Optimized Sequence and Path Planning for the Feller Buncher

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Abstract

The sequence of operations for the feller buncher to reach and cut a single tree is proposed; and a cost function related to the total maneuver time and the distance traveled is formulated to optimize the sequence of operations. Several numerical examples are tested and the results show that the optimal sequence of operations can be found. The reachability map for a forest block area is constructed based on the tree location information. The enumeration algorithm is constructed to find the optimal path for the feller buncher to cut trees in a sub-region, based on the requirements of minimizing the distance traveled by the feller buncher and the number of stops it makes. Several scenarios are tested and the results show that the algorithm is able to produce the optimal path.

Abrégé

La séquence des opérations permettant à l'abatteuse-empileuse d'atteindre et de couper un seul arbre est proposée; et une fonction de coût liée au temps de manœuvre total et à la distance parcourue est formulée pour optimiser la séquence d'opérations. Plusieurs exemples numériques sont testés et les résultats montrent que la séquence optimale d'opérations peut être trouvée. La carte d'accessibilité pour une zone de bloc forestier est construite sur la base des informations d'emplacement d'arbre. L'algorithme de dénombrement est construit pour trouver le chemin optimal pour que l'abatteuse-empileuse coupe des arbres dans une sous-région, en fonction des exigences de minimisation de la distance parcourue par l'abatteuse-empileuse et du nombre d'arrêts qu'elle effectue. Plusieurs scénarios sont testés et les résultats montrent que l'algorithme est capable de produire le chemin optimal.

Acknowledgements

First, I would like to express my sincere gratitude to my thesis supervisor, Professor Inna Sharf, for her support and valuable guidance during this research. She has given me great instruction about the research. This thesis could not have been completed without her.

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Chapter 1

Introduction to Timber-harvesting Operation

Timber-harvesting operation is a process of felling (cutting), processing, and transporting trees in a forest area. Today, tracked-base machines are widely used to carry out these processes. In this thesis, the focus will be on optimizing the felling process when using a typical kind of machine called the feller buncher.

Figure 1.1: Timber-harvesting process

1.1 Fell Buncher Background

Feller buncher is widely used in the timber-harvesting industry: it can cut, grab several trees, and place them at the desired storage location. It is an articulated machine comprised of a tracked base and a manipulator-like crane, the latter is a swinging boom (referred to as boom in the rest of the thesis) with an end-effector mounted on a tracked base. The boom can rotate and extend/retract itself within a certain range, allowing the operator to reach a tree without moving the base. The end-effector includes a chain saw and a gathering arm; the former is used to cut the tree, and the latter is used to grab it.

Figure 1.2: L855E feller buncher

The feller buncher model used in this thesis is Tigercat L855E, as shown in Figure 1.2. The detailed dimensions of this type of feller buncher are shown in Figure 1.3.

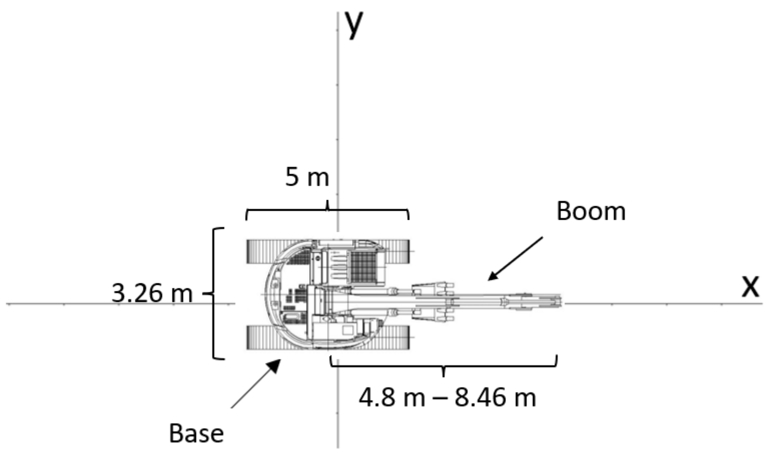


Figure 1.3: L855E feller buncher specifications

1.2 Process of Felling a Single Tree

By observing the operation of the feller buncher, there are 3 types of strategies that are used to reach and cut a single tree:

1) Move the tracked base only
2) Extend/retract and rotate the boom only
3) Combination of moving the tracked base and extending/retracting and moving the boom

As shown in Figure 1.4, when a tree is out of the reachability of the boom, the operator needs to choose either strategy 1) or strategy 3) to relocate the base so that the end-effector can reach and cut the tree.

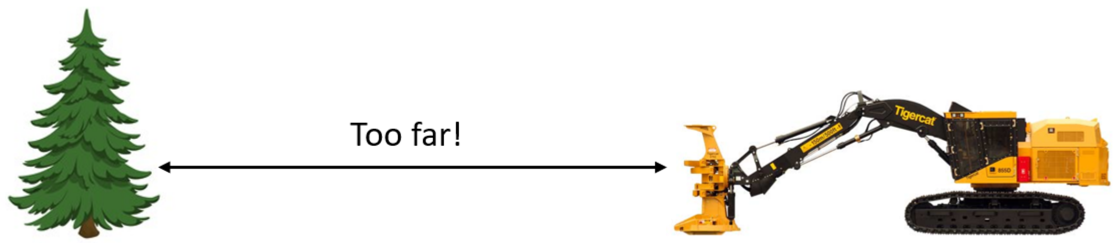


Figure 1.4: Unreachable tree

1.3 Environmental Concerns and Constraints

Feller buncher is a very heavy machine. For example, L855E feller buncher weighs 38780 kg without the end-effector. When the feller buncher traverses through the forest block, it will cause damage to the land due to its weight, as shown in Figure 1.5. Therefore, minimizing the path traveled by the feller buncher during felling operation is important. The government also enacts a restriction that the the area through which the feller buncher travels cannot exceed 25 % of the total forest block area [1].

Figure 1.5: Footprint of the feller buncher

1.4 Strategy of Felling Process in a Forest Block

When felling trees in a large forest block, FPInnovation provides the following strategies to follow [2]:

1) Dividing a forest block into several smaller sub-regions, represented by the black crossing lines in Figure 1.6

2) Feller buncher will travel between each sub-region through the extraction (main) trail

3) Feller buncher will enter each sub-region to cut trees and exit through the secondary trail

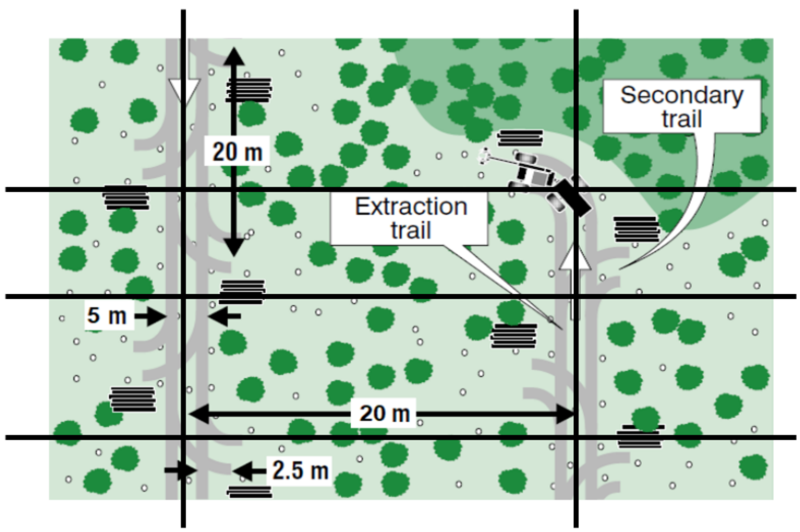


Figure 1.6: Visual representation of dividing a forest block [2]

When the feller buncher enters the sub-region, a sequence will be followed to cut trees. As shown in Figure 1.7, it will first move to a certain location, then stop and cut a certain number of trees and place them at a storage point. After that it will repeat this process until all the trees in that sub-region are cut (clear cutting) or a certain percentage of trees are cut (partial cutting) [2]. When the cutting process is finished, the feller buncher will exit the current sub-region and move to the next one through the main trail. When the cutting process is finished, a machine called the forwarder will collect the trees at each storage point.

In order to facilitate the operation of the forwarder, it is desirable to minimize the number of storage points, or equivalently, the number of stops.

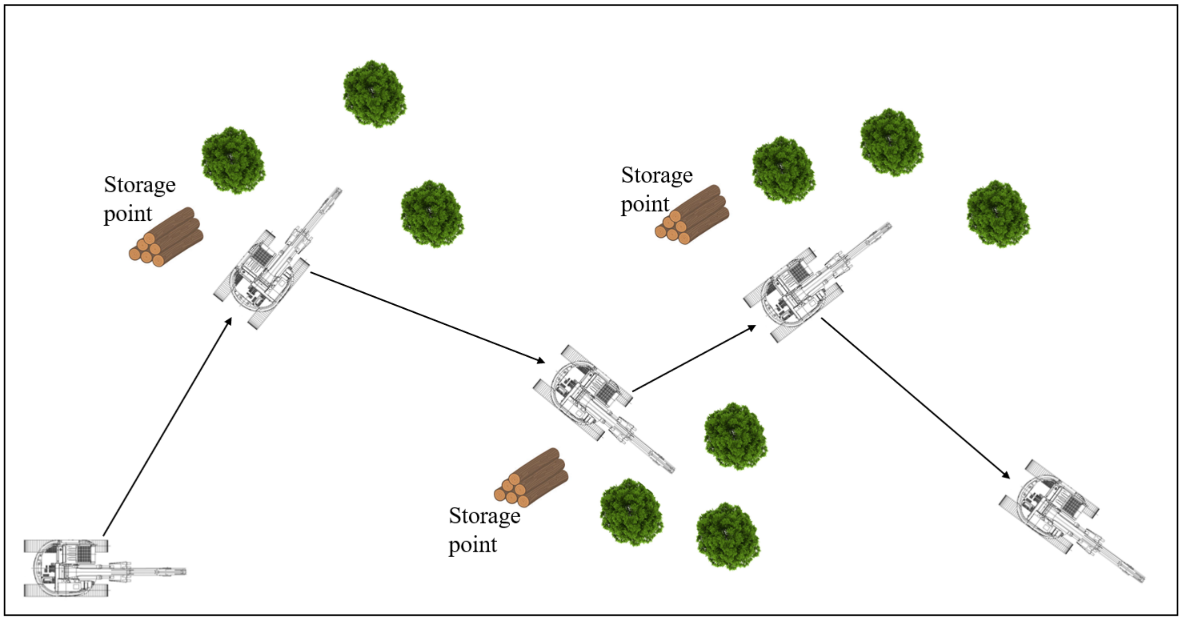


Figure 1.7: Visual representation of cutting trees in a sub-region

1.5 Research Objevtives

Two primiary objectives are defined for this thesis:

1) To develop an optimal sequence of operations to assist the operator to reach the target tree

2) To find the optimal path to move the base that helps the operator cut multiple trees in a sub-region

In Chapter 2, the focus will be on developing the sequence of operations in an obstacle-free scenario. The objective function will be formulated to minimize the maneuver time and the distance traveled by the tracked base during the operation. Chapter 3 and 4 will formulate a concept of reachability map and an enumeration algorithmn to find the optimal path for cutting multiple trees in a sub-region.

Chapter 2

Sequencing strategies for felling a single tree

This chapter will majorly discuss about the construction of sequence of operations for the feller buncher to cut the tree that is unreachable from its initial position.

2.1 Reference Frame and Basic Action Primitives

The reference frame used in the discussion is denoted with RF_0. The origin is at the center of the initial position of the base. The positive x axis is aligned with the initial pose of the feller buncher and the y axis is perpendicular to it, as shown in Figure 2.1. All x-y coordinates of points mentioned in this chapter are based on this reference frame.

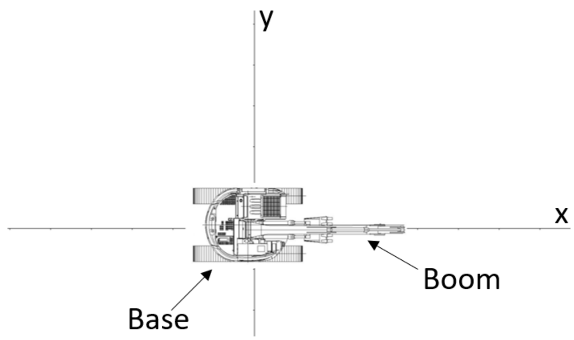


Figure 2.1: Reference frame RF_0

Based on the observation of operating the feller buncher in the field, four types of basic motion primitives are introduced to construct the sequence:

1) *Translational motion of the base*: tracked base can move forward or backward in a straight line. The distance associated with this motion is denoted with the letter d; the curved path won't be considered in this thesis since minimizing the distance traveled by the base is desired

2) *Neutral turn of the base*: tracked base can rotate itself. The angle associated with this rotation, measured from the positive x direction, is denoted with θ_{base}

3) *Extension/retraction of the boom*: the boom can extend or retract itself by a certain amount. The length of extension/retraction is denoted with δ

4) *Rotation of the boom*: the boom, along with the cabin, can rotate to a certain angle without moving the tracked base. The angle associated with this rotation, measured from the direction of the base, is denoted with θ_{boom}

2.2 Sequence Construction

As mentioned in Section 1.3, the footprint created by the tracked base must be minimized; therefore, we choose to relocate the base using a straight-line segment. The new sequence of operations is proposed as follows (also shown in Figure 2.2, the blue rectangle and the black line on it represent the base and the boom respectively; the initial length of the boom is denoted with r_i):

I. Neutral turn the base by angle θ_{base}.

II. Move the base forward by distance d to reach a waypoint W.

III. Rotate the boom by angle θ_{boom} to point it towards the target tree G.

IV. Extend/retract the boom by distance δ to make the end effector reach the target tree G.

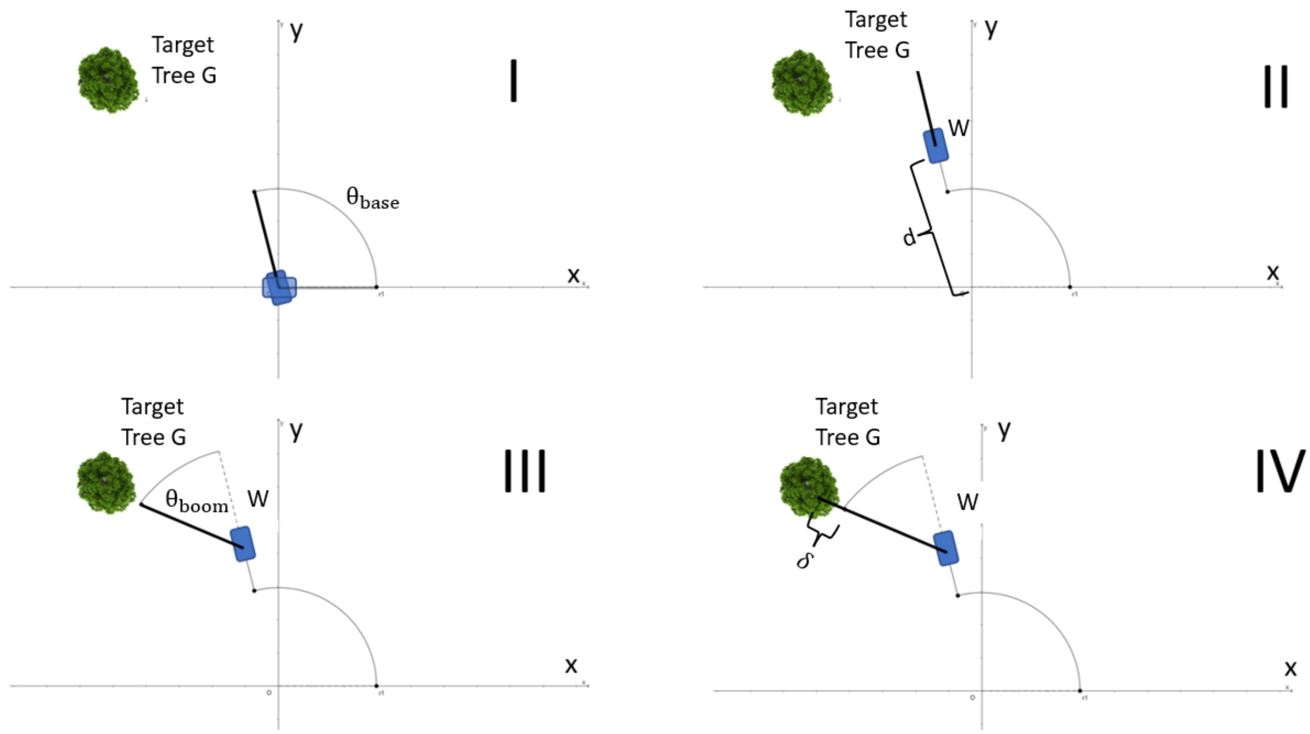


Figure 2.2: Sequence of operations illustration

Since the boom cannot extend to infinity or retract to 0, the position of the waypoint W must be constrained. It must lie in the blue annulus region shown in Figure 2.3. The inner boundary's and outer boundary's radii are the minimum cutting radius r_{min} and the maximum cutting radius r_{max} of the boom, respectively. Based on the equation of circle, this annulus constraint can be formulated as follows:

$$\begin{bmatrix} x_W \\ y_W \end{bmatrix} = \begin{bmatrix} x_G + r \cdot \cos(\beta) \\ y_G + r \cdot \sin(\beta) \end{bmatrix}$$
$$r_{min} \leq r \leq r_{max} \tag{2.1}$$
$$0 \leq \beta \leq 2\pi$$

where (x_G, y_G) represents the position of the target tree G and (x_W, y_W) represents the position of the waypoint W.

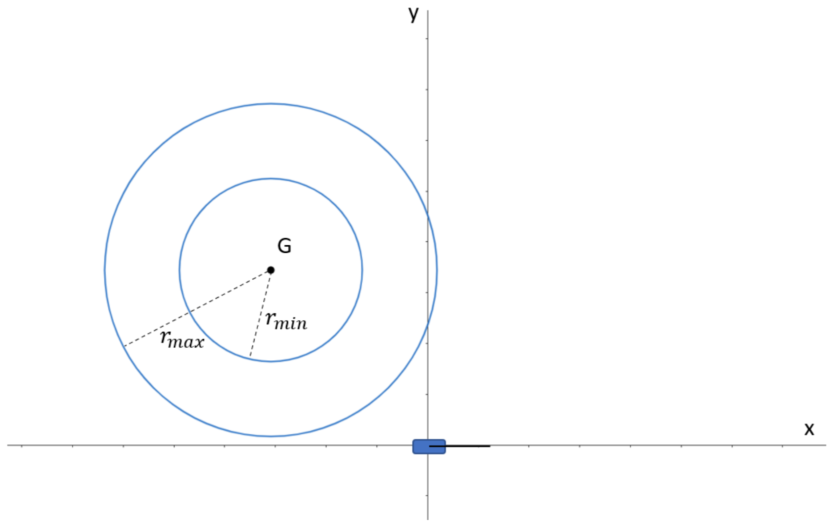


Figure 2.3: Constraint of waypoint W

2.3 Cost Function for Optimization

In this section, the cost function is constructed to find the optimal waypoint W that optimizes the sequence of operations from 2 aspects.

The position of the waypoint W determines the values of θ_{base}, d, θ_{boom} and δ. They can be written as functions of x_W and y_W :

$$\begin{aligned}\theta_{base}(x_W, y_W) &= ATAN2(\frac{x_W}{y_W}) \\ d(x_W, y_W) &= \sqrt{x_W^2 + y_W^2} \\ \theta_{boom}(x_W, y_W) &= |ATAN2(\frac{x_G - x_W}{y_G - y_W}) - ATAN2(\frac{x_W}{y_W})| \\ \delta(x_W, y_W) &= |\sqrt{(x_G - x_W)^2 + (y_G - y_W)^2} - r_i|\end{aligned} \tag{2.2}$$

The next step is to construct the cost function. There are two factors that must be minimized: the total maneuver time of the sequence and the distance d traveled by the base. Since minimizing both factors simultaneously is not possible, the weighted sum of both factors will be considered.

Total maneuver time is the time required to carry out the sequence of operations to reach the target tree. The speeds of different steps in the sequence are not the same; therefore, four basic kinds of nominal speeds are defined:

1) Angular speed of step I, denoted with ω_{base}
2) Linear speed of step II, denoted with v_{base}
3) Angular speed of step III, denoted with ω_{boom}
4) Linear speed of step IV, denoted with v_{boom}

In an ideal case, steps II-IV can happen simultaneously, since they are actuated by different components of the feller buncher. The cost function of the total maneuver time becomes:

$$h_1 = \frac{\theta_{base}}{\omega_{base}} + max\{\frac{d}{v_{base}}, \frac{\theta_{boom}}{\omega_{boom}}, \frac{\delta}{v_{boom}}\} \tag{2.3}$$

The second cost function is the distance d and it is formulated as follows:

$$h_2 = d \tag{2.4}$$

By normalizing both cost functions with respect to their maxima, they can be combined together with weights. The optimization problem in negative null form is:

$$\begin{aligned} min\ H(x_W, y_W; x_G, y_G, r_i, \omega_{base}, v_{base}, \omega_{boom}, v_{boom}) &= w_1 \cdot H_1 + w_2 \cdot H_2 \\ &= w_1 \cdot \frac{h_1}{h_{1_{max}}} + w_2 \cdot \frac{h_2}{h_{2_{max}}} \\ subject\ to:\ r_{min} \leq \sqrt{(x_G - x_w)^2 + (y_G - y_W)^2} &\leq r_{max} \\ w_1 + w_2 &= 1 \end{aligned} \tag{2.5}$$

where w_1 and w_2 are weights that can be chosen based on requirements. Increasing w_1 will place more emphasis on minimizing distance d, and increasing w_2 will place more emphasis on minimizing the total maneuver time.

2.4 Numerical Example

This section shows the optimization results for different tree locations. The necessary parameters are listed in Table 2.1. A more detailed list of parameters of L855E feller buncher is shown in Appendix A.1.

ω_{base}	v_{base}	ω_{boom}	v_{boom}	r_{max}	r_{min}	r_i
0.71 rad/s	1.167 m/s	0.84 rad/s	5 m/s	8.46 m	4.8 m	4.8 m

Table 2.1: L855E feller buncher parameters

Example 1

If the tree is located at (-8 m, 9 m) in RF_0, and w_1 and w_2 are both set to be 0.5; Figure 2.4 shows the objective function values in the annulus constraint around the target tree. The optimal waypoint G is at (-1.6 m, 3.4 m), and the objective function value is 0.239.

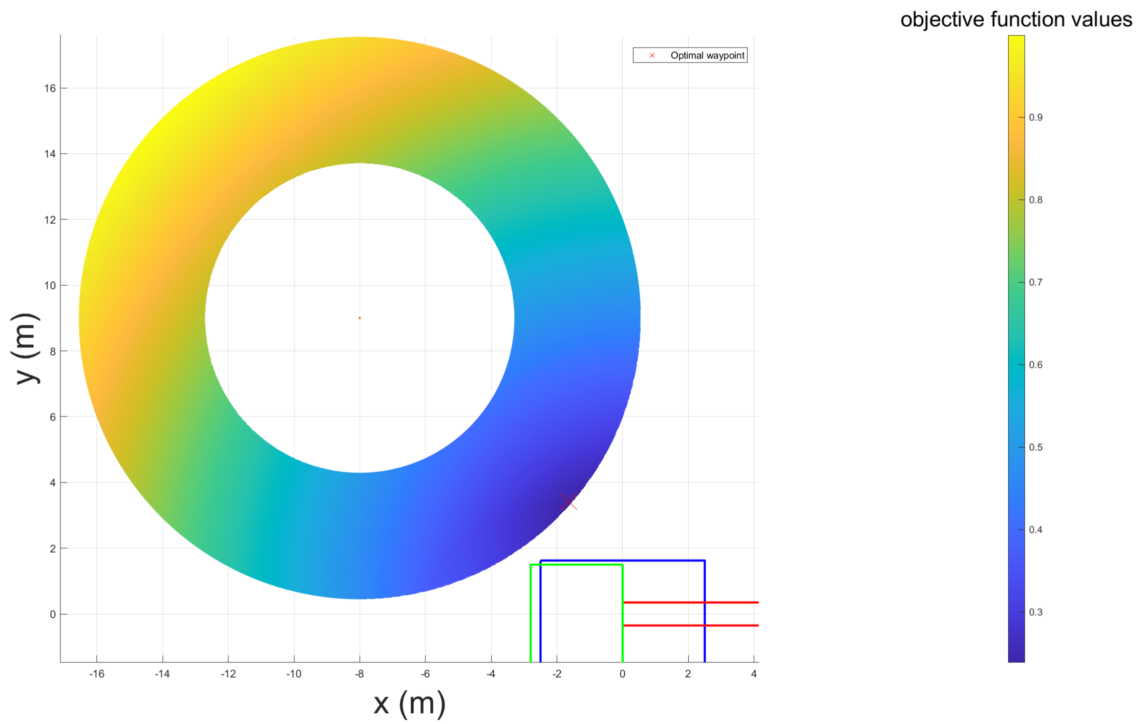


Figure 2.4: Objective function plot with tree location (-8 m, 9 m)

The corresponding values of optimal sequence of operations are:

$$\begin{aligned} \theta_{base}(-1.6, 3.4) &= 2.01 \text{ rad} \\ d(-1.6, 3.4) &= 3.76 \text{ m} \\ \theta_{boom}(-1.6, 3.4) &= 0.41 \text{ rad} \\ \delta(-1.6, 3.4) &= 3.70 \text{ m} \end{aligned} \tag{2.6}$$

Figure 2.5 shows how the location of optimal waypoint G changes by changing w_1 from 1 to 0. As w_1 decreases, we can see that the location of G gradually deviates from the origin. The reason is that as w_1 decreases, the emphasis on minimizing the distance d will decrease accordingly.

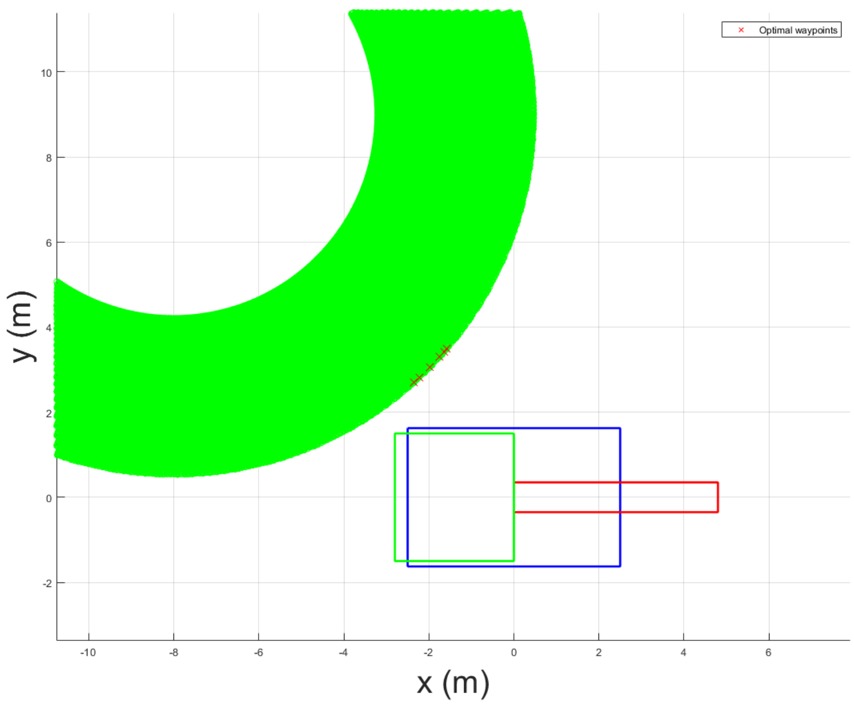


Figure 2.5: Optimal waypoint W with different w_1 and w_2

Example 2

If the tree is located at (9 m, 9 m) in RF_0, and w_1 and w_2 are set to be 0.3 and 0.7; Figure 2.6 shows the objective function values in the annulus constraint around the target tree. The optimal waypoint G is at (3.6 m, 2.5 m), and the objective function value is 0.229.

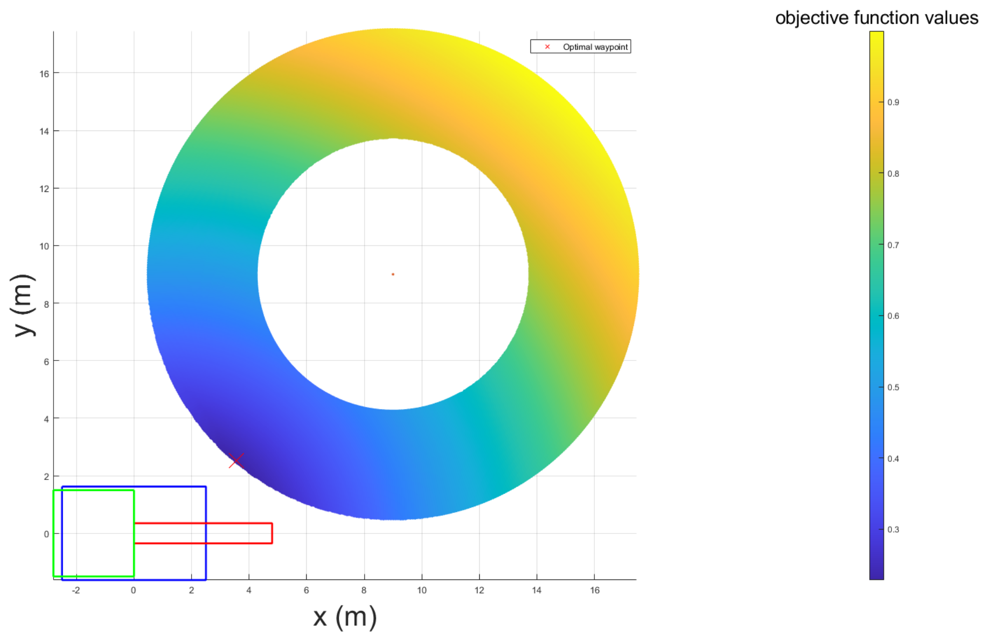


Figure 2.6: Objective function plot with tree location (9 m, 9 m)

The corresponding values of optimal sequence of operations are:

$$\begin{aligned} \theta_{base}(3.6, 2.5) &= 0.60 \text{ rad} \\ d(3.6, 2.5) &= 3.75 \text{ m} \\ \theta_{boom}(3.6, 2.5) &= 0.27 \text{ rad} \\ \delta(3.6, 2.5) &= 3.65 \text{ m} \end{aligned} \tag{2.7}$$

Chapter 3

Feller Buncher Reachability Map for a Forest Block

This chapter will focus on how to use the tree location data in a forest block to construct the reachability map which will be used in Chapter 4

3.1 GPS Data Interpretation

In order to construct the reachability map, it is necessary to know the position of each tree in the forest block. The GPS data provided by FPInnovation contain the locations of all trees in a forest block, along with the height of each tree. Figure 3.1 shows an example of GPS data. It contains information in a 300-m by 200-m forest block. The coordinates are measured from the bottom left corner of the forest block. The locations of all trees in the forest block are saved as a x-y-coordinate list in a .txt file, which will be used in Section 3.2.

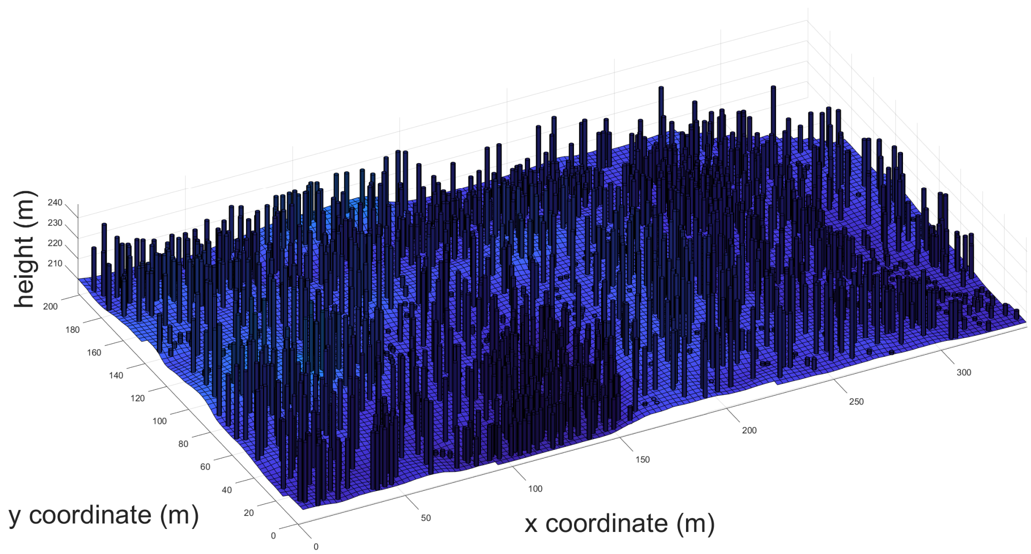


Figure 3.1: GPS data of tree locations in a forest block (side view)

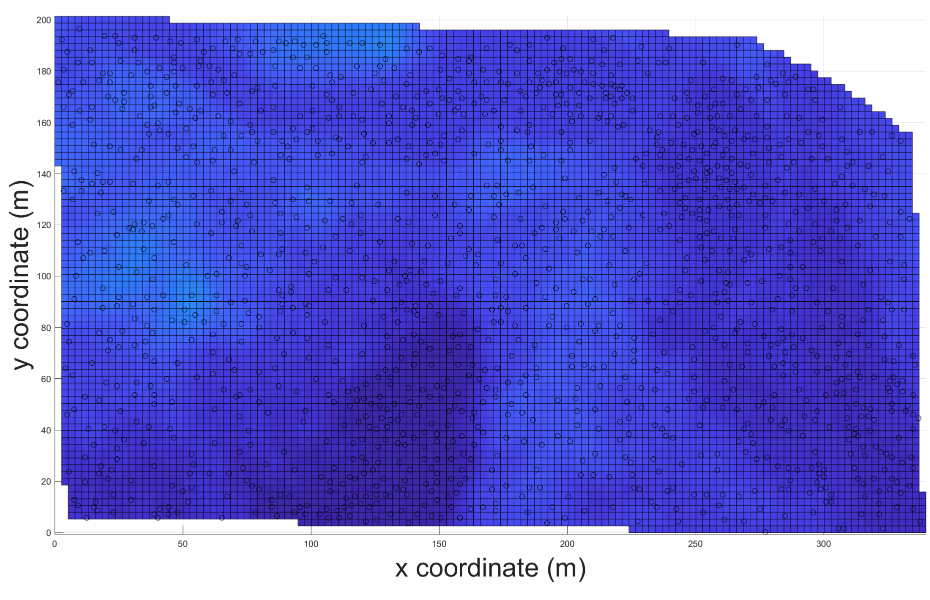


Figure 3.2: GPS data of tree locations in a forest block (top view)

3.2 Reachability Map Construction

After obtaining the tree location information in Section 3.1, the reachability map can be formulated. As mentioned in Section 1.4, the forest block is divided into several sub-regions, and the reachability map will be constructed for each sub-region. In this thesis, the sub-region will be a 100 m by 20 m area. Figure 3.3 shows a sub-region example of the forest block with the x coordinate starting from 0 m to 100 m and the y coordinate starting from 180 m to 200 m. The shape in the bottom left corner represents the initial position of the feller buncher and the bottom left corner will be set as the origin (0,0).

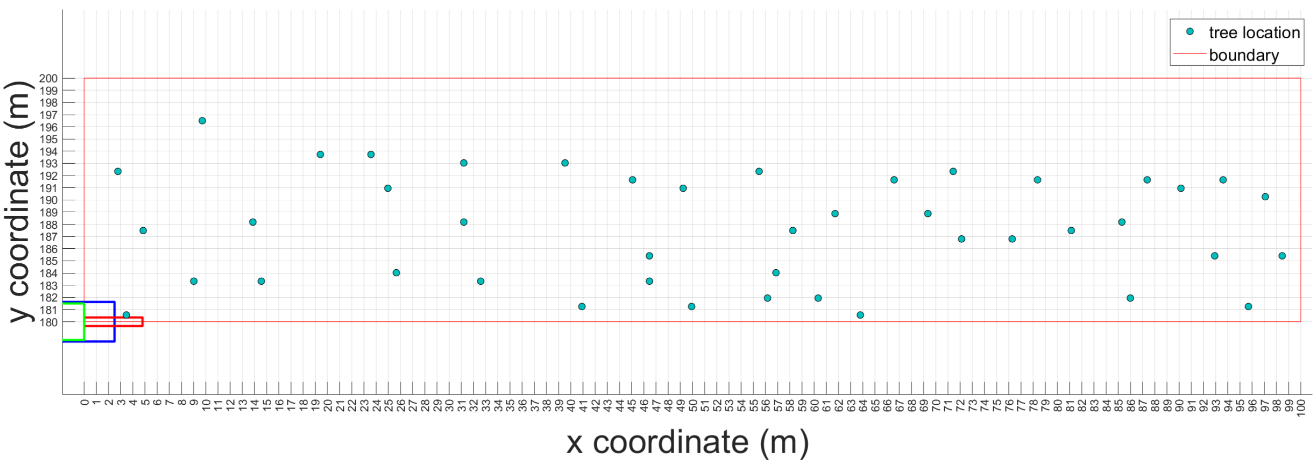


Figure 3.3: 100 m by 20 m sub-region with tree locations

The reachability map contains the information of reachable trees from different locations in the sub-region. It is constructed through the following steps:

1) Discretize the sub-region with 1 m by 1 m cell block; it is unnecessary to use higher resolution since the feller buncher is a large machine

2) Record the coordinates of the trees in the sub-region as a tree list

3) Calculate how many trees are reachable from each cell block based on the reachability of the boom, similar to the process in Section 2.2

4) Create the reachability map based on the number of trees that are reachable from each

cell block

The reachability map for the sub-region in Figure 3.3 can be created, as shown in Figure 3.4. Different colors represent the number of reachable trees.

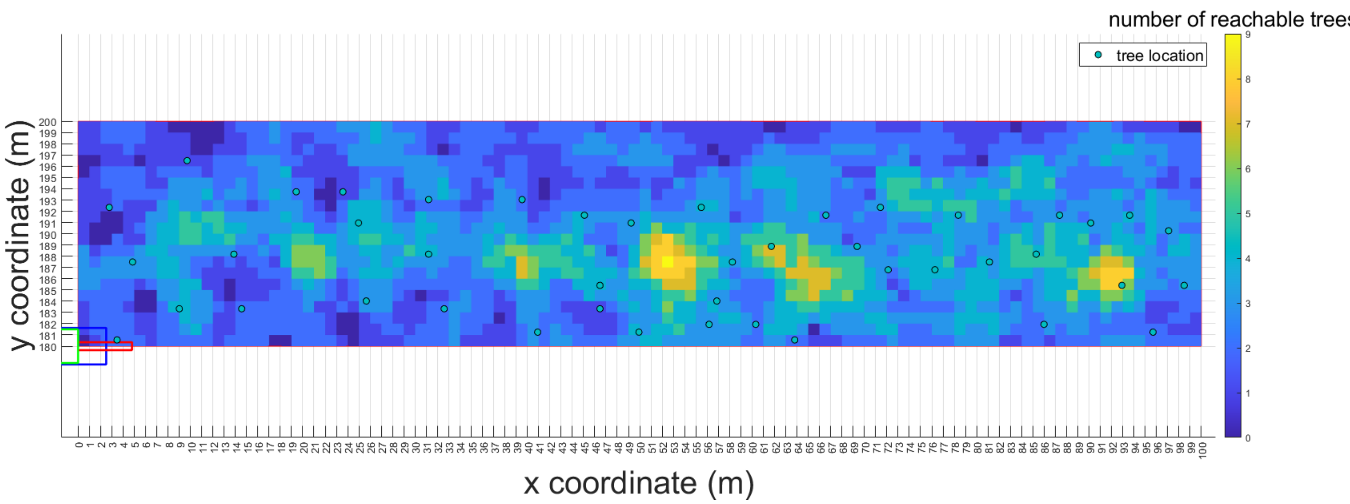


Figure 3.4: 100 m by 20 m sub-region reachability map

3.3 Data Point for Cell Block

A concept of data point is introduced to record the information of the reachability map. Each data point contains the following elements:

1) Coordinate of each cell block

2) A list of coordinates of reachable trees from each cell block

For instance, [(1 m,1 m),[(5 m, 2 m),(6 m, 3 m)]] represents that the cell block at (1 m,1 m) has 2 reachable trees at (5 m,2 m) and (6 m,3 m), respectively. The information in the data point will be used when formulating the enumeration method in Chapter 4.

Chapter 4

Enumeration Method of Finding the Optimal Path

This chapter will focus on formulating an enumeration algorithm to find the optimal path to cut multiple trees in a sub-region. The enumeration method will look for all possible paths for cutting trees in a sub-region and find the optimal path based on the reward function.

4.1 Occupation Map

Based on the tree location data, an occupation map can be created as follows:

1) Assume that each tree will occupy 1 cell block, which is 1 m by 1 m;

2) When the cell block is occupied by a tree, it will be marked as "occupied"

3) When the cell block is not occupied, it will be marked as "0"; the feller buncher can move to that cell freely; it is assumed that the feller buncher also occupies 1 cell block

3) The bottom left corner is defined as the origin (0,0)

Unfortunately, the occupation map at the current stage cannot be large due to the heavy computing requirement, which will be discussed in Section 4.7. Figure 4.1 shows an example of an occupation map. It can be seen that the cell blocks at (1, 1), (1, 2), (4, 2) and (2, 0) are occupied by trees and the rest cell blocks are free.

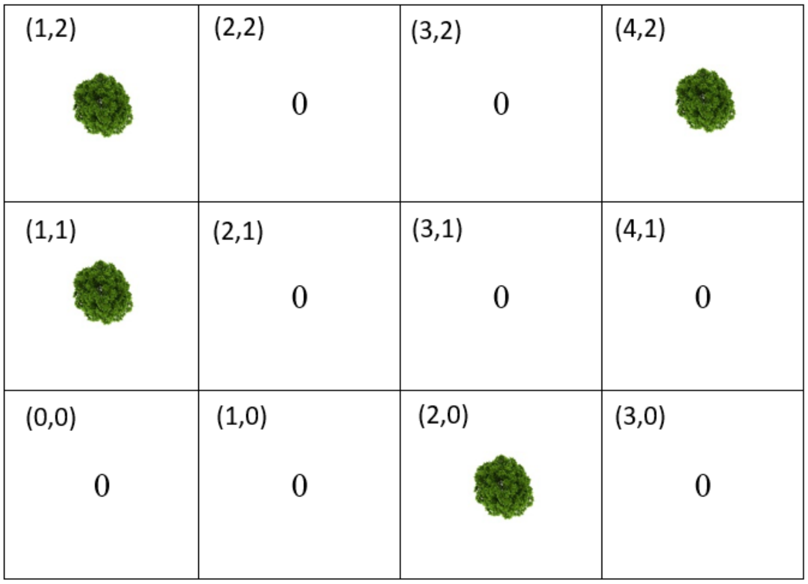


Figure 4.1: Occupation map example 1

4.2 Basic Actions

In order to discretize the motion of the feller buncher, it is assumed that the feller buncher is allowed to move in 4 directions at each cell block: up, down, right or left. If the neighboring cell block is occupied by a tree or it is outside of the occupation map, the feller buncher is not allowed to move in that direction.

When the feller buncher moves to a new cell block, it can either stop and cut the reachable trees, or it can keep on moving to the next cell block without stopping and cutting any tree.

By combining the possible directions of movement and the possible stop, 8 basic actions can be created for moving the feller buncher:

1) up, stop and cut trees

2) up, not stop

3) down, stop and cut trees

4) down, not stop

5) left, stop and cut trees

6) left, not stop

7) right, stop and cut trees

8) right, not stop

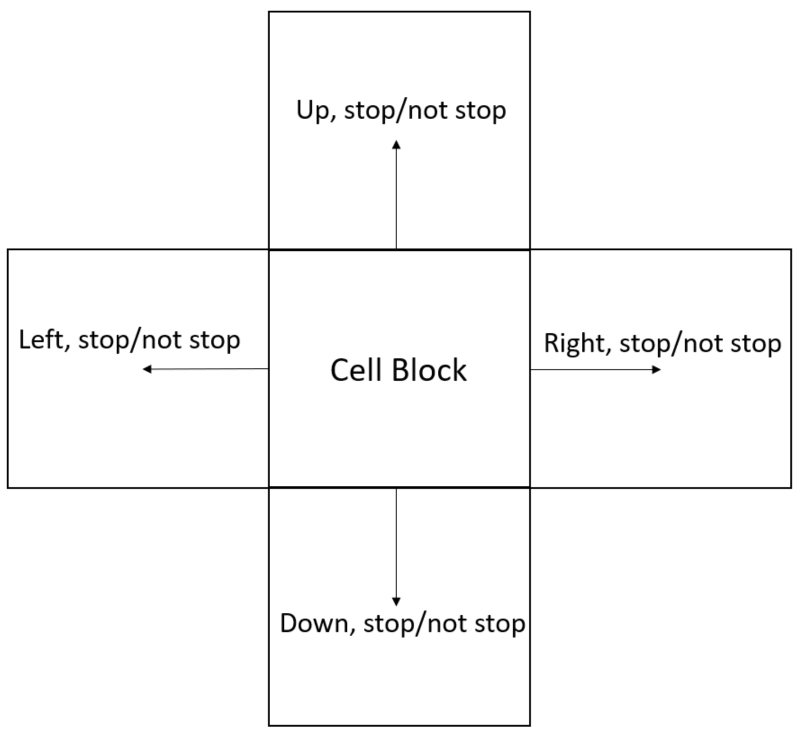


Figure 4.2: Basic actions

4.3 State

This section will focus on introducing the concept of state, which will be essential for tracking when looking for all possible paths in the occupation map. The state s is defined with 4 elements:

1) Coordinate of the cell block followed a binary value "1" or "0" to indicate whether the feller buncher stops at this cell block or not
2) The path through which the feller buncher has traveled to reach the cell block; it is a list of coordinates
3) A reachable tree list at the cell block
4) A list of the remaining trees that have not been cut

Element 3) and element 4) are from Sections 3.2 and 3.3, respectively.

[(2, 1, 1),[(0, 0), (1, 0), (2, 0), (2, 1)],[(2, 2)],[(2, 2), (4, 2), (3, 3)]] is an example of a state. (2,1,1) represents that the feller buncher is currently at cell block (2,1) and decides to stop and cut the reachable trees. [(0,0), (1,0), (2, 0), (2, 1)] represents the path through which the feller buncher has traversed to reach cell block (2,1). [(2,2)] represents the coordinate of the reachable tree. [(2, 2), (4, 2), (3, 3)] shows the locations of the remaining trees in the sub-region.

4.4 Path Traversing

This section will show the strategy for traversing through the occupation map and find all valid paths. The traversal will be conducted through the following steps:

1) Start at the initial state s_0, which is at the origin, and let the current state $s_{current} = s_0$
2) Create a queue to store the states; create a path list to store the valid paths that cut all the trees
3) Use basic actions to find a list of next states s_{next} from $s_{current}$

4) Loop through the list of s_{next}:

    1. If s_{next} stops and cuts trees, update the occupation map by deleting these trees in state elements 3) and 4); and s_{next}'s element 1) is appended to its state element 2)

    2. If s_{next} does not stop, the occupation map will not update; and s_{next}'s element 1) is appended to its state element 2)

    3. If s_{next}'s element 4) is empty, which means that all the trees are cut, store s_{next}'s element 2) to the path list

5) Store s_{next} in the queue if it is not in $s_{current}$'s element 2) to avoid repetition

6) Pop one state in the queue and let it be the new $s_{current}$; repeat step 3) - 5); if there is no state in the queue, end the program

4.5 Reward Function

In order to find the optimal path, a reward function is defined. As mentioned in Section 1.3 and 1.4, the objectives are to minimize the distance d traveled by the feller buncher and the number of stops n_{stop} during the traversal. The reward function is therefore defined as follows:

$$R = d + n_{stop} \tag{4.1}$$

After getting all the valid paths in Section 4.4, the reward function value will be calculated for each path, and those with a minimum function value will be the optimal paths.

4.6 Simulation Result

Example 1

The occupation map in Figure 4.1 is used for simulation. Figure 4.3 shows the reward function values for all the valid paths.

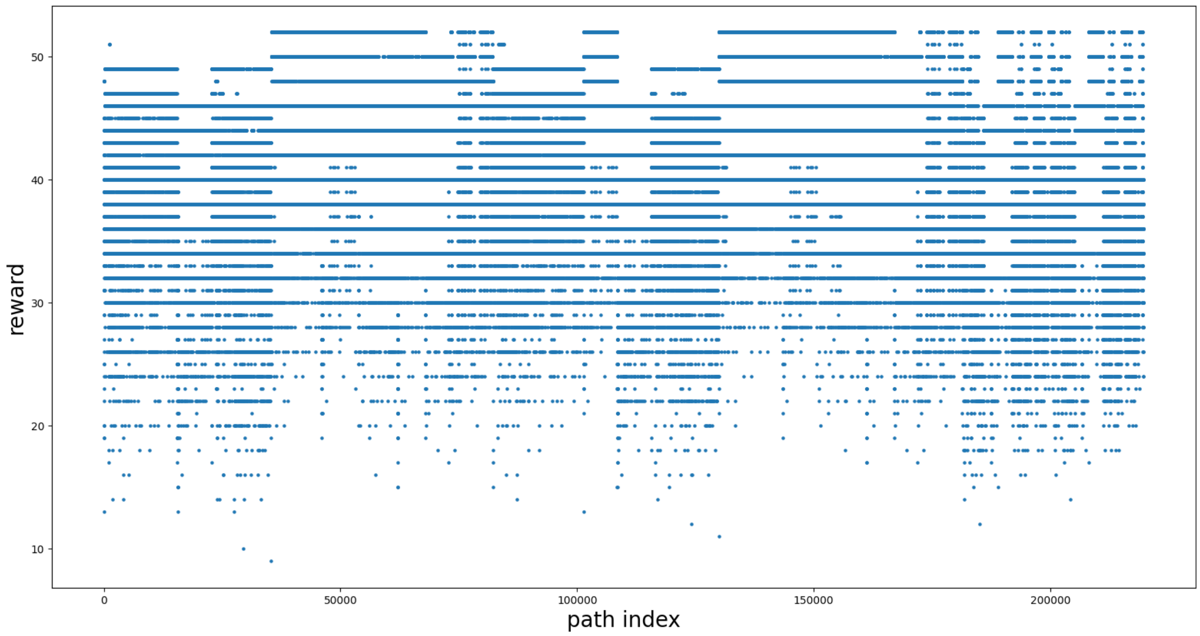


Figure 4.3: Reward function example 1

The result shows that there are 219724 valid paths. The minimum reward is 9 and the corresponding optimal path is:

1) Start at cell block (0, 0)

2) Go to cell block (1, 0), not stop

3) Go to cell block (2, 1), stop and cut the reachable trees located at (1, 2), (1, 1) and (2, 0)

4) Go to cell block (3, 1), stop and cut the reachable tree located at (4, 2)

5) Exit

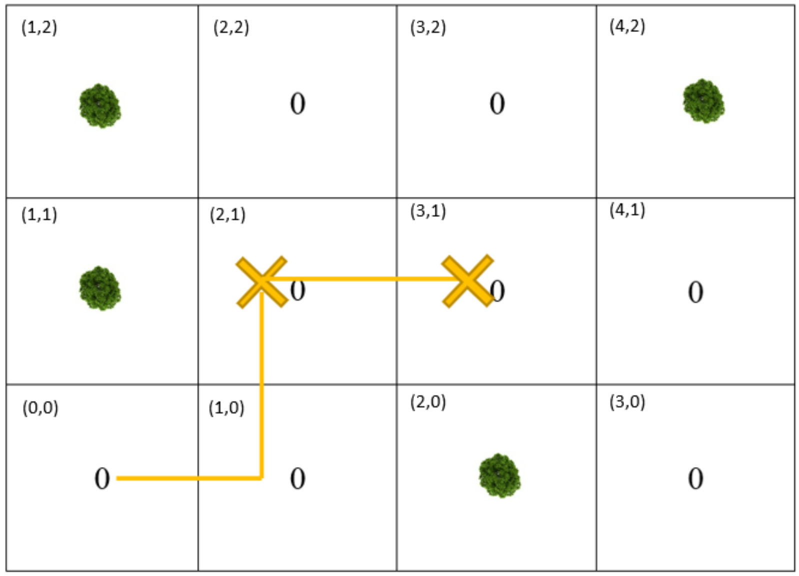


Figure 4.4: Optimal path for occupation map in Figure 4.1

Example 2

Figure 4.5 shows another example of occupation map:

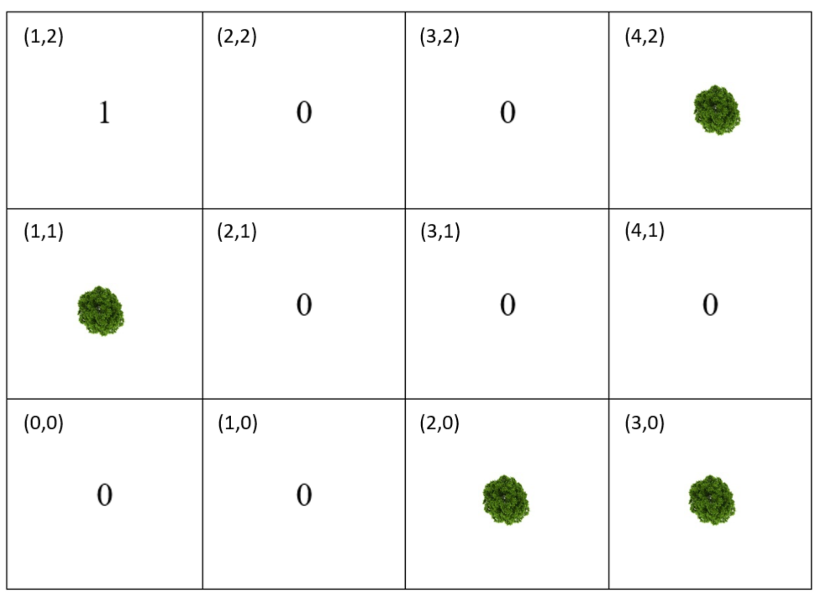


Figure 4.5: Occupation map example 2

After the simulation, the corresponding reward function values can be obtained, as shown in

Figure 4.6:

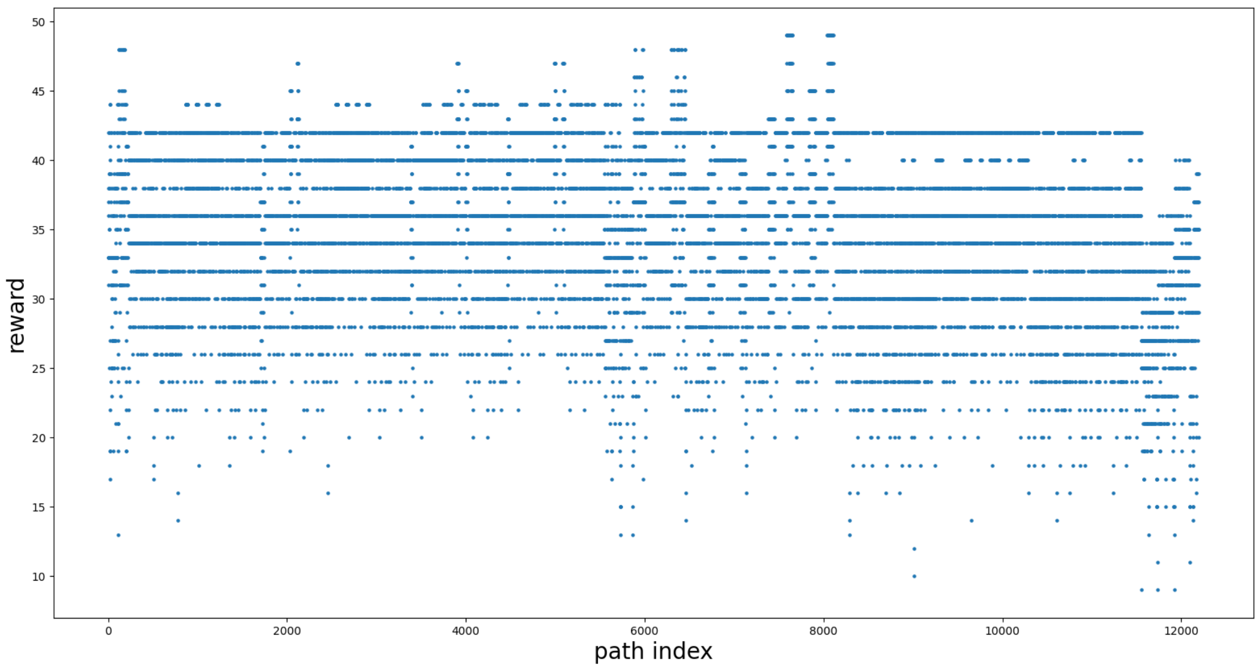


Figure 4.6: Reward function example 2

The result shows that the total number of valid paths is 12200. The minimum reward is 9 and there are 3 optimal paths:

1) (0, 0, 0)→(1, 0, 0)→(2, 1, 1)→(3, 1, 1)

2) (0, 0, 0)→(1, 0, 1)→(2, 1, 0)→(3, 1, 1)

3) (0, 0, 0)→(1, 0, 1)→(2, 0, 0)→(3, 1, 1)

4.7 Limitation of the Current Enumeration Method

The limit of the enumeration method is majorly due to the heavy computing requirement. From 1 state, there are at most 8 actions that can be applied, which means there are at most 8 possible next states. Then 8 more states can also be generated from each next state. As a result, the number of states is growing exponentially with respect to the number of cell blocks in an occupation map. As an example, when the size of the occupation map is 4 by 4, the method will need to execute for more than 10 hours to find all possible paths , which is not practical.

The method also does not consider about the size of the feller buncher. It is assumed that the feller buncher only occupies 1 cell block, but in reality it will occupy at least 10 cell blocks, which will further limit the feller buncher's permissible directions of motion. The method also assumes that the reachability of the feller buncher is limited to the neighbors of the cell block, instead of the real case. In the future, those factors will be considered to better simulate the real-life scenario.

Chapter 5

Conclusion and Suggested Future Work

In conclusion, the thesis achieved the objectives of constructing the sequence of operations for the feller buncher to reach a single tree; and finding the optimal path for cutting multiple trees in a sub-region.

In Chapter 2, the basic motion primitives of the feller buncher was proposed, and based on these motion primitives, the sequence of operations was constructed to move the feller buncher to reach and cut a tree. In order to find the optimal waypoint W, the cost function was formulated considering both the total maneuver time and the distance d traveled by the feller buncher.

In Chapters 3 and 4, we investigated how to use the enumeration method to find the optimal path for the feller buncher to cut trees in a sub-region. First, in Chapter 3, a reachabilty map was constructed based on the tree location data and the information it contains helps to formulate the enumeration algorithm. In Chapter 4, the occupation map, state, basic actions and reward function were constructed to formulate the enumeration algorithm for finding the optimal path. A 3 by 4 occupation map was tested and the result showed that the algorithm was able to find all optimal paths. However, the enumeration algorithm is unable to handle large occupation map and further work needs to be done to improve its performance.

5.1 Suggested Future Work

It is suggested that Markov Decision Process (MDP) should be applied for finding the optimal path when cutting multiple trees since the enumeration method is taking too long to find out all possible paths if the occupation map is large. Some necessary components for the MDP method, including state, actions and reward function have been defined in Chapter 4. In the future, MDP will be applied so that the path planning for larger occupation map is possible.

Bibliography

[1] British Columbia Government, "Forest planning and practices regulation, b.c. reg. 64/2021."

[2] J.-P. Gaudreau, "Adaptation of the shortwood method in a context of natural disturbance," 2020.

Appendix A

Supplementary Information

A.1 L855E Feller Buncher Specifications

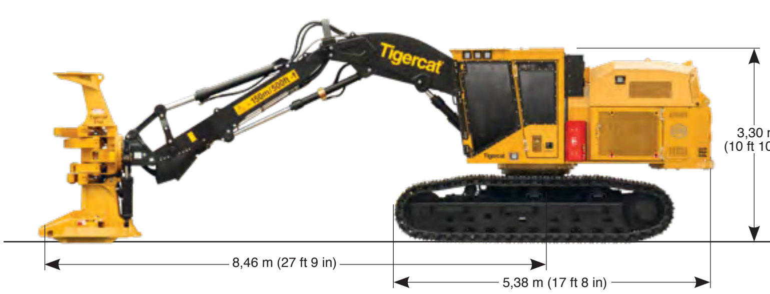
Tigercat

	855E	L855E
DIMENSIONS WITH STANDARD TRACK SHOE		
WIDTH	3 380 mm (133 in)	3 430 mm (135 in)
LENGTH less boom	5 380 mm (212 in)	5 280 mm (208 in)
HEIGHT less skylight	3 290 mm (130 in)	3 710 mm (146 in)
GROUND CLEARANCE	710 mm (28 in)	710 mm (28 in)
WEIGHT less attachment	30 845 kg (68,000 lb)	38 780 kg (85,500 lb)
TAIL SWING over side	1 385 mm (54 in)	1 360 mm (54 in)
POWER		
ENGINE Tier 4f	Tigercat FPT N67 Tier 4f	Tigercat FPT N67 Tier 4f
▸ RATED	210 kW (282 hp) @ 2,200 rpm	210 kW (282 hp) @ 2,200 rpm
▸ PEAK	210 kW (282 hp) @ 2,200 rpm	210 kW (282 hp) @ 2,200 rpm
ENGINE Tier 2	Tigercat FPT N67 Tier 2	Tigercat FPT N67 Tier 2
▸ RATED	205 kW (275 hp) @ 2,100 rpm	205 kW (275 hp) @ 2,100 rpm
▸ PEAK	210 kW (282 hp) @ 2,000 rpm	210 kW (282 hp) @ 2,000 rpm
AIR FILTRATION	Precleaner and 2-stage engine air cleaner	Precleaner and 2-stage engine air cleaner
COOLING	Aluminum side by side radiator, oil cooler and charge air cooler Removable intake debris screen	Aluminum side by side radiator, oil cooler and charge air cooler Removable intake debris screen
FAN	Hydraulically driven, automatic variable speed, reversible	Hydraulically driven, automatic variable speed, reversible
FUEL CAPACITY	800 L (211 US gal)	800 L (211 US gal)
DEF CAPACITY	80 L (21 US gal)	80 L (21 US gal)
HYDRAULIC SYSTEM		
PUMP, MAIN	Piston	Piston
PUMP, SAW*	Piston	Piston
PUMP, CLAMP ARMS	Piston	Piston
PUMP, COOLING FAN	Piston	Piston
RESERVOIR	225 L (60 US gal)	225 L (60 US gal)
FILTRATION	(5) Spin-on, 7 micron full flow; (1) Water absorbing	(5) Spin-on, 7 micron full flow; (1) Water absorbing
CYLINDERS, HOIST	(2) 120 mm (4.7 in) bore	(2) 120 mm (4.7 in) bore
CYLINDERS, STICK/ER	(2) 110 mm (4.7 in) bore	(2) 110 mm (4.7 in) bore
CYLINDER, TILT	130 mm (5.2 in) bore	130 mm (5.2 in) bore
CYLINDERS, LEVELING	N/A	(2) 180 mm (7 in) bore
HORSE POWER CONTROL	Electronic speed sensing; All-speed antistall	Electronic speed sensing; All-speed antistall
UNDERCARRIAGE		
TRACK FRAMES	R6-152 heavy-duty forestry Integral track guides/ramp angles	R7-163L super-duty forestry leveling Integral track guides/ramp angles
TRACK CHAIN	F8 203 mm (8 in) pitch sealed and greased	FH400 215 mm (8.5 in) pitch sealed and greased
FINAL DRIVE	(2) Piston motors with brake valves; Infinitely variable speed	(2) Piston motors with brake valves; Infinitely variable speed
TRACTIVE EFFORT	277 kN (62,300 lbf)	367 kN (82,600 lbf)
GEARBOX	Triple reduction planetary type with brake	Triple reduction planetary type with brake
FRONT IDLER	Hydraulic track adjuster; Spring shock absorber	Hydraulic track adjuster; Spring shock absorber
ROLLERS, UPPER	(2) D6D excavator type	N/A
SLIDES, UPPER	Optional, bolt-on	Bolt-on
ROLLERS, LOWER	(9) D6 single/double flange tractor type	(10) FH400 excavator type
TRACK SHOE	610 mm (24 in) single/double grouser	610 mm (24 in) single grouser
▸ Optional	710 mm (28 in) single grouser tri-track 760 mm (30 in) double grouser tri-track 915 mm (36 in) triple grouser tri-track	710 mm (28 in) single grouser
LEVELING	N/A	20° forward; 6° rear; +/-17° side
MAXIMUM CUT RADIUS	8 460 mm (333 in)	8 460 mm (333 in)
MINIMUM CUT RADIUS	4 800 mm (189 in)	4 800 mm (189 in)
BARE PIN LIFT full reach	8 440 kg (18,600 lb)	8 440 kg (18,600 lb)
BRAKES		
TRACK	Friction disc; Automatic spring applied, hydraulic release	Friction disc; Automatic spring applied, hydraulic release
SWING	Friction disc; Manual spring applied, hydraulic release	Friction disc; Manual spring applied, hydraulic release

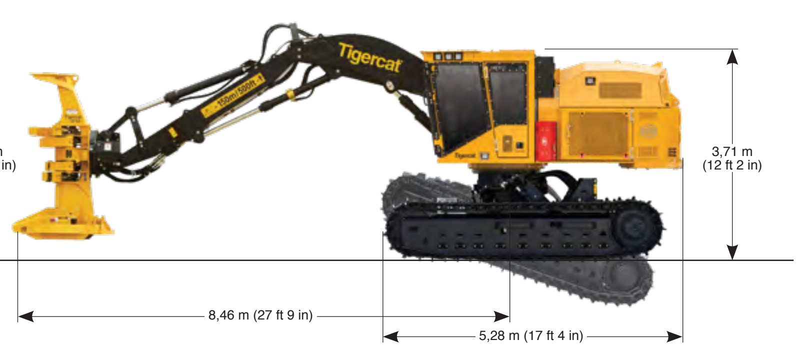
* For disc saw felling attachments only.

	855E	L855E
ROTATING UPPER		
SWING DRIVE	8 rpm variable speed; 360° continuous rotation; Double reduction, twin swing drive planetary gearboxes; Twin piston swing motors	
SWING BEARING	1 190 mm (47 in) ball circle diameter	
ENCLOSURE	Perforated plate on doors for ventilation; Hydraulic operated engine enclosure with manual back-up; Vandal protection; Smooth exterior Rear air intake for cooling	
ELECTRICAL		
BATTERY	(2) AGM, 12 v	(2) AGM, 12 v
ALTERNATOR	110 amp, 24 v	110 amp, 24 v
SYSTEM VOLTAGE	24 v	24 v
LIGHTING	(14) LED; (4) LED service lights, engine enclosure	(14) LED; (4) LED service lights, engine enclosure
OPERATOR'S STATION		
CAB	Insulated, pressurized and isolation mounted A/C, heater, defroster; skyVIEW and rearVIEW camera systems Full length polycarbonate windshield/entry door; Polycarbonate right and left side windows; One-piece polycarbonate side door window with steel guarded upper sliding section for ventilation; AM/FM digital stereo and auxiliary input port; Bluetooth® audio and hands-free calling (2) Power points; LogOn™ telematics system	
CONTROLS	Hydraulic proportional for boom/travel/swing with electronic travel speed control limiter; Electronic for leveling; Electric switch for swing brake and 3-mode ER control; Electronic control system with colour LCD display screen for machine monitoring and function adjustment	
SEAT	Full suspension air ride, fully adjustable, angled mounting; Armrest mounted Tigercat joysticks	
OTHER STANDARD EQUIPMENT		
	Fuel suction strainer; Alarm for track movement	Fuel suction strainer; Alarm for track movement
OPTIONAL EQUIPMENT		
	Counterweight kit; Cold weather kit; Bolt-on tool box R6-152 undercarriage; Electric hydraulic oil fill pump RemoteLog™ telematics system	Cold weather kit; Bolt-on tool box; Electric hydraulic oil fill pump RemoteLog™ telematics system
FELLING HEAD		
	Flexible hydraulic system to accept various felling heads	Flexible hydraulic system to accept various felling heads

855E FELLER BUNCHER



L855E FELLER BUNCHER



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