

Environmental Stress & Comfort Analysis

Documentation & Technical Methodology

1. Concept

Sensors (Temperature, Humidity, Light, Soil Moisture) provide raw data, but they don't directly measure plant health. This analysis module translates raw data into a "**Quality of Life**" metric for the plants.

- **Comfort:** The state when *all* environmental parameters are within their optimal ranges.
- **Stress:** The state when *one or more* parameters deviate from the optimal range, potentially hindering growth or causing damage.

2. Key Metrics

A. Comfort Time

The total duration (in hours/minutes) during a 24-hour period where the plant is in a "perfect" environment.

```
Comfort Time = Σ Time where (T_min ≤ T ≤ T_max) ∧ (H_min ≤ H ≤ H_max) ∧ ...
```

B. Stress Time

The duration where the plant is fighting against adverse conditions.

$$\text{Stress Time} = \text{Total Time} - \text{Comfort Time}$$

3. Analysis Methods

The system evaluates stress using three dimensions:

1. **Frequency & Duration:** How often does stress occur, and for how long? (e.g., "2 hours of heat stress every afternoon").
2. **Rate of Change:** How quickly do conditions deteriorate? Rapid changes (thermal shock) are more damaging than gradual ones.
3. **Actuator Response:** Did the fan/pump/light turn on? Did it successfully mitigate the stress?

4. Analysis Outputs

A. Comfort vs. Stress Timeline (Diagram)

This ASCII diagram visualizes a 24-hour day, distinguishing between comfortable periods and specific stress events.

```
      Status
      ^
| [COMFORT] [HEAT STRESS] [COMFORT] [DRY SOIL]
| (Ideal) (Temp > 35C) (Ideal) (Moisture < 30%) |
| ++++++-----+-----+-----+-----+
+-----+
08:00 12:00 15:00 18:00
```

B. Stress Summary Table

Parameter	Ideal Range	Current Status	Stress Duration (Last 24h)	Actuator Action
Temperature	15°C - 35°C	38°C (High)	3 hrs 15 min	Fan: ON (Cooling)
Humidity	40% - 80%	45% (OK)	0 min	Misting: OFF
Soil Moisture	30% - 70%	28% (Low)	45 min	Pump: ON (Watering)
Light	20% - 100%	10% (Low)	1 hr 20 min	Grow Light: ON

C. Predictive Improvements

- **Pre-emptive Cooling:** Turn on fans *before* temperature hits the critical limit based on the rate of rise.
- **Smart Watering:** Delay watering if humidity is very high (to prevent mold) or if rain is predicted (if connected to weather API).
- **Stress Accumulation:** Calculate a "Daily Stress Index" score (0-100) to track long-term plant health trends.