Design of an Automated Controlled Pollination System for Loblolly Pine

Piyush Pandey[1,2], Kitt G. Payn[2], Austin J. Heine[2], Sierra Young[1]

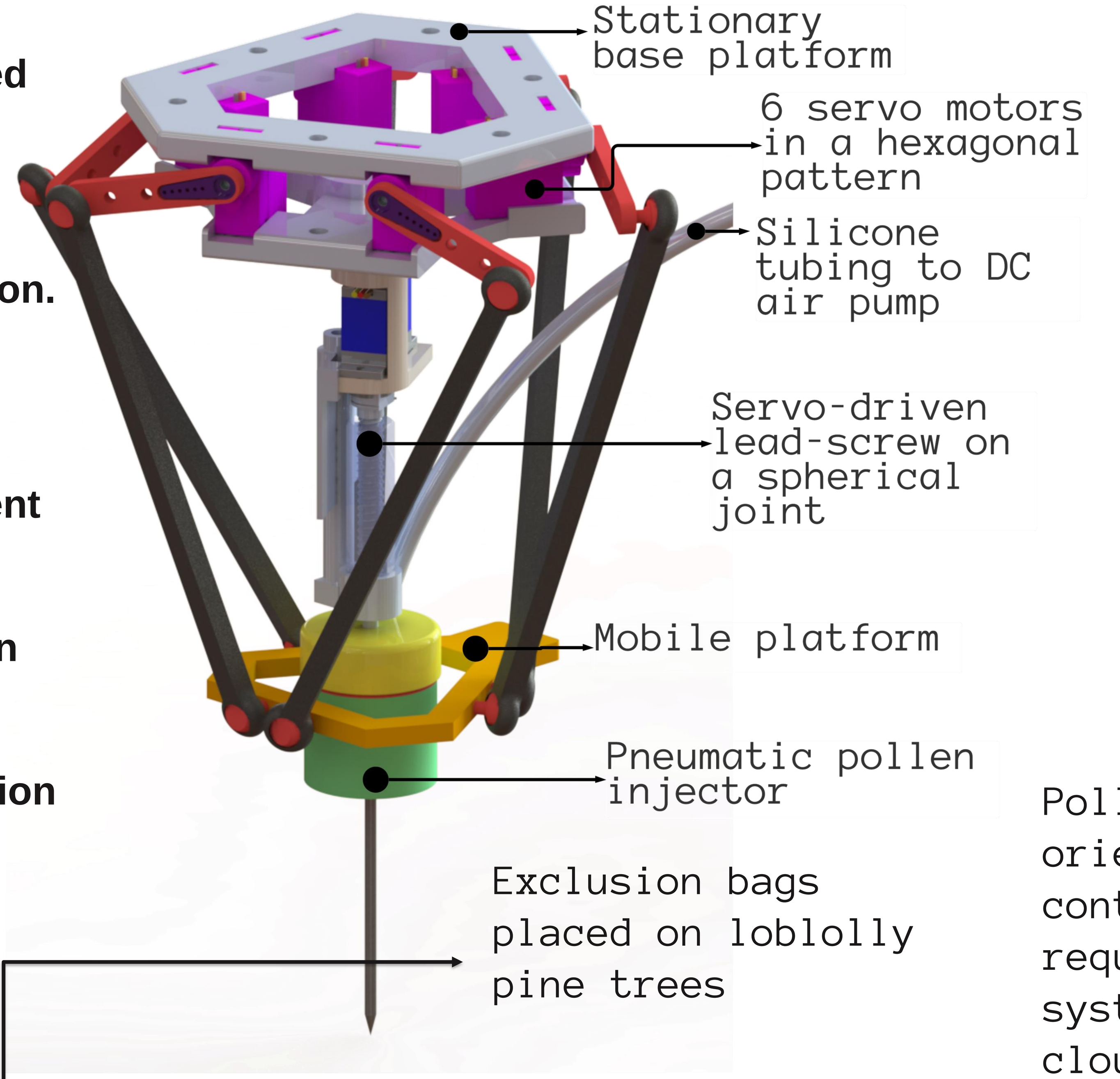
[1] Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, NC

[2] North Carolina State University Cooperative Tree Improvement Program, Raleigh, NC

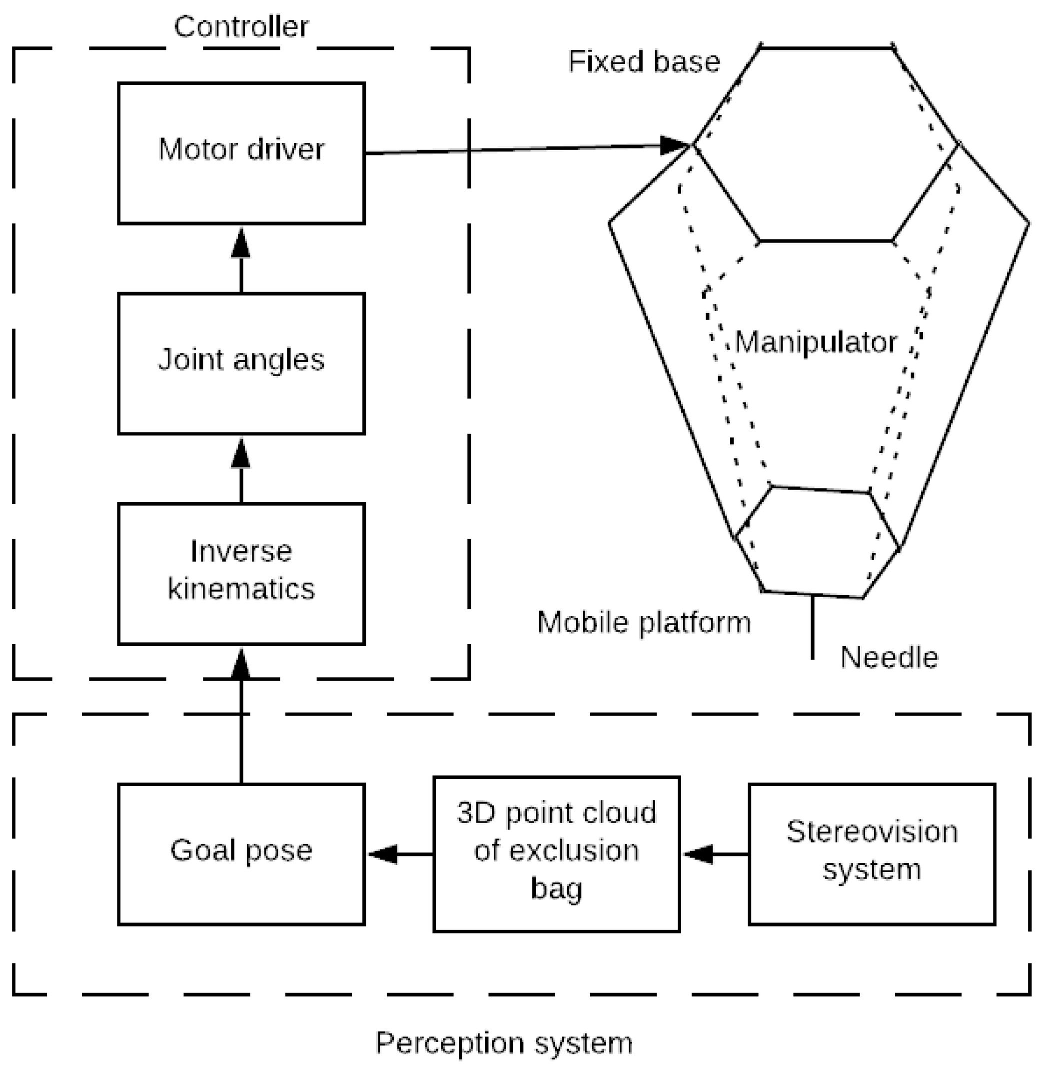
Contact: ppandey4@ncsu.edu

INTRODUCTION

We present an automated pollination system aimed specifically at loblolly pine, which is the most planted tree species in the United States. The production of seeds of high genetic quality in seed orchards is achieved through the process of controlled pollination. In this process, pollen (from male strobili) collected from a selected tree is used to artificially pollinate female strobili (flowers) that are isolated from ambient pollen using an exclusion bag. Pollen is manually introduced into the bag using pneumatic injectors. In this study, a robotic manipulator equipped with a pneumatic pollen injection device and a 3-D perception system was developed to automate pollen injection. The ultimate objective is to mount the device on an aerial robot so as to increase efficiency and reduce soil compaction in orchards.



Exclusion bags placed on loblolly pine trees



Pollination system architecture. The orientation of the end effector (needle) is controlled through the actuator angles; the required pose is derived from the perception system which processes exclusion bag point cloud.

Conventional pollination conducted using aerial work platforms. This process is expensive and results in soil compaction, which affects the quality of the seed orchard.

MECHANCAL DESIGN

The device is a parallel manipulator with six degrees of freedom needed to orient the injecting device for a suitable angle of injection into the bag. It belongs to a group of manipulators referred to as Stewart platforms. The implemented design is a 6-RSS Stewart platform.

WORKSPACE

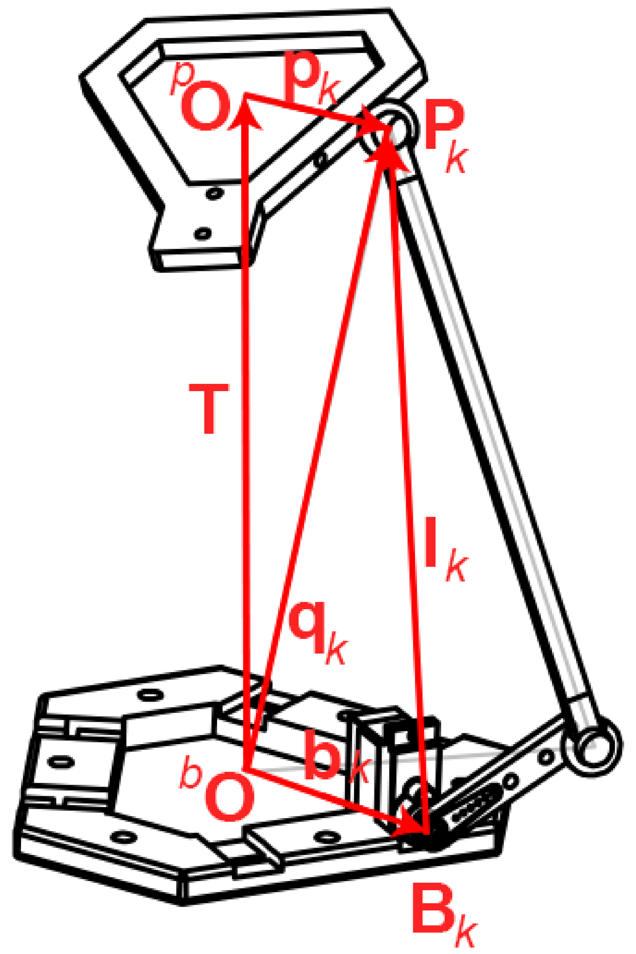
Translation with 0 rotation:

$Z-axis$: $\pm 40\ mm$ | $X-axis$: $\pm 40\ mm$ | $Y-axis$: $\pm 40\ mm$

Rotation with 0 translation along X, Y:

$Roll$: $\pm 45°$ | $Pitch$: $\pm 45°$ | Yaw: $\pm 50°$

The workspace is limited by motor rotation, link dimension and joint geometry. Motor rotation limited to $\pm 80°$ $around\ horizontal$.



INVERSE KINEMATICS

$$\mathbf{q}_k = {}^{p}\mathbf{T}_b + {}^{p}\mathbf{R}_b \cdot \mathbf{p}_k$$

Rewriting in terms of quaternion rotation:

$$\mathbf{q}_k = \mathbf{T} + \mathbf{R} \times \mathbf{p}_k \times \bar{\mathbf{R}}$$

Calculating leg length for each actuator:

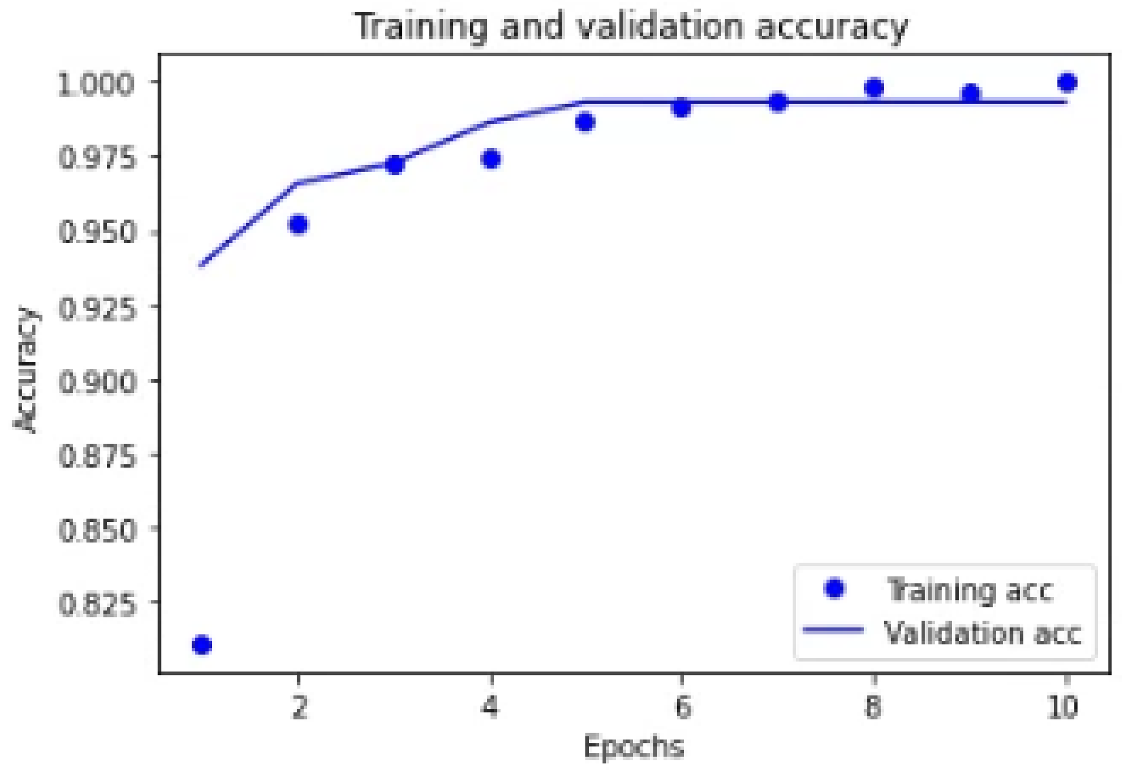
$$\boldsymbol{l}_k = \mathbf{P}_k - \mathbf{B}_k$$

$$= \mathbf{T} + \mathbf{R} \times \mathbf{p} \times \bar{\mathbf{R}} - \mathbf{b}_k$$

PERCEPTION

The perception system consists of a depth sensor that is used to create a point cloud data of an exclusion bag. The system needs to determine the best location for insertion of the needle; this is accomplished by training a neural network model on the FPFH vectors derived from the down-sampled point cloud of the bag. On the extreme right is a plot showing the training and validation accuracies of the binary classifier that classifies points into 'good for needle insertion" and "bad for needle insertion."

Point cloud representing a paper bag, collected using a stereovision camera. The green points are on the surface which is ideal for needle insertion.



This work was supported in part by the USDA National Institute of Food and Agriculture Hatch project 1021499.