# Lunar Lander

Trabalho Prático Nº1 para a cadeira de Fundamentos de Inteligência Artificial

Francisco Silva, Miguel Pereira and Guilherme Rodrigues
Nº 2022213583, 2022232552 and 2022232102

Department of Informatics Engineering
University of Coimbra, Coimbra, Portugal
**{francisco.lapamsilva,miguelmpereira0409,grf04}**@gmail.com

March 9th, 2025

## 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.

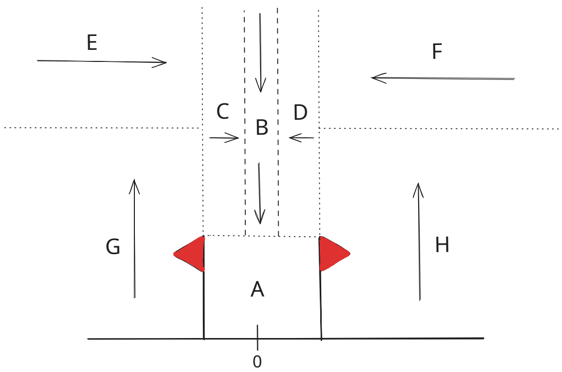


Figure 1: Zoning System of the lunar landing

### 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

- **Mp0**: Main Motor OFF (0.0)
- **Mp1**: Main Motor partially ON (0.1)
- **Mp2**: Main Motor ON (1.0)
- **Ms0**: Secondary Motors OFF (0.0)
- **Msl1**: Left Secondary Motor partially ON (0.55)
- **Msl2**: Left Secondary Motor ON (0.8)
- **Msr1**: Right Secondary Motor partially ON (0.55)
- **Msr2**: Right Secondary Motor ON (0.8)

# 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 $\rightarrow$ Mp1, Msl1 — prevents spinning
2. $V_a \leq -$MAS $\rightarrow$ Mp1, Msr1 — prevents spinning
3. $V_x$[2] $\geq$ MXS $\rightarrow$ Mp1, Msl2 — prevents rightward drift
4. $V_x \leq -$MXS $\rightarrow$ Mp1, Msr2 — 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

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

### 3.2 Constants

With the basic Production System we can create the final Production System, changing the {...} 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 (e.g., 0.1)
- **MXS**: Maximum Horizontal Speed (e.g., 0.01)
- **MYS**: Maximum Vertical Speed (e.g., 0.1)

### 3.3 Final Production System

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

1. Za, $V_a \geq 0 \rightarrow$ MP1, Msl1 prevents lander spinning out
2. Za, $V_a \leq 0 \rightarrow$ MP1, Mrl1 prevents lander spinning out
3. Za, $V_x \geq 0 \rightarrow$ MP1, Msl2 prevents lander moving right
4. Za, $V_x \leq 0 \rightarrow$ MP1, Mrl2 prevents lander moving left
5. Za, $V_y \geq 0 \rightarrow$ MP0 prevents lander flying away
6. Za, $V_y \leq 0 \rightarrow$ MP2 prevents lander descending too fast
7. Zb, $V_a \geq 0 \rightarrow$ MP1, Msl1 prevents lander spinning out
8. Zb, $V_a \leq 0 \rightarrow$ MP1, Mrl1 prevents lander spinning out
9. Zb, $V_x \geq 0 \rightarrow$ MP1, Msl2 prevents lander moving right
10. Zb, $V_x \leq 0 \rightarrow$ MP1, Mrl2 prevents lander moving left
11. Zb, $V_y \geq 0 \rightarrow$ MP0 prevents lander flying away
12. Zb, $V_y \leq -\text{MYS} \rightarrow$ MP2 prevents lander descending too fast
13. Zc, $V_a \geq 0 \rightarrow$ MP1, Msl1 prevents lander spinning out
14. Zc, $V_a \leq -\text{MAS} \rightarrow$ MP1, Mrl1 prevents spinning, allows rotation right
15. Zc, $V_x \geq \text{MXS} \rightarrow$ MP1, Msl2 prevents moving too fast right
16. Zc, $V_x \leq 0 \rightarrow$ MP1, Mrl2 prevents moving left
17. Zc, $V_y \geq 0 \rightarrow$ MP0 prevents flying away
18. Zc, $V_y \leq -\text{MYX} \rightarrow$ MP2 prevents descending too fast, allows descent
19. Zd, $V_a \geq \text{MAS} \rightarrow$ MP1, Msl1 prevents spinning, allows rotation left
20. Zd, $V_a \leq 0 \rightarrow$ MP1, Mrl1 prevents spinning
21. Zd, $V_x \geq 0 \rightarrow$ MP1, Msl2 prevents moving right
22. Zd, $V_x \leq -\text{MXS} \rightarrow$ MP1, Mrl2 prevents moving too fast left
23. Zd, $V_y \geq 0 \rightarrow$ MP0 prevents flying away
24. Zd, $V_y \leq \text{MYX} \rightarrow$ MP2 prevents descending too fast, allows descent
25. Ze, $V_a \geq 0 \rightarrow$ MP1, Msl1 prevents spinning
26. Ze, $V_a \leq 0 \rightarrow$ MP1, Mrl1 prevents spinning
27. Ze, $V_x \geq \text{MXS} \rightarrow$ MP1, Msl2 prevents moving too fast right

28. Ze, $V_x \leq 0 \rightarrow$ MP1, Mrl2 prevents moving left
29. Ze, $V_y \geq$ MYS $\rightarrow$ MP0 prevents flying up too fast
30. Ze, $V_y \leq 0 \rightarrow$ MP2 prevents descending too fast
31. Zf, $V_a \geq 0 \rightarrow$ MP1, Msl1 prevents spinning
32. Zf, $V_a \leq 0 \rightarrow$ MP1, Mrl1 prevents spinning
33. Zf, $V_x \geq 0 \rightarrow$ MP1, Msl2 prevents moving right
34. Zf, $V_x \leq$ MXS $\rightarrow$ MP1, Mrl2 prevents moving too fast left
35. Zf, $V_y \geq$ MYS $\rightarrow$ MP0 prevents flying up too fast
36. Zf, $V_y \leq 0 \rightarrow$ MP2 prevents descending too fast
37. Zg, $V_a \geq 0 \rightarrow$ MP1, Msl1 prevents spinning
38. Zg, $V_a \leq -$MAS $\rightarrow$ MP1, Mrl1 prevents spinning, allows rotation right
39. Zg, $V_x \geq$ MXS $\rightarrow$ MP1, Msl2 prevents moving too fast right
40. Zg, $V_x \leq 0 \rightarrow$ MP1, Mrl2 prevents moving left
41. Zg, $V_y \geq 0 \rightarrow$ MP0 prevents flying away
42. Zg, $V_y \leq 0 \rightarrow$ MP2 prevents descending too fast
43. Zh, $V_a \geq$ MAS $\rightarrow$ MP1, Msl1 prevents spinning, allows rotation left
44. Zh, $V_a \leq 0 \rightarrow$ MP1, Mrl1 prevents spinning
45. Zh, $V_x \geq 0 \rightarrow$ MP1, Msl2 prevents moving right
46. Zh, $V_x \leq -$MXS $\rightarrow$ MP1, Mrl2 prevents moving too fast left
47. Zh, $V_y \geq 0 \rightarrow$ MP0 prevents flying away
48. Zh, $V_y \leq 0 \rightarrow$ MP2 prevents descending too fast

# 4 Conclusion

The presented control system emphasizes stability prior to descent, relying on zone-specific velocity constraints and corrective actions. Further improvement is possible by optimizing threshold values, adjusting motor actions, modifying zone boundaries, and incorporating combined perceptions to handle complex scenarios beyond the current system's capabilities.