# Lunar Lander

Project #1 for Artificial Intelligence Fundamentals

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March 9th, 2025

# Contents

# 1 Perceptions

We use built-in perceptions of the lander and a zoning system that determines safe and unsafe zones, so that the lander reacts according to its placement, as described in Figure 1.

## 1.1 Zoning System

The Zoning System helps us determine where to do what. We consider zones **G** and **H** to be difficult to move the Lunar Lander to the landing zone, so we move them up to zones **E** and **F**. Zones **E** and **F** are almost acceptable, we have to move the to, which we call the chimney. The chimney is in zones **B**, **C**, and **D**. They're the zones where we move the lander down while trying to center it in the middle of the landing. **C** and **D** make the small adjustments to get the lander to the **B** zone, where it slowly descends to zone **A**. Zone **A** is where we determine that the Lunar Lander is in a safe enough place that we can turn off the jets and safely land it without the need for minor adjustments.

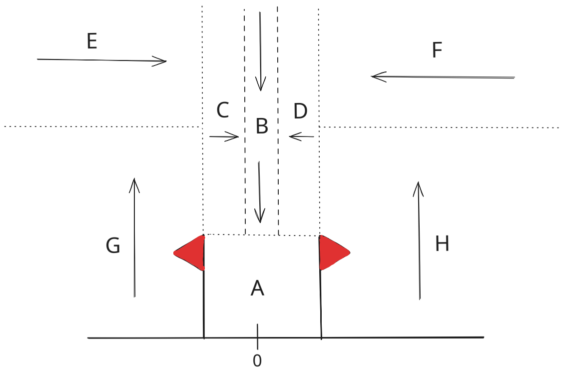


Figure 1: Zoning System of the lunar landing

The positioning of each zone was determined by enabling the *Keyboard Agent* mode and disabling the *fail condition* in the code, where the position of the agent is printed into console each frame.

## 1.2 Perceptions

We utilize the following perceptions to determine horizontal, vertical and angular speeds, as well as angular directions, if the left and right legs are touching the ground, and, again, the zoning systems.

- **Za**: Landing Zone
- **Zb**: Safest Descent Zone
- **Zc**: Left Safe Descent Zone
- **Zd**: Right Safe Descent Zone
- **Ze**: Left Upper Safe Zone
- **Zf**: Right Upper Safe Zone
- **Zg**: Left Unsafe Zone
- **Zh**: Right Unsafe Zone
- **Vx**: Horizontal velocity (positive rightward)
- **Vy**: Vertical velocity (positive upward)
- **A**: Angular direction (positive counter-clockwise)
- **Va**: Angular velocity (positive counter-clockwise)
- **L**: Left leg in ground contact
- **R**: Right leg in ground contact

# 2 Actions

To control the Moon Lander we utilized the actions that were given to us on different levels. They are ON, partially ON and OFF. The partially ON levels help us stabilize the Lunar Lander by making minor adjustments so we don't overshoot it and end up being in a unwanted state again.

## 2.1 Action Definition

- **DN :** [0,0] Turns main and secondary motors off
- **Main:** [1.0,0] Turns main motor fully on and secondary off
- **Rl:** [0.1, −0.55] Rotates left
- **Rr:** [0.1, 0.55] Rotates right

# 3 Production System

## 3.1 Basic Production System

To maximize successful landings our priority is maintaining the stability of the lander for better maneuvering. Only when the stability is guaranteed the lander tries to land. The basic set of instructions the lander must follow, regardless of position and/or zone are:

1. $V_a$[1] $\geq$ MAS $\rightarrow$ Rr prevents spinning
2. $V_a \leq -$MAS $\rightarrow$ Rl prevents spinning
3. $V_x$[2] $\geq$ MXS $\rightarrow$ Rl prevents rightward drift
4. $V_x \leq -$MXS $\rightarrow$ Rr prevents leftward drift
5. $V_y$[3] $\geq$ MYS $\rightarrow$ Mp0 prevents ascending
6. $V_y$[4] $\leq -$MYS $\rightarrow$ Mp2 prevents excessive descent speed

## 3.2 Constants

With the basic Production System we can create the final Production System, changing the constants values according to what the lander should do in its current zone. We also need to define constants, determining the values that we want to set for the perceptions.

Constants:

- **MAS**: Maximum Angular Speed 0.1
- **MXS**: Maximum Horizontal Speed 0.01
- **MYS**: Maximum Vertical Speed 0.1

## 3.3 Final Production System

The final production system adjusts control rules based on the current zone and observed velocities.

Zone A Rules:

1. Za, $V_a \geq 0 \rightarrow$ Rr prevents lander spinning out
2. Za, $V_a \leq 0 \rightarrow$ Rl prevents lander spinning out
3. Za, $V_x \geq 0 \rightarrow$ Rl prevents lander moving right
4. Za, $V_x \leq 0 \rightarrow$ Rr prevents lander moving left

[1] $V_a$: angular velocity
[2] $V_x$: horizontal velocity
[3] $V_y$: vertical velocity (upwards)
[4] $V_y$: vertical velocity (downwards)

5. Za, $V_y \geq 0 \rightarrow$ Dn — prevents lander flying away
6. Za, $V_y \leq 0 \rightarrow$ Main — prevents lander descending too fast
7. Za $\rightarrow$ Dn — move towards objective

Zone B Rules:

1. Zb, $V_a \geq 0 \rightarrow$ Rr — prevents lander spinning out
2. Zb, $V_a \leq 0 \rightarrow$ Rl — prevents lander spinning out
3. Zb, $V_x \geq 0 \rightarrow$ Rl — prevents lander moving right
4. Zb, $V_x \leq 0 \rightarrow$ Rr — prevents lander moving left
5. Zb $\rightarrow V_y \geq 0 \rightarrow$ Dn — prevents lander flying away
6. Zb, $V_y \leq -\mathrm{MYS} \rightarrow$ Main — prevents lander descending too fast
7. Zb, Dn — move towards Zone A

Zone C Rules:

1. Zc, $V_a \geq 0 \rightarrow$ Rr — prevents lander spinning out
2. Zc, $V_a \leq -\mathrm{MAS} \rightarrow$ Rl — prevents spinning, allows rotation right
3. Zc, $V_x \geq \mathrm{MXS} \rightarrow$ Rl — prevents moving too fast right
4. Zc, $V_x \leq 0 \rightarrow$ Rr — prevents moving left
5. Zc, $V_y \geq 0 \rightarrow$ Dn — prevents flying away
6. Zc, $V_y \leq -\mathrm{MYX} \rightarrow$ Main — prevents descending too fast, allows descent
7. Zc $\rightarrow$ Rr — move towards Zone B

Zone D Rules:

1. Zd, $V_a \geq \mathrm{MAS} \rightarrow$ Rr — prevents spinning, allows rotation left
2. Zd, $V_a \leq 0 \rightarrow$ Rl — prevents spinning
3. Zd, $V_x \geq 0 \rightarrow$ Rl — prevents moving right
4. Zd, $V_x \leq -\mathrm{MXS} \rightarrow$ Rr — prevents moving too fast left
5. Zd, $V_y \geq 0 \rightarrow$ Dn — prevents flying away
6. Zd, $V_y \leq \mathrm{MYX} \rightarrow$ Main — prevents descending too fast, allows descent
7. Zd $\rightarrow$ Rl — move towards Zone B

Zone E Rules:

1. Ze, $V_a \geq 0 \rightarrow$ Rr — prevents spinning
2. Ze, $V_a \leq 0 \rightarrow$ Rl — prevents spinning
3. Ze, $V_x \geq \mathrm{MXS} \rightarrow$ Rl — prevents moving too fast right
4. Ze, $V_x \leq 0 \rightarrow$ Rr — prevents moving left
5. Ze, $V_y \geq \mathrm{MYS} \rightarrow$ Dn — prevents flying up too fast
6. Ze $V_y \leq 0 \rightarrow$ Main — prevents descending too fast, allows descent
7. Ze $\rightarrow$ Rr — moves towards Zone C

Zone F Rules:

1. Zf, $V_a \geq 0 \rightarrow$ Rr — prevents spinning

2. Zf, $V_a \leq 0 \rightarrow$ Rl — prevents spinning
3. Zf, $V_x \geq 0 \rightarrow$ Rl — prevents moving right
4. Zf, $V_x \leq$ MXS $\rightarrow$ Rr — prevents moving too fast left
5. Zf, $V_y \geq$ MYS $\rightarrow$ Dn — prevents flying up too fast
6. Zf, $V_y \leq 0 \rightarrow$ Main — prevents descending too fast, allows descent
7. Zf $\rightarrow$ Rl — moves towards Zone D

Zone G Rules:

1. Zg, $V_a \geq 0 \rightarrow$ Rr — prevents spinning
2. Zg, $V_a \leq -$MAS $\rightarrow$ Rl — prevents spinning, allows rotation right
3. Zg, $V_x \geq$ MXS $\rightarrow$ Rl — prevents moving too fast right
4. Zg, $V_x \leq 0 \rightarrow$ Rr — prevents moving left
5. Zg, $V_y \geq 0 \rightarrow$ Dn — prevents flying away
6. Zg, $V_y \leq 0 \rightarrow$ Main — prevents descending too fast, allows descent
7. Zg $\rightarrow$ Main — moves towards Zone E

Zone H Rules:

1. Zh, $V_a \geq$ MAS $\rightarrow$ Rr — prevents spinning, allows rotation left
2. Zh, $V_a \leq 0 \rightarrow$ Rl — prevents spinning
3. Zh, $V_x \geq 0 \rightarrow$ Rl — prevents moving right
4. Zh, $V_x \leq -$MXS $\rightarrow$ Rr — prevents moving too fast left
5. Zh, $V_y \geq 0 \rightarrow$ Dn — prevents flying away
6. Zh, $V_y \leq 0 \rightarrow$ Main — moves towards zone F
7. Zh$\rightarrow$ Main — moves towards zone F

### 3.4 Observations

With this Production System we can achieve a success rate of roughly 50%, with successful scenarios taking 17517 steps on average. We also track the fail conditions of each attempt and print them out at the end. In a random test of 1000 episodes, there were 530 failures:

- Rollover count: 90
- Horizon left count : 29
- Horizon right count: 41
- Outside left count: 158
- Outside right count: 129
- Crash on landing zone count: 39

As we can see, most of the failures (158+129=297) are due to the lander outside of the landing zone, by the looks of it, often not by much.

# 4 Conclusion

In order to achieve this system, we experimented different strategies. In the first phase, we only had 6 basic rules to not lose control and only after that we guaranteed that we had a rule perzone to move the lander in accordance with the position. This strategies did not pass of the 30% so we changed to the current approach that made us go to 50%. The presented control system prioritizes stability prior to descent, relying on zone-specific velocity constraints and to move safely towards the target. Further improvement is possible by optimizing threshold values, adjusting motor actions, modifying zone boundaries, and combining perceptions to handle complex scenarios beyond the current system's capabilities, like handling lateral and vertical movement by combining both perceptions and acting accordingly.