Branch Accessibility of A Robotic Pruner For Pruning Apple Trees

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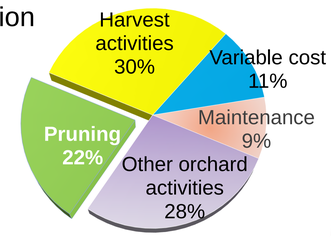
Problem Statement

Cost Breakdown of Apples

- Pruning ~ 22% of total production cost
- ~ 80-120 working hours per hectare

Available labor decreasing!

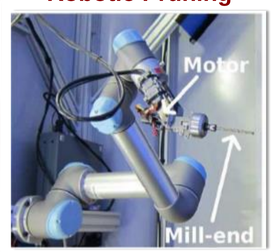


Research Objectives

- Virtual environment establishment for simulation in MATLAB
- Developing simulation algorithm to generate a collision free trajectory for reaching the target pruning points
- Integration of pruning end-effector and robotic arm for field evaluation

Method and Challenges

Robotic Pruning

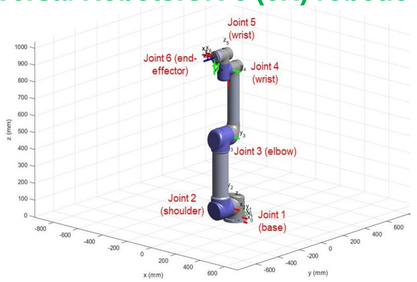


- Highly unstructured environment→ Collision free trajectory
- Selective pruning → Identify target branches for pruning
- Integration of end-effector → Reaching target with appropriate cutter orientation

Materials and Methods

Manipulator Model

Universal Robots:UR-5 (6R) robotic arm



- Denavit–Hartenberg (DH) convention parameters were calculated
- The end-effector cutter is added (210 mm) parallel to the yz plane of frame

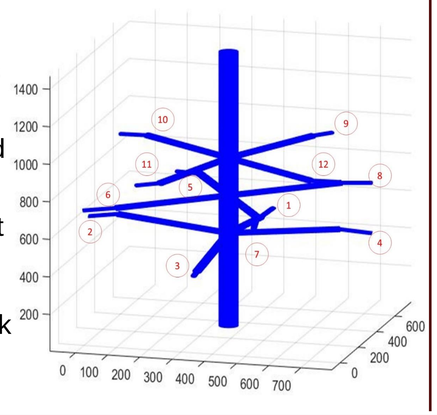
Tree Obstacle Model

Parameters of the branches

Sr. No	Dia-meter (mm)	Starting point coordinates			Terminal point coordinates		
		x (mm)	y (mm)	z (mm)	x (mm)	y (mm)	z (mm)
1	15	-355	415	513	338	844	448
2	18	-370	402	513	-789	282	533
3	14	-355	430	513	-324	-40	451
4	16	-340	402	513	92	408	539
5	17	-334	410	713	-604	758	647
6	14	-348	394	713	-746	205	643
7	17	-363	440	713	-282	-42	715
8	18	-348	394	713	33	630	716
9	15	-351	415	914	-137	792	885
10	14	-370	397	914	741	617	893
11	15	-351	382	914	-510	-19	902
12	13	-337	397	914	43	182	900

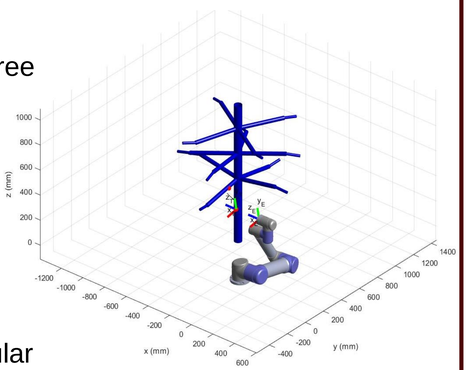
- Virtual tree structure with a tree trunk and 12 primary branches
- Each branch was given a start and end point coordinate
- The width and height of canopy was modelled 350 mm each side of the trunk and 600 mm respectively

Virtual tree model



Virtual Environment Setup

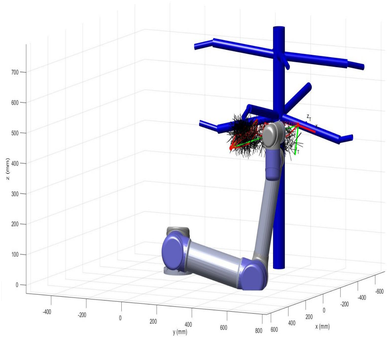
- The tree structure was placed within the workspace of UR-5 robotic arm
- Rapidly-exploring Random Tree (RRT) algorithm was used to find a collision-free path
- Smoothing algorithm (sRRT) was used to remove the unnecessary nodes in the collision-free path
- The algorithm was trained to aligned the cutter perpendicular to the branch orientation



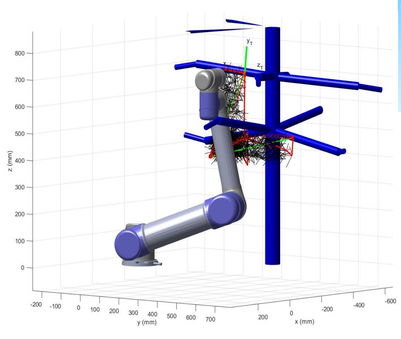
Results and Conclusions

- The RRT algorithm was successful in finding a collision free path for targets defined in simulation. The results suggest that the UR-5 robotic arm can be used for pruning apple trees
- The algorithm was successful in reaching pruning point with the end-effector cutter posture aligned perpendicular to target branches
- The smoothing (sRRT) reduced the time for trajectory generation and streamlined the joint angles, velocity and acceleration. The sRRT also reduced the path length
- The RRT algorithm performs slow during path finding. There is a need to introduce optimization algorithm to improve the path finding efficiency

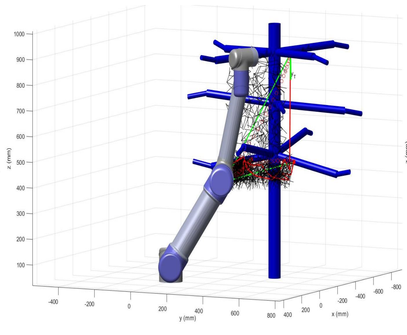
Path finding branch 1 to 3



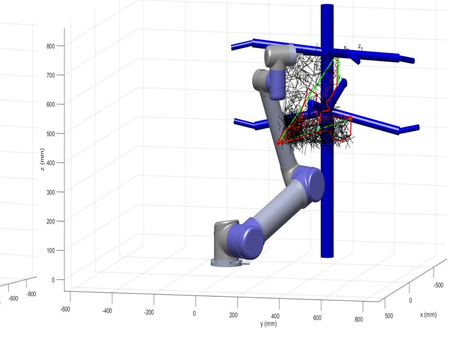
Path from branch 3 to 10



Path finding branch 1 to 12



Path finding branch 1 to 8



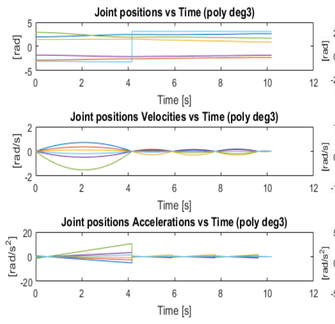
Branch accessibility simulation with RRT & sRRT

Test No.	Branch location	Number of obstacles	Path length RRT (mm)	Path finding time RRT (sec)	Trajectory generation time RRT (sec)	Path length sRRT (mm)	Path finding time sRRT (sec)	Trajectory generation time sRRT (sec)
1	3	1	502	37	6	310	4	3
2	1	1	521	68	15	258	13	7
3	10	2	412	73	14	274	35	9
4	2	Fail	-	-	-	-	-	-
5	12	3	670	118	15	463	103	12
6	4	2	356	51	13	187	19	9
7	6	2	624	65	16	367	26	8

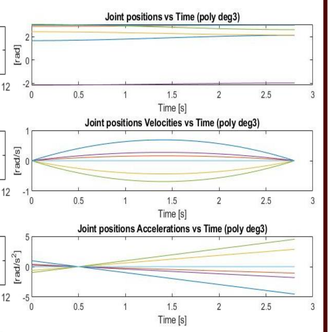
Experimental setup for robot hardware interface

Branch 3 to 1

RRT

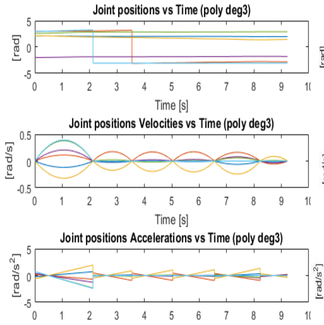


sRRT

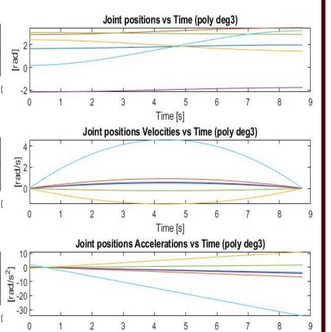


Branch 1 to 10

RRT



sRRT



Future Work

- The robotic arm will be integrated with a modified shear blade pruner end-effector to perform the robotic pruning
- A series of field/lab tests will be conducted to validate the simulated collision free path
- A machine vision system will be integrated with the robotic manipulator to develop a robotic pruning system

Integration of robotic arm and end-effector (Field evaluation) → Vision system development (Image acquisition and processing) → Defining of pruning parameters → Integration of vision and robotic system → Field testing of the integrated robotic pruning system

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