LabMate: A Forearm-Mounted Plate Streaking Device

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Augmenting Human Dexterity – Spring 2023

Term Project: Report and Research Proposal

Abstract

Congenital limb defects are the result of either a portion or the entire upper or lower limb failing to form while a baby is developing. While the exact cause is unknown, and there is a wide range of possible severity, the two main ways of addressing such a defect are through surgery or prosthetics since there is no simple cure. This report addresses the need of an individual for an arm mounted device to use certain research laboratory tools, specifically to assist with the task of plate streaking, a microbiology technique for bacterial colony growth. In this study, we propose a functional prototype for a wrist mounted petri-dish gripper with rotational motion for ease of use and increased efficiency in task completion. To determine usability, several iterations of a functional prototype were constructed.

I. Introduction

Limb loss is a widespread phenomena, caused by either congenital defects or acquired later in life through amputation or other method. Full hand loss from the wrist downwards leads to close to total reduction in ability of dexterous manipulation with the given limb. Without a full functionality prosthetic hand, either specific assistive devices are needed to help with certain tasks, or the processes for completing those tasks must be adapted. LabMate focuses on efficiency and functionality in streaking petri-dishes for people with upper limb loss.

A. Background

Current development of prosthetic devices focus on creating multifunction gripping devices. Unfortunately these devices frequently do not meet the requirements of the user with a study from Salmer et al. seeing rejection rates of up to 44% for upper limb amputees [1]. Further studies on the cause for high rejection rates reveal product rejection having strong ties to under-delivering on user expectation on functionality and comfort [2], [3]. As such, this study will focus on the development of a device optimized for user comfort with a highly focused use-case.

The task requirement is assisting in the fixturing of a petri dish used in the plate streaking process. Plate streaking is a technique that has been used for over a century to isolate microorganisms in a laboratory setting [4]. It typically involves a round dish filled with an agar base material that is then inscribed with the desired inoculum [5], [6]. Plate streaking is one of the leading methods for bacterial strain isolation and requires a high level of dexterity with multiple discrete actions [7]. Current devices on the market are desktop mounted, require a trained technician to operate, a fixed location of operation and are optimized for large batches [7]. A cheap, simpe, and easy to modify device optimized for user comfort, small batch functionality, and flexibility will be the focus of this study.

We put forward the hypothesis that our proposed device will increase the efficiency of plate streaking petri dishes without compromising the comfort of the user.

B. Overview

In section II, we will cover the insights gained from our interview to understand the interviewee's unique needs. In section III, we propose a device to address one of their most directly stated needs. This

device assists with the process of plate streaking for use in a microbiology lab. In section IV, we will explore the merit of such a device in today's landscape. In section V, we discuss the device's impact, and since it is designed for a very specific need, instead of a broadly enrolled study we propose releasing the assistive device plans online for anyone that would find it useful to adapt to their own needs.

II. Interview case study

This study utilizes an interview case study as a guide. The interview was conducted by a team of a primary interviewer and two note takers and took place over a 90 minute period at a coffee shop. The audio, video, and transcript was recorded using Zoom. The interviewee is an individual missing their full left hand from the wrist down, who has had significant time to develop routines and procedures for one handed manipulation. They highlighted their independence and ability to independently complete the majority of tasks while still being comfortable asking for assistance. The interview is split into two sections focused on previous prosthetic experiences and descriptions of tasks that would benefit from an assistive device.

Two experiences with prosthesis were described, a rudimentary gripping device and a fully functional prosthetic. The initial device was described as a plate attached to the palm side of the wrist that the palm could be pushed against to provide a grip. The intention of the device was to provide a form of grasping, however gripping was limited to thin flat objects and limiting arm and wrist mobility. It was described as having poor ventilation and causing skin irritation. The device was abandoned for not meeting requirements and inconveniencing the user. The interviewee is also in process of receiving a full prosthetic device for general usage. The goal is to create opportunities in work and daily life that would not be possible without a true prosthetic. The interviewee has high expectations for the hand and is nervous that the new prosthetic will not meet expected functionality. However, it's a long process to get a fully costomized prosthetic so they will not receive it in the near term.

The second section of the interview focused on the plate streaking process. The standard procedure involves dividing a petri dish into four sections and scratching the culture media from the outside of the dish to the center in each section with a loaded inoculation loop [5], [6]. The interviewee described methods that they had developed to plate streak with only one hand. The described methods required multiple steps to fixture the petri dish and switch tools. It also required the interviewee to remain stationary at the lab table and adopt non-ergonomic positions. From the interviewees descriptions a list of requirements were developed. The device needs to fixture the petri-dish to the user's arm, allow rotation to fixed positions, be easy to use, have comfortable mounting, and maintain current mobility.

Prompt/Theme	**Interview Statement**	**Interpreted Need**
Work	"I need to streak plates for work, and it's hard to both hold it, streak, and observe at eye-level at the same time."	A tool to hold the plate at eye-level that they can use quickly
Prosthetics	"Yet I feel like the prosthetic I did have kind of got in the way more than it helped."	Ergonomic
	"that was really like as much as it was good, for like I could just maybe hold some papers or something small"	Versatality
	"it was plastic, and my hand will get super sweaty, and it would slide off yeah, it was sweaty"	Breathable, comfortable, stays in place, maintains current mobility

TABLE I: Interview deep dive.

III. Proposed Device & Test Methods

A. Proposed Device

Responses in the interview drive the device criteria: task fulfillment, ease of use, and ergonomic design. The main functionality of the device is to securely fixture a petri dish on the wrist and allow the user to adjust rotational orientation. The device consists of three main structural groups: straps to mount to the arm, a turntable to rotate the device, and a two-jaw gripper to grip the petri dish. Together, these components make up the LabMate.

The device is mounted to the forearm using two adjustable elastic straps and velcro that provide comfort and breathability. The straps can be adjusted to fit the user's arm comfortably and tight so that the device does not fall or tip over. The underside of the turntable has velcro that mates with the elastic straps.

The turntable consists of a bottom, stationary component, and a top component which rotates about the bottom component. The top and bottom components are held together with free rotation by a bolt and washer. The top component has slots to house a pin and a rubber band in tension that holds the pin in place. The bottom component has slots every 45 degrees around the center which serve as discrete rotational positions. The pin housed by the top and bottom components fit into the rotational positions and lock the gripper in place as can be seen in Figure 1. The rubber band is present to provide a spring-loaded force so that the resting position of the pin is in a discrete angular position around the center. Together, these components create a turntable with a spring-loaded pin that can be operated with one hand to change rotational position.

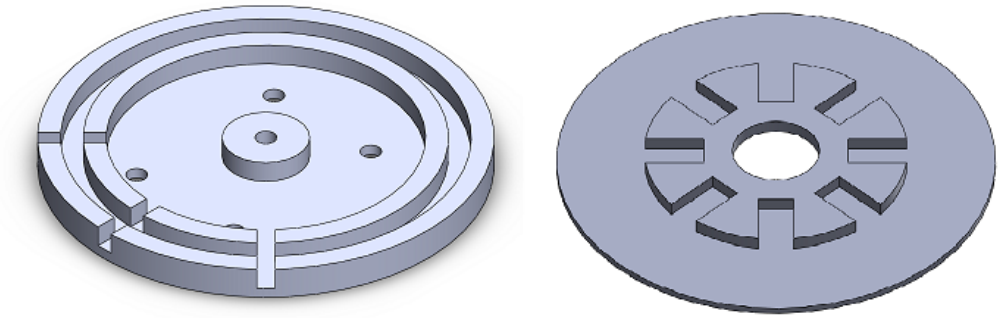

Fig. 1: The rotational mechanism internal components

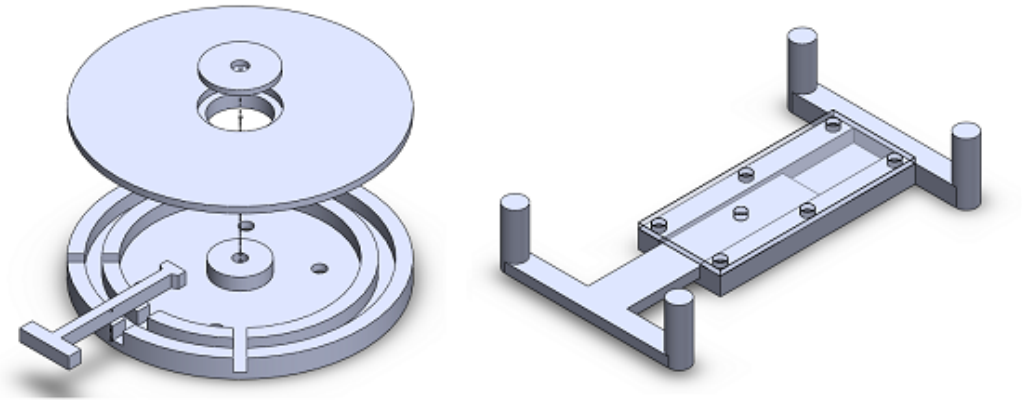

Fig. 2: Exploded view of plastic components. Left: Turn Table; Right: Gripper

The gripper on the LabMate is a spring loaded design with male and female sliding components as seen in Figure 2. The gripper is mounted onto the top turntable via four screws on the female sliding component

and rotates with the top of the turntable. The male component slides into the female component and they are held together by rubber bands that keep the jaws closed at rest. Tension springs can be used if a more robust solution is desired. The jaws of the gripper are made of two prongs spanned by rubber bands which conform to the shape of the held object. This increases surface contact and stability. With a low number of moving parts, a user could customize the gripper to meet aesthetic or additional functionality requirements without inhibiting functionality.

The device is designed to be quick and easy to use with one hand. The straps can be adjusted to fit the user using one hand and the grip assembly can be mounted to the arm with one motion. The petri dish can be used to push open the grip and fits into the grip. The pin is pulled to change position and used as a handle to rotate the turn table. Altogether, the device is simple to use one-handed with a low barrier to entry. For information on materials used, refer to the bill of materials in Appendix A.

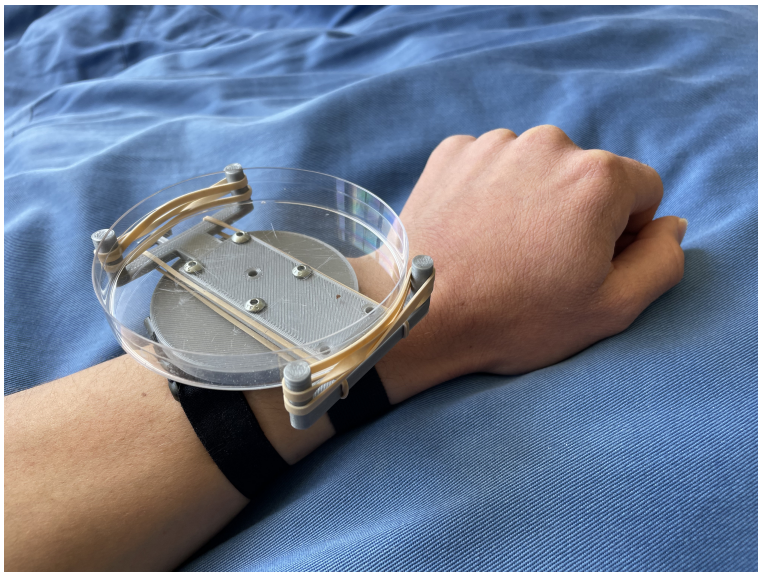

Fig. 3: Final Prototype

B. Test Methods

Our proposed study would evaluate how LabMate affects efficiency in a laboratory setting. To assess our concept's functionality and efficiency, a group of 10 human subjects will be asked to streak plates with the device operational, with the device non-operational, and without the device. The efficiency can be quantified in the number of plates streaked in four hours, and the data collected will be used to compare results with and without the device operational. After proceeding through all three cases, the participants will be surveyed on their thoughts and perspectives of the device, and what changes they would make to the device to improve functionality. Since this study involves the use of human subjects, approval from the Institutional Review Board would be required before proceeding with research for the protection of human subjects. All researchers have completed the CITI training Group 1: Biomedical Research Investigators as of April, 17th 2023.

IV. Intellectual Merit

Currently, since there is very little assistive technology available to users with disabilities in microbiology labs, our device opens the door for a family of assistive technology tailored to task-specific needs. If our device can increase task completion efficiency and feasibility without compromising our user's capabilities, our device can inform future iterations and the potential for assistive lab tools. Even an individual without a physical disability could potentially benefit from a device such as this since it

allows increased multi-functionality without getting in the way of the hand. If our hypothesis is false, returning to the device concept and changing the prototype would be necessary to suit the user's needs, and additional interviews would be required to meet new design criteria. Our study does not compare how lab technicians with disabilities that limit grasping compare to their peers without disabilities. A future study could be introduced to test a hypothesis on if a technician with a disability can surpass their peers in the workplace with the aid of assistive technology. More improvements would need to be made to the current prototype over time to inform such a study.

V. Broader Impact

This device has a highly specific use case for those with disabilities in dexterous manipulation looking for a quick and easy way to hold and rotate a petri dish. While intended for users with disabilities that limit their grasping abilities, our proposed device can benefit others as well. Our forearm mounted device can be customized to hold other items as well and does not have to be exclusively used for holding petri dishes. We would like to make the design open source, since it is cheap, 3D-printed, and uses commonly available items. It can be adapted to be more personalized for each user or to suit other needs. LabMate should pave the way for assistive technology in the workplace.

References

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APPENDIX A
INVESTIGATIONAL DEVICE DETAILS

A BILL OF MATERIALS

Component	**Source/Material**	**Cost**
Turn Table	3D Printed (PLA)	$\tilde{\$}$1.00
Gripper	3D Printed (PLA)	$\tilde{\$}$1.00
5x #5-40x3/8 Button Head Socket Screw	Stainless Steel (Off the shelf)	$1.10
Single Sided Velcro with adhesive	Fabric Store (Off the shelf)	$2.00
Side Release Buckles	Fabric Store (Off the shelf)	$5.00
Elastic Straps	Fabric Store (Off the shelf)	$2.00

TABLE II: Specialty Tools Required: 3D Printer

B CAD FILES

3D CAD models can be found at the following github repository:

`https://github.com/Erik-Francis/LabMate_ME179`