Logical Design Proposal Automatic Uniaxial Tensiometer Team 4

Farid Barak, Alex Reyes, Kihyun Lee, Nour El Banna

Activity Report

Abstract—The purpose of this design proposal is to improve the existing tensiometer design. The current system is functional but does not meet the set requirements. The main problem with the system is its accuracy. The sensors and the method which data is collected produces results with considerable amounts of error. The largest requirements set for the system are accuracy and precision, therefore the results from the tensiometer must be close to known results for tested materials which the current system does not produce reliably. This problem with the current system can be improved by upgrading the current load and distance sensors. Other ways to improve the accuracy and precision of the system is to improve the software used to interface with the sensors and to collect the data. With an improved and simplified method to use the collected data, the results from the system fall closer to the expected results. Improvements in the sensors and the way that they interface with the system as well as addressing a few physical design flaws that make the tensiometer more difficult to use such as the method that the material being tested is held in place, improves and solves problems with the system that fail to meet the requirements.

Index Terms—Uniaxial Tensiometer, System Analysis, Engineering Design

1 Background

Modern commercial uniaxial tensile testers can cost anywhere in between \$8,700 and \$29,000 [1], a cost arguably justified to higher institutions. Although commercial tensiometers feature tight tolerances, rugged durability, and are engineered for their reliability, uniaxial tensiometers work under the basic principle of straining a material until failure. Building a similar machine with a lower budget can potentially achieve the same results while keeping tolerances within a reasonable limit. The University at Albany's Chemistry department, for example, is in such a predicament. This proposed design of a tensiometer consisting of a microcontroller can satisfy most tensile testing requirements while keeping the budget low within a set of constraints.

- *Farid Barak,*
  E-mail: fbarak@albany.edu,
- *Alex Reyes,*
  E-mail: areyes7@albany.edu,
- *Kihyun Lee,*
  E-mail: klee23@albany.edu,
- *Nour El Banna,*
  E-mail: nelbanna@albany.edu,
  University at Albany.

2 System Requirements & Constraints

In building a tensiometer to a market with a lower budget, multiple constraints and requirements must be met to cater to such a market. One can immediately think of the cost. This build is designed not to exceed \$150. Such as cost is relatively minor compared to a commercial machine. Due to the nature of the tensiometer and easy accessibility to students, parts used are required to be easily accessible and ready to be changed on demand. [2] Figure 1 depicts the system use cases.

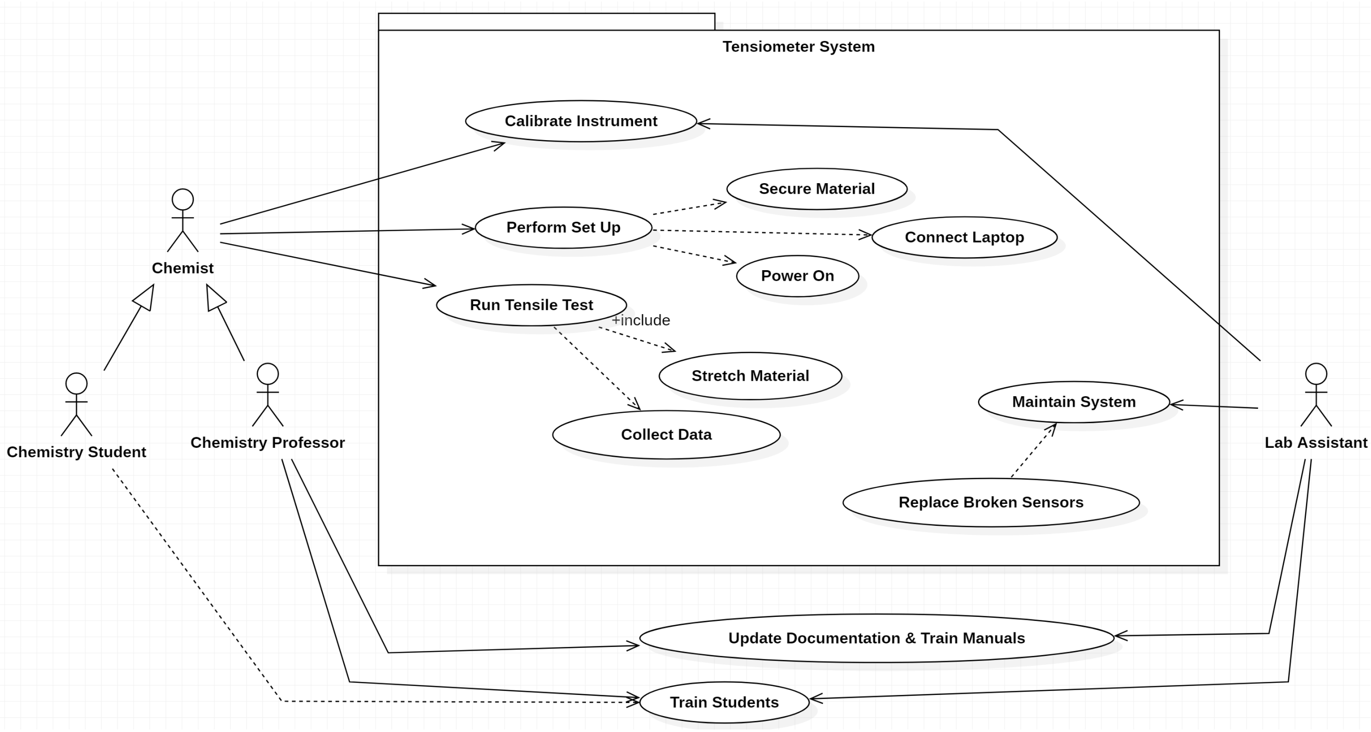

Figure 1. Use case model of the tensiometer system depicting system actors and the desire actions the system is required to support.

2.1 Requirement #1 Accuracy/Precision

The largest requirement for the system is its accuracy and precision when taking measurements. The desired results should be close to those from professional equipment and must be easily reproducible. The user must be able to collect accurate results for the material being tested. The resulting stress-strain curve should be clear and accurately represent the characteristics of the tested material. When using the system, the same results must be able to be collected reliably as well. Multiple samples of a material may be tested, and the results should be identical for the same material despite the physical dimensions of the material being varied.

Normal Flow
This describes the default flow of the use case. Often referred to as the ”happy path”.

- **Step #1: Calibrate Instrument**
- **Step #2: Run Tensile Test**
- **Step #3: Collect Data**

Alternative Flow This describes what will happen under an error condition.

- **Step #1: Replace Broken Sensors**
- **Step #2: Update Documentation Train Manuals**
- **Step #3: Maintain System**

2.2 Requirement #2 Ease of use

System usability must always be taken into consideration. The way that the user interacts with the system is key to producing the desired results from the tensiometer. The current method for collecting data is not very user friendly and produces results with large amounts of error that can be improved by changing the way the user interacts with the system. The existing system has various points where the user interfacing with the tensiometer can cause error when collecting the data from the test. The physical layout of the tensiometer can be changed to reduce user error and prevent possible failures in the system. Changing the way that the actual tensile test is run by automating parts of the tensiometer make its use and measurements more accurate and its results easier to read and use.

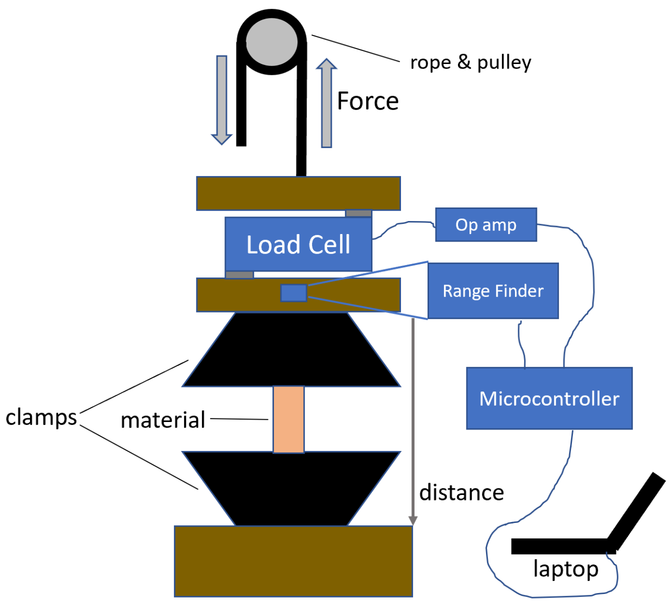

Figure 2. The proposed design of the prototype illustrated above. Note the rope and pulley is replaced by a stepper motor.

2.3 Constraints

These constraints are typically imposed by the project sponsor, end user, or by external regulations. Constraints restrict the design process and limit the potential solutions. For this project, system constraints have already been defined and have been given to you below:

- **Time Constraint:** Completed and read to presentation/demonstrate by April 22nd
- **Budget:** Cost needs to be below $150. Going over budget will require strong justification as to the value added from the cost overrun. [3]
- **Replication:** Relatively straight-forward process to replicate your work, such that we can build out a lab of identical tensiometers.
- **Accessibility of Parts:** Parts need to be readily accessible, ship quickly (not on back order) and available from common part suppliers (e.g., Digikey, Mouser, Adafruit, SparkFun, Amazon). Avoid parts that are difficult to source.
- **Safety:** System must be safe to operate without significant training or supervision

3 Logical Design

The design of this tensiometer consists of a basic structure consisting of a base, supporting pillars, and a top that together creates a rectangular uniaxial tensile tester as illustrated in Figure 2. A clamp holds the material to be tested and a load cell measures the instantaneous force applied to the material. A pulley is connected to a stepper motor which calculates the distance stretched (strain) automatically, negating the need for a range sensor.

3.1 Design Justification

The chosen configuration of the clamp and load cell was favored over other alternative designs due to its ease of use and simplicity. Unneeded complexity of the equipment was avoided by negating the use of parts as much as possible while reducing the need for user interference. One way this is accomplished is by using a stepper motor for precise control over the strain of the material as opposed to simply tugging on a string to strain the material. Using this method negates the need for a range sensor. By incorporating a motor to automatically stretch the material until failure, significant error is eliminated as well as increasing the simplicity and reliability of the design.

References

[1] L. Novotny, "What is the price of a universal test machine?" *TestResources*, Apr 2020. [Online]. Available: https://www.testresources.net/blog/what-is-the-price-of-a-universal-test-machine/#:~:text=perhaps\%20an\%20extensometer.-,Low\%20force\%20(ranging\%20from\%201\%20kN\%20to\%2025\%20kN\%20max,price\%20from\%20\%2425\%2C000\%20to\%20\%2448\%2C000.

[2] R. Shiroor, "IPTV and VoD services in the context of IMS," *IP Multimedia Subsystem Architecture and Applications, 2007 International Conference on*, pp. 1–5, December 2007.

[3] H. Schulzrinne, A. Rao, and R. Lanphier, *RFC 2326 - Real Time Streaming Protocol*, RFC, IETF, 1998.