compared with the maximum torque that the steering gear can bear, the maximum wind force that the device can bear was obtained. The calculation process is as follows:

It is known that the diameter of the umbrella cover is 100cm, the length of the umbrella handle is 60cm, the maximum inclination angle of the pitch axis is 10°, and the maximum torque that a single steering gear can bear is 17kgcm.

According to the standard wind speed conversion table, it can be concluded that the intelligent umbrella can be used in an environment below scale 5 wind speeds.

Theoretically calculated, the maximum bearable wind speed is 8.24 m/s, and the corresponding wind scale is scale 5, so the intelligent umbrella can operate in an environment below scale 5. At the same time, the maximum torque also ensures that the umbrella can be used in an environment below heavy rain.

4.3. Measurement of Rain-shield Efficiency of Intelligent Umbrella
In order to verify the extent to which this intelligent umbrella improves the rain-shield efficiency, the experimenter designed an experiment and compared it with the situation without an umbrella, and obtained the experimental data.

Experimental steps:
1. The experimenter placed the intelligent umbrella backpack vertically and hung clothes and trousers under the intelligent umbrella backpack. At the same time, another umbrella was placed in the venue, and clothes were hung under the umbrella as a control.
2. In rainy days, the variable group with umbrella backpack turns on the backpack switch and puts it in the rain for 5 minutes with the control group.
3. Remove clothes and trousers after five minutes, and judge the rain area by the light and dark color after being soaked in water.
4. And bear the weight to judge the net weight wet by rain.
5. Repeat Steps 1-4 three times
6. Rotate the bracket 90°, change the wind direction, and repeat steps 1-4 three times
7. Ensure that the experiment is over after the four orientations in the southeast and northwest are fully measured.

Experimental data and analysis:
Table 2. Rain-shield Efficiency of Intelligent Umbrella-Processed Data.

| Experimental group | Control group |
|--------------------|---------------|
| Wet area | Net weight of raindrops (g) | Area percentage error | Net Weight Error (g) | Wet area | Net weight of raindrops (g) | Area percentage error | Net Weight Error (g) |
| N | 5.5% | 26.8 | 1.05% | 3.1 | 22.9% | 101.0 | 1.95% | 8.1 |
| E | 6.0% | 31.2 | 1.20% | 4.2 | 24.2% | 104.2 | 1.80% | 5.7 |
| S | 4.7% | 25.9 | 0.60% | 3.9 | 23.1% | 97.8 | 0.85% | 2.1 |
| W | 5.8% | 26.9 | 1.15% | 5.0 | 21.5% | 99.8 | 1.00% | 3.1 |
| Average | 5.5% | 27.7 | 0.65% | 2.7 | 22.9% | 100.7 | 1.4% | 3.2 |

The first column of the experimental data table is the orientation of the smart backpack, the second column is the average wet area of the lower body clothes, the third column is the average net weight of raindrops falling on the clothes, and the rest are the corresponding control groups and errors.

Conclusion:
From the experimental data, it can be seen that the rain-shield efficiency under the intelligent umbrella is 76% higher than that of the ordinary hand-held umbrella. When using smart umbrellas, the average wet area of the lower body is 5.5% and the net weight is 27.7. In the normal umbrella-holding model, the average wet area of the lower body is 22.9%, and the net weight is 100.7. The wet area decreased by 76% and the net weight decreased by 72%. It can be seen from this that the intelligent umbrella has increased the rain-shield efficiency by 76%, and has higher efficiency when used in real life.

5. Conclusion
Through scientific verification, the researchers have reached a preliminary conclusion for the intelligent backpack umbrella: for the disabled, the intelligent umbrella backpack can complete daily outdoor walking in moderate to heavy rain, and has high rain-shield efficiency.

From experiments 1 and 2, the researchers came to the conclusion that umbrellas can be used by disabled people in daily life.

From Experiment 3, the experimenter came to the conclusion that umbrellas have higher rain-shield efficiency than ordinary umbrellas.

According to theoretical calculation, the experimenter concluded that umbrellas can be used in five winds, that is, they can be used in moderate rain and light rain.

At the same time, this project is also very convenient for users and disabled people of this research project. In the 4.5 umbrella usage method, only 5 steps are needed to complete the entire usage process of the umbrella. At the same time, the umbrella rotating platform is located behind the neck, and the forward inclination of the umbrella will not affect the head and will not cause potential safety hazards.

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