Project Closeout

Pilot Health Monitoring System

Group 44
Sachin Betrabet, Rami Hansen, Jack Woods
ECE Senior Capstone Group #44
Oregon State University

30 April 2021

Design Impact Statement

Public Health, Safety, and Welfare Impacts

Public health and safety is put at risk everyday as people fly on airplanes around the world. According to the Flight Safety Foundation, studies of human factors in aviation have associated stress with pilot error [1]. There are two kinds of stress that affect pilots: acute stress and chronic stress [2]. Acute stress is how the body responds to immediate threatening situations (real or imagined). In contrast, chronic stress is how the body copes with long term threats. Groups such as the European Aviation Safety Agency and the British Airline Pilot's Association stress the danger of fatigue of pilots. Pilots who are not cognitively able to pilot aircraft are a huge liability that can put everyone both on the plane and on the ground at immediate risk. The mental health of passengers should also be considered. Passengers who know that the pilot is being evaluated on a constant basis may feel more comfortable traveling by aircraft.

Cultural and Social Impacts

The cultural and social impacts of the Pilot Health Monitoring System are profound. One possible impact is that air travel may begin to be perceived as safer. Despite being one of the safest modes of transportation available, air travel does have a reputation for danger because of how violent its incidents tend to be [3]. Cultural differences in air travel can lead to disastrous consequences if not dealt with properly. Cultures have different expectations and norms related to risk-avoidance, individualism, and uncertainty-avoidance [4]. Different cultures have different ways of expressing concern based on how hierarchical their culture is and how much they value individuality which can lead to ambiguity and miscommunication [4]. The pilot health monitoring system would be able to act as an unbiased measure of the pilot state. If a pilot is feeling really stressed, and for some reason based on cultural differences is not able to express the severity of a problem, the system would be able to inform those on the ground of the state of the pilot.

Environmental Impacts

The pilot health monitoring system should be able to help allow for more air travel to occur as pilots can be monitored for a longer period of time. Increased aviation leads to carbon dioxide and water vapor emissions that accelerate the process of climate change [5]. Aviation also leads to emissions in Nitrogen oxide, hydrocarbons, methane, carbon monoxide, sulfur oxides, and particulate matter which leads to negative impacts on air quality [5]. A system that can monitor a pilot's state would enable airlines to push the boundaries of where they can travel by providing confidence in the pilot's cognitive ability in far off places. The pilot health monitoring system would be liable for the increased usage of air travel, thus being a culprit for the pollution of air.

Economic Factors

The Pilot Health Monitoring System can not only increase an airline's income, it also has the potential to decrease their operating costs. Airline insurance is an expensive industry that covers anything from passenger injuries to complete hull loss [6]. These rates generally increase in cost every single year [6]. Safer airplanes have the potential to reduce the cost of airline insurance by a great deal. The monitoring system would be able to track areas where pilots are more stressed and less stressed which could be used to staff the appropriate pilots to where they feel the most comfortable. By making sure pilots are flying where they are most comfortable, airlines would be able to boost productivity and create a more streamlined system for air travel.

Sources

[1] "HUMAN FACTORS & AVIATION MEDICINE", *Flightsafety.org*, 2006. [Online]. Available: https://flightsafety.org/hf/hf_jan-feb06.pdf. [Accessed: 17- Apr- 2021].

[2] "FAA TV: Stress in Aviation", *FAA.gov*, 2012. [Online]. Available: https://www.faa.gov/tv/?mediaId=450. [Accessed: 17- Apr- 2021].

[3] H. Ranter, "Aviation Safety Network > Statistics > By period," Aviation Safety Network. [Online]. Available: https://aviation-safety.net/statistics/period/stats.php. [Accessed: 16-Apr-2021].

[4] L. Werfelman, "Crossing Cultures," *Flight Safety Foundation*, 24-May-2015. [Online]. Available: https://flightsafety.org/asw-article/crossing-cultures/. [Accessed: 17-Apr-2021].

[5] "Aviation Emissions, Impacts & Mitigation A Primer," *Federal Aviation Administration*, Jan-2015. [Online]. Available: https://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/Primer_Jan2015.pdf. [Accessed: 16-Apr-2021].

[6] AON Risk Solutions, Airline Insurance Marketindicators 2010/11. [Online]. Available: https://img.en25.com/Web/AON/airline_indicators_2010_WEB_FINAL.pdf

Project Timeline

Deadline	Description	Involved
11/26/20	Final CS block diagram	All
11/20/20	Recorded ECG data available	ECE sub team
12/10/20	Initial prototype PQRST classifier functional	Rami
12/10/20	Initial prototype data interpreter	Sachin
12/10/20	Initial prototype data visualization	Jack
2/1/21	PQRST classifier final	Rami
2/1/21	Data interpreter final	Sachin
2/1/21	Data visualization final	Jack
2/8/21	Begin software integration testing	CS sub team
2/8/21	Begin hardware integration testing	ECE sub team
3/29/21	Spring term start - Pilot classification system works	All
Spring 21	Engineering Expo - Pilot classification system finalized	All

Scope and Engineering Requirements Summary

Accurate Measurements

Project partner requirement: Pilot biometric data must be measured accurately.
Engineering requirement: The CS system will calculate PO2 within 5% of actual values based on real-time data.

<u>Testing process:</u>
1. Run system and proven biometric device under regular conditions for 2 minutes
2. Collect and store data from both devices. Will likely need to record the output from proven biometric device with video and transcribe by hand.
3. The data collected by our system does not deviate from the data collected by proven biometric device by more than 5%

Biometric Calculations

Project partner requirement: Classification must occur within the cockpit on a hardware device.
Engineering requirement: The CS sub-system will calculate BPM within 10% of actual values based on real-time data.

<u>Testing process:</u>
1. Run system and proven biometric device under regular conditions for 2 minutes
2. Collect and store data from both devices. Will likely need to record the output from proven biometric device with video and transcribe by hand.
3. The data collected by our system does not deviate from the data collected by proven biometric device by more than 5%

Classify Pilot State

Project partner requirement: System should be able to classify the pilot into unstressed and stressed conditions, and output the condition. The system should be as accurate as possible.
Engineering requirement: The System will produce "stressed" or "unstressed" output with less than 30% false positives/negatives rate compared to the user reported stress level real-time using a trained model.

<u>Testing process:</u>
1. Run the system while collecting test pilot data.
2. Pilot will specify their own state during data collection.
3. Compare the test pilot's self-assessment to the output of the classifier.
4. Count the number of false positives and false negatives. Verify that the total number false positive and false negative classifications do not exceed 30% of classification outputs.

Data Output Latency Graph

Project partner requirement: System should provide low latency data output as a graph.
Engineering requirement: The CS system, on average, will provide PO2 data and graphs of the system with at most 200ms latency.

Testing process:
1. Run system with mock sensor hardware
2. Switch mock data to 'stressed' mock data, record exact time, likely with video camera
3. Record time that 'stressed' mock data appears in user system

Haptic Feedback Response

Project partner requirement: Pilot state classification must occur within the cockpit on a hardware device
Engineering requirement: The software system must return two warnings, based on the pilot state classification (stressed or unstressed), to the hardware device for haptic response.

Testing process:
1. Run system under stressed pilot conditions
2. If software sends a warning response after 30 seconds of stressed classification - passes condition
3. If software sends a high alert response after 1 minute of stressed classification - passes condition

Mitigate Sensor Malfunction

Project partner requirement: Pilot biometric data must be measured accurately.
Engineering requirement: The CS system classification and PO2 output will be based on as few as 1 sensor inputs and as many as 3 sensor inputs without retraining.

Testing process:
This testing procedure will be run with X=1, 2, and 3 sensors.
1. Connect X mock sensors to the CS system.
2. Boot the CS system.
3. Verify that the user interface indicates that X sensors are connected.
4. Trigger the mock sensors to change the PO2 data to imitate a "stressed" pilot.
5. Verify that the user interface indicates the correct PO2 data and classification output.

Persistent Data Storage

Project partner requirement: Heart rate data should be stored in a format accessible by full-time engineers.
Engineering requirement: The system will store at least 2 hours of data to an SD card in CSV format.

Testing process:
1. Run system under regular conditions for 2 hours
2. Verify that SD card data transfer occurs
3. Verify that data is in valid CSV format and can be imported to Excel or similar application
4. Import CSV into Excel and count number of samples recorded, compare against expected number of recorded samples

Sensor Data Rate

Project partner requirement: Pilot biometric data must be measured accurately and at a high resolution
Engineering requirement: The system will report raw samples at an average frequency 64hz or higher.

Testing process:
1. Run system under regular conditions for 1 minute

2. Verify that an average of 64 samples or higher are written to the database each second. (~3840 total samples)

Risk Register

Risk Category	Risk Description
Academic	Risks imposed by academic requirements, course schedule, student life, etc.
External	External hazards such as storms, floods, vandalism, civil unrest, disease, etc.
Legal	Legal and regulatory obligations pertaining to intellectual property, IP disclosure, aviation laws, etc.
Market/Project Partner	Risks imposed by business requirements set by our project partner. Timelines, demands, costs, etc.
Operational	Risks encountered while actually creating the project deliverables. Miscommunication, risks imposed by adopting/using tools/resources, etc.
Strategic	Risks which result from poor strategic decisions. Using the wrong tools/technology, poor planning, etc.
Support	Risks associated with supporting our project deliverables. Inadequate documentation, knowledge transfer, etc.

Action Plans
Avoid — change your project so the risk becomes obsolete
Retain — decide the risk is reasonable to proceed with your project
Reduce — decrease the likelihood of the risk occurring without changing the project
Transfer — delegate responsibility for that particular risk area to a stakeholder or someone outside the team

ID	Risk Description	Risk Category	Risk Probability	Risk Impact	Performance Indicator	Responsible Party	Risk Action Plan
A-1	Course requirements / goals do not align with project partner's goals/requirements.	Academic	70%	Low	Do deadlines and timelines align? Are requirements documents accurate?	All team members.	Reduce
A-2	Course schedules are incompatible during winter or spring quarter.	Academic	35%	Medium	Check schedules during course registration.	All team members.	Retain

A-3	Team member drops the course.	Academic	5%	High	Is a team member unresponsive? Failing to meet objectives? Low Trello velocity?	Instructors	Transfer
E-1	COVID-19 poses risks to the project. The situation *could* become worse.	External	70%	Varies	University email sentiment. Communications from instructors. COVID-19 case counts in Benton County.	OSU Administration	Transfer & Reduce
L-1	Team member accidentally violates software license while using open source software.	Legal	40%	Low	Friendly cease and desist letter? Have the licences from each library been thoroughly read and understood by the team?	All team members.	Avoid
M-1	Performance metrics cannot be attained through mediums required by Project Partner.	Market	25%	High	Performance metrics. Latency (ms), resolution (hz), accuracy (% type I and type II error).	Component owners (team members responsible for a component).	Avoid
M-2	Project partner requirements change.	Market	15%	Varies	Are many wearable heart rate monitor devices coming to market? Changing demands?	Project Partner	Avoid
O-1	Cannot access lab space as a result of A) loss of privileges or B) schedule conflicts.	Operational	30%	Medium	Lab appointment attendance.	ECE Team Members	Retain
O-2	Cannot effectively share hardware.	Operational	25%	High	Is someone designated as the "Hardware Inventory Guy"? How often is hardware changing hands? Number of blocked tickets due to hardware unavailability.	Designated Hardware Inventory Person	Reduce
O-3	Interfaces interpreted incorrectly by developers. Components are not compatible.	Operational	70%	Low	% of automated integration tests passing/failing.	Component Owner	Avoid

STG-1	Inaccurate effort estimation results in missed deadlines.	Strategic	100%	Low	Trello progress & weekly point velocity.	Jack W	Reduce
SUP-1	Insufficient knowledge transfer between project team members and project partner.	Support	90%	High	Grades on documentation-related assignments. Communication from project partner.		Reduce

Future Recommendations

Get test data early.
Getting reliable test data is essential for testing each block in the system. Our group relied on templating code and making assumptions about what data would appear in recorded biometric samples. Because of this, sweeping changes had to be made throughout the code when a final sample format was decided. This could have been avoided by deciding on a data type and obtaining test data earlier in the project.

Recommendation
Obtain test data that represents the actual data that will be transmitted during the earlier stages of the project. This will enable future groups to design their systems around the data type rather than designing generic types to work with any data type.

Focus on inter-group communication.
COVID restrictions prevented the two sub teams from working closer together. While the teams were in regular contact through weekly meetings the project did suffer somewhat from lack of communication throughout the project.

Recommendation
Set up a more robust communication structure and stick to it. This will allow the development of the two systems to proceed more efficiently.

Get access to accurate biometric sensors.
The team relied on fitness watches to provide accurate data to judge the system against. While these systems may be accurate with a generous tolerance, they do not provide adequate methods for retrieving the data. Our team's Fitbit Charge 4 provided semi-accurate BPM data but only provided average SpO_2 during overnight use, despite advertising that claimed otherwise. It also did not provide a good method for accessing the raw recorded data.

Recommendation
Look into the College of Public Health at Oregon State for their recommendations. It may be possible to gain access to a medical grade device to collect example data with. This would provide a far more accurate data set to compare with device data. A consumer grade smartwatch that uses an optical sensor may also be necessary for further testing.

Use a Kanban board or other group control tool more effectively. Our group used Trello for tracking individual tasks among group members. This was useful for around two weeks until the group stopped using it. Knowing the progress of teammates is essential for group work. **Recommendation** Make an effort to stick to whatever tool the team chooses for keeping track of the project's necessary tasks. Knowing the progress of each individual part of the project will help move the project forward at a quicker pace.
Make shared decisions early. Indecision surrounding the exact schema to use for Bluetooth packets and Database entries caused some delays in finalizing the system. Having made these decisions and defined the schemas earlier on in the project would have made things easier during the final stages. **Recommendation** Making decisions that affect both groups' projects earlier rather than later will eliminate headaches later on, especially regarding data communication between the two systems.
Plan ahead to mitigate supply chain disruptions. The COVID-19 pandemic, combined with widespread "just-in-time" logistics, created supply chain disruptions that prevented the hardware team from procuring a hardware device. This made testing and verification difficult. **Recommendation** Create contingency plans so that testing can be completed in the absence of the target hardware. Test benches can be used to mock connections between software components and hardware.
Integrate software components early. Our team developed software blocks mostly in isolation. This ultimately resulted in unplanned hours spent on rewriting certain components so they would be compatible. Integration testing also revealed shortcomings that were not apparent through exploratory unit testing. **Recommendation** Class interfaces should be defined early in the project's planning and should be strictly adhered to. Modifications to these interfaces must be communicated and discussed thoroughly.
Choose technologies and languages that everyone is familiar with. The bulk of our team's software was written in C++. Unfortunately, this excluded a team member from being able to meaningfully contribute to some of the more advanced parts of our software system. **Recommendation** Discuss and catalog technologies that team members are familiar with. This course is a great opportunity to learn new technologies, but that will add to a team member's workload. I highly recommend that team members elect to work on components they are confident they can finish. It is important to remember that each team member will likely be learning how to effectively collaborate on a software project; selecting familiar technologies reduces the overall cognitive workload for the team.