Analyzing the Effectiveness of the Greedy Algorithms in RimWorld

Justin Aditya Putra Prabakti - 13522130
Program Studi Teknik Informatika
Sekolah Teknik Elektro dan Informatika
Institut Teknologi Bandung, Jalan Ganesha 10 Bandung
E-mail (gmail): 13522130@std.stei.itb.ac.id

***Abstract*—When playing colony simulator games, often times player would use greed as basis for their actions and decisions, this paper attempts to look into the mechanics of the game to see if greedy algorithms could recreate or replace the greedy will of a player in hopes of possibly opening up the path to create a model or AI that could fully play the game.**

Keywords—greedy algoithm, decision making.

I. INTRODUCTION (*HEADING 1*)

RimWorld is a video game where the player plays as an overseer for a colony, stranded on a planet far from home. The player is then tasked to survive by building a base, gathering resources, and ultimately escape the planet, or stay long enough to become the strongest faction.

Like most colony sim games, RimWorld is quite “micro intensive”, meaning that the player needs to attend to most events happening in the game, which might make it confusing for other players and a less ideal of a game to play on the side.

However, what if there was a way to automate the game? By using decision making algorithms, we can let the machine do all the hard work and calculations for decision making, and leave us free to do other more important things.

Because of the survival theme, I believe that survival is strongly tied to one’s greed, that is the want to survive, and even become powerful.

II. THEORY

A. Greedy Algorithm

Greedy algorithms, simply are algorithms that aims to solve a problem heuristically by plotting a problem and its related variables in such a way that we can generate a single, comparable value for each possible solution that we use to determine which step is locally optimal to achieve the determined goal. While it isn’t the most effective algorithm, it is considerably quicker and provides a good enough approximation.

The greedy algorithm consists of around 6 elements :

- Candidate set (C): A set that consists of all possible choices from a step.
- Solution set (S): A set that consists of all the chosen candidates up until the current point.
- Solution function: Determines whether the given set of candidates (steps) provides a solution.
- Feasibility function: Checks if a given candidate may be inserted into the solution set (how feasible it is).
- Objective function: A function that provides maximal or minimal value to a solution

B. Deciding variables for contol

When deciding what a pawn should do or how a pawn should act, we will be using their stats and current health to determine what they should do or use. Thanks to the very detailed information pane the game gives us, we know what stats and health matters where, and therefore use for the Greedy Algorithm.

There are many variables in RimWorld, thanks to its very detail information panel, from a pawn’s health, to their assigned stats, everything has an effect on the pawn’s efficiency.

We will consider the ultimate goal of this paper to be keeping our pawns alive, since there are no true “lose” conditions. To keep a pawn alive means to manage all of it needs which is reflected from a pawn’s “Mood” bar. Because all aspects of a pawn affect its mood, a high mood means this pawn is satisfied and considerably healthy, while a low mood may cause the pawn to have a "mental breakdown" which may cause harm to the colony, and ultimately other pawns.

Therefore, we will focus on activities or routines within the game that aim to please one or more needs of our pawns, or helps us attain and maintain the needs of our pawns. The following aspects must be upkept in order to keep a pawns mood high:

- Food
- Sleep
- Recreation
- Beauty
- Comfort
- Outdoors (The need to be inside a room)
- Drug addictions (if any)

With these needs in mind, we will focus on implementing the following tasks into a greedy algorithm :

- Construct a base
- Secure food sources
- Combat any incoming enemies
- Reacting to medical disasters
- Pursue research for better equipment

C. Limitations

RimWorld is a highly modifiable game with a community that produces many types of mods. Often time these mods introduce many features that either help the player progress, or introduce new milestones to pursue, effectively adding goals for the player. This is due to the fact that RimWorld was designed to be a "story generator", not something the player necessarily completes, but rather to feel drama. Because the way the game is played differs from person to person, we will be only focusing on the basics of the game; the tasks mentioned above.

III. Implementation

A. Constructing a base

When constructing a base, we need to consider the shape of the base, the compositions of materials used to construct the base, and how close it is to an fertile soil for growing crops.

1) Base composition

A base is the main area where the player will designate their storage, work stations, and beds for their pawns. The bare minimum for a base would usually accommodate **a room**, **enough beds for the colony**, **necessary work stations** (which at least consists of a stove and a research bench), and if the colony has access to it : power generation. For simplicity, we will put off future design planning and focus on surviving, especially when the player first enters the game.

The cost of the bare essentials are as follows :

- 1 Wall : 5 Material
- 1 Floor : 3 Wood OR 1 Steel OR 2 Steel
- 1 Door : 25 Material
- 1 Bed : 45 Material
- 1 Stove : 80 Steel (+2 Components for electric stove)
- Research table : 25 Steel + 75 Material

To illustrate, the following 7 x 8 Base would cost : 240 Wood for the building, 210 Wood for Research table and beds, and 105 Steel for research table. With a grand total of 450 Wood and 105.

However, the same plan might not be ideal for different settings, there are certain conditions where wood is actualy more scarce than metal (for example, if starting out in an area with less forestry like arid shrublands or desert). Therefore another aspect must be considered : **material scarcity.**

A simple way to rate scarcity would be to take **how much material is needed** and divide it by **how much material is available in the map**:

$$Resource\ Scarcity = \frac{Ammount\ available - Ammount\ needed}{Ammount\ available}$$

For example, in a situation where we need 25 mateial but only have 80 Wood and 40 Steel, wood would have the resource scarcity rating of 0.6875 and steel would have the resource scarcity rating of 0.375 . With this we could discourage the use of scarce materials and promote the use of abundant materials

However, this method undermines the fact that steel as a resource is considerably more valuable than wood since it is heavily used in the near future after the colony has settlled : constructing power generators, upgrading the reasearch table, and better tech like transport pods and communications console. To address this concern, we will assign another value to represent this usefullness as Resource importance or **Resource rarity** (how often a resource would be used in the long run). For the sake of simplicity, the resource rarity will be : **3 for steel**, and **1 for wood**. This decision is based on the fact that steel is roughly used three times more frrequent compared to wood. However there are situations where wood would have higher importance than steel : if the player cannot generate electricity or does not have access to an electric stove, wood would then have a higher rarity as it is the only way we can cook food.

With this, we can change the **Resource Scarcity** formula to be:

$$Resource\ Scarcity = \frac{Ammount\ available - Ammount\ needed}{Ammount\ available \times Resource\ rarity}$$

Now, wood has a resource scarcity of 0.6875 and steel has 0.125. And when we swap the conditions (80 steel and 40 wood), wood has 0.375 scarcity and steel with 0.2291 scarcity.. Wood is still less scarce but has the possibility of being replaced by steel if we increase its rarity.

2) Farms for food source

There are 2 main ways to procure food for the colony : **hunting wild animals** and **growing crops**. We will focus on the crop growing aspect and account the following factors :

- How far the center of the base will be from the center of the map (positive for center, negative for edge of map)
- For each plot of soil : how far the edge of a plot is from the center of the base including how much tiles it has

Distance from the center of the map is accounted for to discourage constructing the base at near edges of the world, as it would cause security issues due to raiders spawning at edges of the world.

With the above factors in mind, we will calculate how feasible a location is in respect to agricultural potential as so:

$$Agriculture\ Potential = \left(\sum_{i=0}^{n} \frac{P_i}{M^2} \times \frac{d_i}{M \times 0.5}\right) * \left(1 - \frac{C}{M * 0.5}\right)$$

P_i : Tiles of fertile soil in that plot

d_i : distance of plot from the base (specifically, distance from the outmost wall nearest edge of the plot i)

C : Center distance

M : Size of map (width/length)

B. Combat

Periodically, enemies factions will send a raid to attack our base until they either defeated all of our pawns, decided its better to steal something and leave, or retreat after accumulating too many losses.

A pawn attacks with either melee attacks, or ranged attacks. Positioning when using a melee attack is not too important since melee attacks require the pawn to be within adjacent tiles of their target. However when it comes to ranged attacks, positioning becomes important as each different weapon has different effectiveness at different ranges.

A weapon's effective range is categorized into 4 groups:

- Close : 3 Cells or less
- Short : 4 to 12 Cells
- Medium : 13 to 25 Cells
- Long : 26 to 40 Cells or more

Usually a weapon forms some sort of curve that peaks on its designated range (A pistol peaks at Close range for 80% accuracy while a sniper would peak at medium long and more) We will simplify the calculation of weapon accuracy by calculating it like so:

$$Approx.\ weapon\ accuracy : 100\% - \left(\frac{Range - Ideal\ range}{Max\ weapon\ range}\right)^2$$

The "value" of a pawns shooting accuracy is calculated by first calculating the value of the pawns ability to manipulate objects (health of their arm), the pawns ability to see (health of their eye, light, and any obstruction like smoke), and finally the pawn's shooting stat itself:

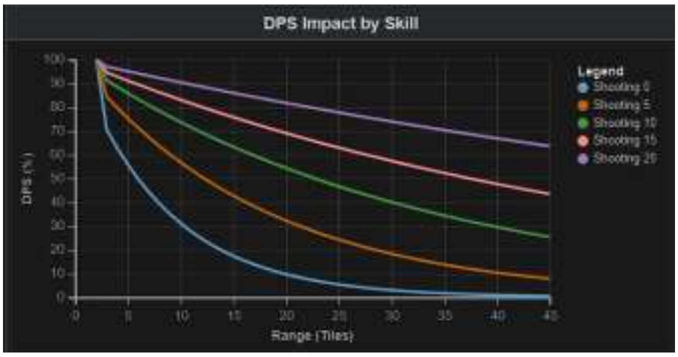
$$Manipulation\ factor : \begin{cases} Manipulation \leq 100\% : -8.0 \times (100\% - Manipulation) \\ Manipulation > 100\% : 0 \end{cases}$$

$$Sight\ factor : 12 \times (100\% + Sight)$$

$$Shooting\ accuracy\ index = Shooting\ skill + Manipulation\ factor + Sight\ factor$$

The actual shooting accuracy of a pawn corresponds to the following table, with a minimum of 0 and a maximum of 20

Skill Level	Standard	Careful Shooter	Trigger-Happy	Skill Level	Standard	Careful Shooter	Trigger-Happy
0	89%	94.5%	84%	-	-	-	-
1	91%	95%	85%	11	97.25%	98.333%	95%
2	93%	95.5%	86%	12	97.5%	98.5%	95.5%
3	93.5%	96%	87%	13	97.75%	98.666%	96%
4	94%	96.5%	88%	14	98%	98.833%	96.5%
5	94.5%	97%	89%	15	98.167%	99%	97%
6	95%	97.25%	91%	16	98.333%	99.125%	97.25%
7	95.5%	97.5%	93%	17	98.5%	99.25%	97.5%
8	96%	97.75%	93.5%	18	98.666%	99.313%	97.75%
9	96.5%	98%	94%	19	98.833%	99.375%	98%
10	97%	98.167%	94.5%	20	99%	99.438%	98.167%



By plotting the points using polynomial interpolation, we can get a rough estimate of a pawns shooting skill as so:

$$Accuracy = -0.000273x^2 + 0.009892x + 0.899212$$

where X is the "shooting accuracy index" of the pawn

Finally, to get the accuracy at which a pawn can aim, we simply calculate the accuracy to the power of distance between the pawn and its target.

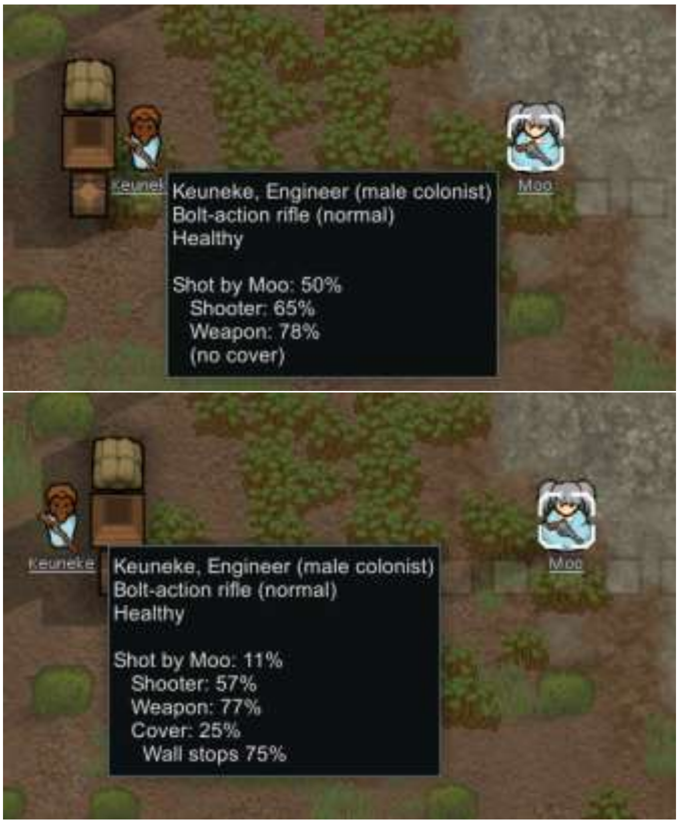
$$Pawn\ aim\ accuracy = Accuracy^{distance}$$

With this in mind, we will reserve weapons that are effective at close range to be used by pawns with lesser shooting skill.

Next is the positioning of a pawn, pawns can stand behind objects like trees, sandbags, stone chunks, or walls and have a lesser chance of being hit. To gain an advantage in battle, we will prioritize positions in cover compared to out of cover

$$Accuracy \times (1 + Cover\ effectiveness)$$

Although it must be noted that cover is only effective if it is in the way between the pawn and its target, i.e. standing in front of cover wouldn't provide any real benefit.



Another thing to note is that walls that are 3 tiles wide prevents the pawn from shooting and being shot altogether

However this only affects walls, that is to say that pawns can still shoot through/above sandbags.

Also, when an attacker is positioned at a certain angle from the cover, its effectiveness will also decrease. Whilst the actual formula for calculating cover effectiveness isn't available, based off the data from the RimWorld wiki, we can approximate the effectiveness of a cover as:

$$\text{Cover effectiveness} = \cos\big(1.38 \times (\theta - \pi)\big)$$

where θ is the smallest angle between the pawn, the cover in question, and the enemy in radians

With everything in mind, we can calculate how feasible a position is to take in a fight as so:

$Where: T_0 \ldots T_j \text{ are targets within weapon range}:$
$C_0 \ldots C_k \text{ are covers 1 tile within the location}$
$distance(T) \text{ is the distance between pawn and target}$

$$Position\ feasibility: \sum_{n=0}^{j}\left(Approx.Weapon\ Accuracy \times Pawn\ aim\ accuracy + \sum_{m=0}^{k} Cover \frac{effectiveness}{k}\right)$$

In other words, for every threat within weapon range if a pawn were to move there, we calculate the accuracy at which we can shoot the threat, combined with the average cover effectiveness of the surrounding cover against said threat.

There are however some flaws present, a two-wide wall can prevent a pawn from attacking at certain angles

There specific conditions for a wall to completely block sight for shooting is still unknown, however in the event that a position chosen causes our pawn to be unable to shoot, we can either reroll or move to another tile or let the enemy make a move instead, allowing our pawns to have a chance at catching them off-guard.

C. *Medical disasters*

When reacting to medical disasters, we need to be able to choose the correct capable pawn, and the action needed considering the amount of medicine left and time left.

When considering which pawn to do a medical job, we need to account their medical stats, manipulation, and sight. We will use the pawn's medical tend quality as an estimate of their competence at medicine.

A pawn with medicine skill 8 has 100% tend quality, skill 0 has 20% quality, and 20 has 155% quality. We can approximate the medical tend quality of a pawn as:

$$Base\ medical\ tend\ quality: \frac{(-0.271x^2 + 12.167x + 20)}{100} \times 100\%$$

With X as the pawn's medical skill.

Next, we will factor in the pawn's related health to get the estimate medical tend quality for the pawn:

$$Sight\ factor: 100\% + (Sight \times 100\%) \times 70\%$$

$$Final\ tend\ quality = Base\ quality \times Sight\ factor \times Manipulation$$

Note that actual tend quality will still depend on the medicine used and have a randomized value.

When treating time-critical diseases, we will only account for diseases curable by tending only (infection, bleeding, etc). We will need to calculate how fatal a sickness is, so that we can dispatch the correct medicine. This is to avoid the case where we treat a small injury with an expensive medicine, when we can instead use a cheaper alternative : herbal medicine.

Curable diseases starts at 0 severity and will slowly increase to 1 severity, at which will kill the pawn, however if a pawn manages to obtain 1 (100%) immunity for the diseases, the pawn will recover from the disease. Curable fatal diseases have 3 factors :

- Severity rate : how much severity gets added per day, from 0 to +1
- Immunity rate : how much immunity gets added per day, from 0 to +1
- Treatment rate : how much the severity slows down when treated (base at 100% tend quality), from -1 to 0

We then calculate two variables :

1. Immunity delay : We divide immunity by severity to see how slow immunity gain is compared to severity rate
2. Treatment effectiveness : How effective treatment is at slowing down severity

Using these variables, we can calculate how likely a patient is to recover from a disease. We can see the needed minimal treatment effectiveness by reducing 1 with the immunity delay

$$Immunity\ delay = \frac{Immunity\ rate}{Severity\ rate}$$

$$Needed\ treatment: 1 - Immunity\ delay$$

Then, we can calculate the treatment available as so:

$$Available\ treatment\ effectiveness: Treatment\ effectiveness \times Tend\ quality \times Medicine\ multiplier$$

Assuming both severity and immunity is at 0, if the available treatment effectiveness is more than needed treatment, we can guarantee that the affected pawn can indeed recover from the disease.

However, when either Immunity or Severity is ahead of the other, the required treatment will also be affected.

$$Severity\ overhead = \frac{Current\ severity}{Current\ immunity}$$

This number shows how far ahead severity is compared to immunity, and therefore shows us “how much more immunity” we need to get to level out the overhead. Therefore, by multiplying needed treatment by the severity overhead, we get the new needed treatment.

$$\begin{aligned}\textit{New needed treatment} \\ &= \textit{Needed treatment} \\ &\times \textit{Severity overhead}\end{aligned}$$

To prove this, we will make an example: A disease has a severity rate : +0,5/day, Immunity rate of +0,25//day, treatment rate of -0,125/day, and finally severity is at 0,1. This means the disease will become lethal in (1-0,1)/0,5 = 1,8 days and 1/0,25 = 4 days for immunity to reach full.

With a severity overhead of 1.1 and base needed treatment of (1-0,5) = 0,5. Multiplying this number by 1.1 we get 0,55 needed treatment. Reversing this number we get a minimum of 2,2 (220%) tend effectiveness, multiplying treatment rate by this number the severity rate becomes 0,225/day or 4 days to become lethal, equal to the time needed for immunity.

Later on, we can change the medicine type in order to save medicine, prevent death by operation (such as amputating an infected body part), or ultimately leaving the pawn to die.

D. Research and the future of the colony

Research is very subjective, and so there isn’t one correct way to do it. There are two ways to fashion this into a greedy algorithm.

1) Greedy by market value

Essentially, for every research we can immediately research (having all prerequisites unlocked) we will sum up all the market value of the items unlocked by the research in question.

This method could work, however there are some researches that is arguably critical, yet the that is unlocked does not have a market value, which may prove this method difficult.

2) Hardest research first

In the base game, important research milestones usually have the highest research cost compared to other research items which usually unlock a new weapon, equipment, or technology.

IV. Conclusion

For tasks that are straight-forward, we can plot an accurate-enough objective function and feasibility function. Meaning that these tasks could theoretically be automated, however it still cannot replace the ability of a human player to create tactics or schemes to use in for example battles, which may require more advanced techniques like machine learning.

Glossary

Colony – The group of pawns the player controls.
Colonist – A pawn that belongs to the player colony.
Pawn – Usually a human/living being that can be directly controlled (if owned by the player).
Stats – A number associated with the proficiency of a pawn with a certain profession.
Material – Resource used usually to construct or craft something. In the context of construction : Steel, Wood, Bricks.

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PERNYATAAN

Dengan ini saya menyatakan bahwa makalah yang saya tulis ini adalah tulisan saya sendiri, bukan saduran, atau terjemahan dari makalah orang lain, dan bukan plagiasi.

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Justin Aditya Putra Prabakti, 13522130