THE·GRID

Interactive Display Matrix

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Summary

THE·GRID is an art/engineering installation consisting a grid of poles illuminated by white LED strips. Interactivity is provided through a computer vision system utilising a night vision camera. Applications include a virtual maze and interactive display patterns. Primary requirements are a 14m × 24m area of unlit ground and access to mains power (approx 1.5kW peak).

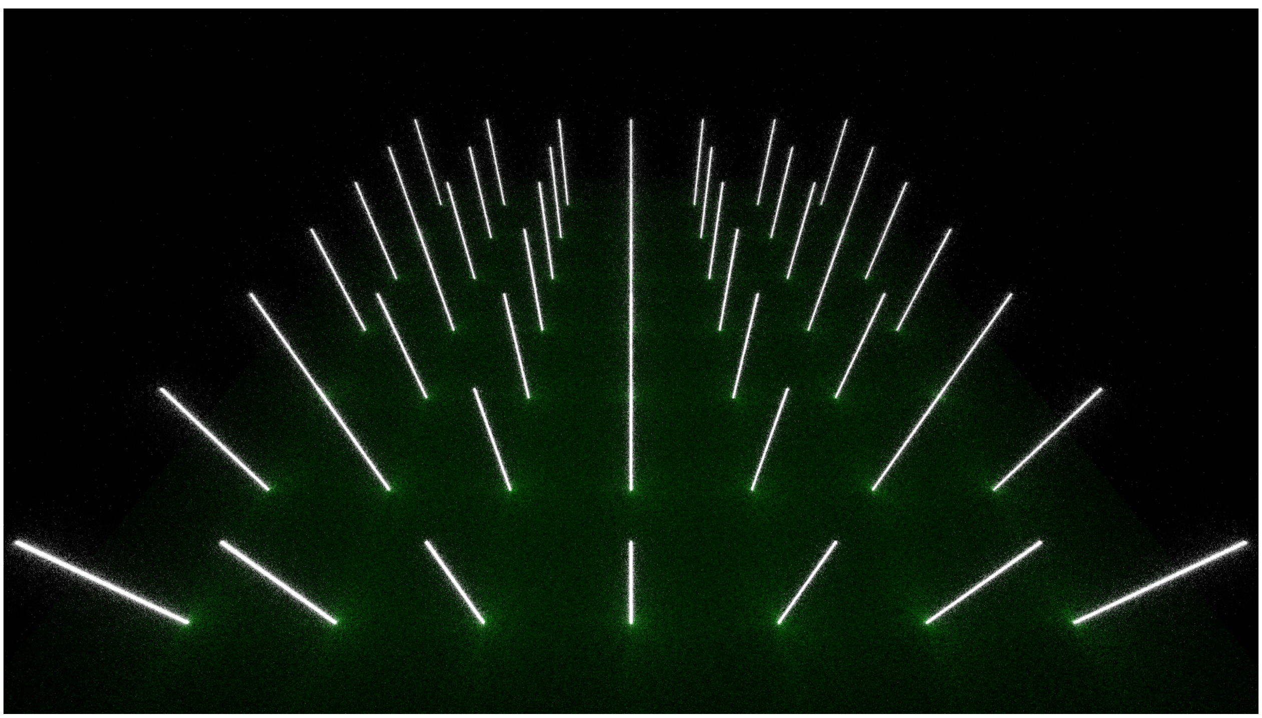

Figure 1: A computer graphics simulation of THE·GRID.

1 Design

1.1 Layout

THE·GRID would occupy a space of approximately 24m × 14m. Of this, 12m × 12m is the grid itself, consisting of a 7 × 7 grid of poles with 2m spacing. A backstage area holds the power and control tent as well as the camera mast.

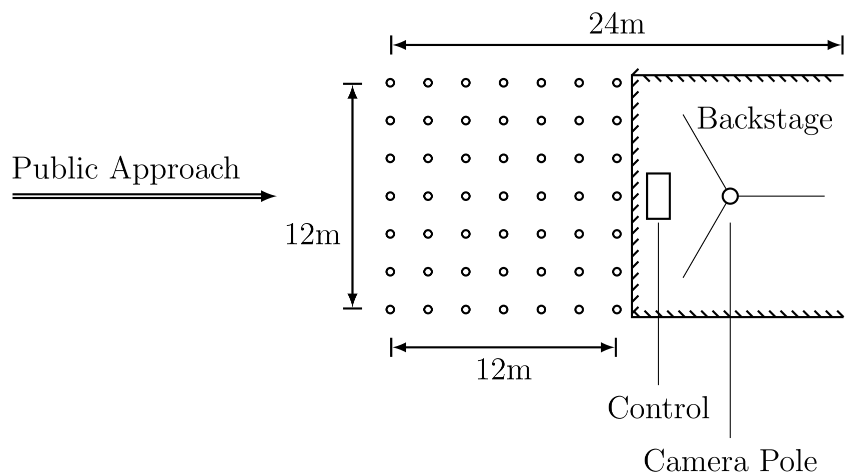

Figure 2: Plan schematic

1.2 Structural

Each pole will protrude 2.5m from the ground. The total length is 3m, with 50cm being inserted into the ground. The poles are constructed from $\frac{3}{4}$" × $\frac{3}{4}$" × $\frac{1}{16}$" aluminium angle section. See Appendix A for detailed drawings.

The interactivity camera will be mounted 8m above the ground on a 10m fishing pole, guyed for rigidity.

1.3 Electrical and Electronics

1.3.1 Cabling

Each LED strip will consume around 2A when active. The wiring for one strip will consist of twin core cable carrying power and return between the strip and the control tent. Additionally, a coaxial connection will run from the interactivity camera to the control tent.

Ideally, all cabling inside THE·GRID will be buried slightly below ground to avoid a trip hazard. If this is not possible, cabling could be run between the tops of poles at a height of 2.5m.

1.3.2 Switching

Each LED strip will be controlled using a BD679 Darlington pair as a driver. The drivers will be switched by six 8-output shift registers, themselves controlled by the CPU.

1.3.3 Power

The maximum power consumption of THE·GRID will be 100A. This will be provided by four 550W ATX power supplies, each rated for 32A on its +12V rail.

1.4 Software and Control

A laptop in the control tent will generate display patterns and handle interactivity. It will transmit lighting data via a serial link to an Arduino. Upon receiving each frame, the Arduino will clock the data into the shift registers, then activate the output latch.

A night vision enabled camera (with separate IR floodlight) mounted on a mast in the backstage area senses movement and tracks the location of people inside THE·GRID. This information is used for interactive applications and patterns.

2 Applications

2.1 aMAZE

aMAZE is an interactive, virtual maze. In this mode, when a user enters THE·GRID, a maze is randomly generated. Squares the user can travel to are lit, while squares representing walls are dark. aMAZE monitors the user's progress and knows if the user completes the maze, or cheats! The twist is that aMAZE only lights the user's square and adjacent squares—the user cannot see ahead and can only explore passages by travelling them!

A variation on this is two-player aMAZE. Two players can simultaneously traverse different (and overlapping) mazes, competing for time.

2.2 Interactive Patterns

A number of interactive patterns will produce interesting visual effects based on the movement of people in THE·GRID, inspired by fluid disturbance and flow.

2.3 Non-interactive Patterns

For times when no users are directly interacting with THE·GRID, non-interactive patterns will display pre-programmed effects resembling waves, stars and sparks.

3 Risk Assessment

3.1 Mechanical

THE·GRID is an interactive exhibit designed for people to walk around. It is also active after sunset. This leads to a number of risks due to people walking around and through a structure in low lighting. However, it is anticipated that there is a minimal risk of injury. As poles are embedded in soft ground and are constructed from thin aluminium section, it is anticipated that there is no serious risk of injury should somebody walk into a pole.

Poles will be 2.5m (8 foot 2 inches) tall, so there should be no risk of impalement or eye injury.

In the very unlikely case of a pole falling on a person, the pole's light weight (around 500g) should mean there is minimal possibility for injury.

With people walking around the installation in low light, there would be a significant trip hazard were any cabling or guy-wires exposed. For this reason, all cabling inside THE·GRID itself will be buried below the surface of the ground. If the cable cannot be buried, it could be run overhead between the top of the poles. Again, this is high enough that it should be impossible to walk into.

The backstage area will contain cabling running at ground level alongside other hazards, and so will be off limits.

3.2 Electrical

All mains electronics will be contained within the control tent and power is distributed through THE·GRID at 12V DC. The control tent will be waterproof, and all exposed cabling, connections and electronics will be waterproof. The low voltage combined with RCD protection means there is a minimal risk of electricution.

There is minimal risk of the low voltage LED strips in THE·GRID itself posing a fire hazard. In the unlikely event of a fire in the control tent the hazard would be contained in the off-limits backstage area, minimizing the risk to users.

3.3 Other

In the event of a nearby thunder storm, the exposed metal poles could attract lightning strikes (although they are likely negligible compared to the main NOC radio mast). If there is a significant chance of a thunder storm, THE·GRID will be disconnected from the mains supply and placed off limits for the duration of the storm.

There is a risk that individuals with photo-sensitive epilepsy could be affected by THE·GRID. We will have to investigate further how to minimize this risk, whether this be through appropriate warning signage or avoiding problematic patterns such as flashing.

A Engineering Drawings

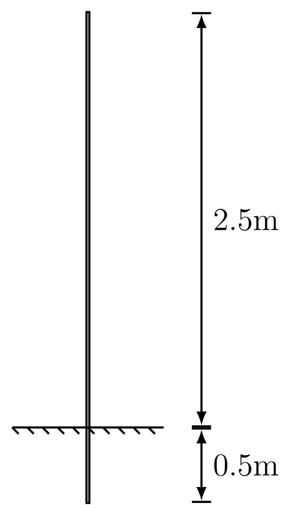

Figure 3: Side view of a single pole

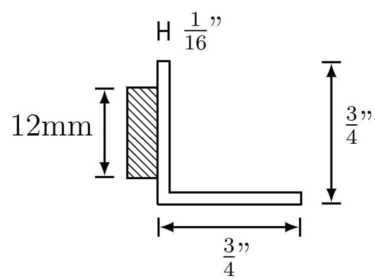

Figure 4: Top view of a single pole with LED strip

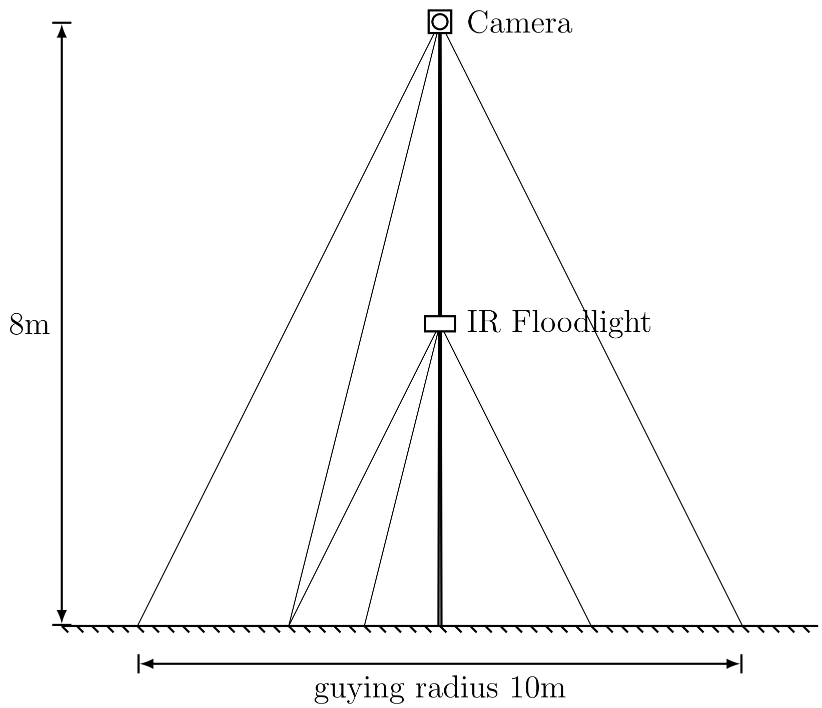

Figure 5: Side view of camera mast

B Structural Design Verification

The structural design can be verified quantitatively using Euler-Bernoulli beam theory. This assumes any deflection is small and that shear forces cause negligible deflection. These assumptions are justified when the beam concerned is slender, i.e. its length is greater than 20 times its thickness, a condition more than satisfied for THE·GRID's poles.

From a basic structural point of view, THE·GRID's poles are slender vertical cantilevers subject to self weight and lateral wind loading.

B.1 Basic Properties

The following calculations are based on the beam's *Second Moment of Area in the X axis* (I_{xx}), *Density* (ρ), and *Young's Modulus* (E). The second moment of area in the U axis (45° from the X and Y axes) is defined:

$$I_{uu} = \int v^2 \, \mathrm{d}A$$

where the V axis is perpendicular to the U axis. For thin walled equal angle section:

$$\mathrm{d}A = 2t\sqrt{2}\, \mathrm{d}v$$

$$\begin{aligned}
I_{uu} &= 2t\sqrt{2} \int_{\frac{-a}{2\sqrt{2}}}^{\frac{a}{2\sqrt{2}}} v^2 \, \mathrm{d}v \\
&= \frac{2t\sqrt{2}}{3} \left[y^3 \right]_{\frac{-a}{2\sqrt{2}}}^{\frac{a}{2\sqrt{2}}} \\
&= \frac{2t\sqrt{2}}{3} \left(\frac{a^3}{16\sqrt{2}} - \frac{-a^3}{16\sqrt{2}} \right) \\
&= \frac{2t\sqrt{2}}{3} \left(\frac{a^3}{8\sqrt{2}} \right) \\
&= \frac{ta^3}{12}
\end{aligned}$$

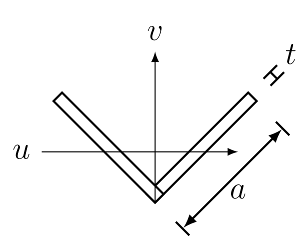

Figure 6: Second Moment of Area for Angle Section

For $a = \frac{3}{4}$" and $t = \frac{1}{16}$", $I = 9.15 \times 10^{-10}$ m^4.

Standard values for the density and Young Modulus of aluminium are used, $\rho = 2,700$kg/m, $E = 69 \times 10^9$GPa.

B.2 Flexural Rigidity

A simple test of a beam's rigidity is its deflection under self weight when mounted as a horizontal cantilever. For a horizontal cantilever of length L with distributed loading w kg/m, the deflection is:

$$\delta = \frac{wL^4}{8EI}$$

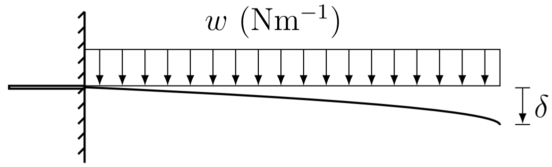

Figure 7: Horizontal cantilever deflection due to self weight

Applying a loading of 1.60 N/m for the weight of aluminium and 0.374 N/m for the LEDs, we get a deflection of $\delta = 0.153$ m.

B.3 Columnar Buckling

Slender columns under a compressive load will tend to fail by buckling rather than crushing. The standard formula for the maximum load (applied at the tip of the column) due to Euler buckling is:

$$F_{\text{crit}} = \frac{\pi^2 EI}{(KL)^2}$$

(KL) is the effective length, determined by boundary conditions. Our column is a vertical cantilever, which implies a correction of $K = 2$. The maximum load of our column is $F_{\text{crit}} = 24.9$ N, or 2.54 kg.

The total weight of the aluminium and LEDs is far less than 2.54 kg and the self-weight loading is distributed rather than applied at the tip, so there is no risk of buckling under self weight.

B.4 Wind Loading

Wind loading upon the poles can be modelled as a vertical cantilever subject to lateral uniform distributed loading. The loading depends on the wind speed and lateral cross sectional area of the pole. At 13.4 m/s (30 mph), loading is 119 N/m^2, and at 17.9 m/s (40 mph), loading is 268 N/m^2. The maximum lateral cross sectional area of the pole is 0.0674 m^2.

Using the formula above for deflection of a cantilever under uniform distributed loading, we find that 30 mph and 40 mph winds give deflection of 0.248 m and 0.559 m respectively.

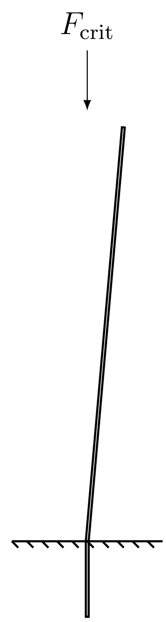

Figure 8: Euler buckling of pole

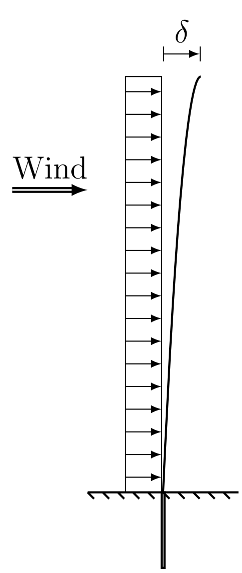

Figure 9: Wind loading on pole

C Electronics Schematic

D Cable layout

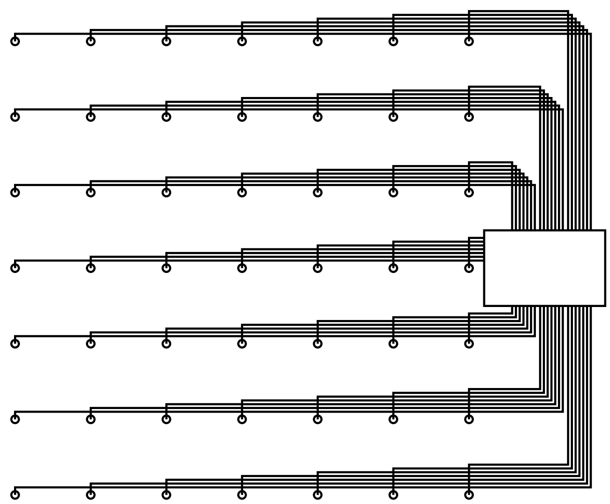

Figure 10: Power/control cable routing

E Electrical Design Verification

E.1 Power and Current Consumption

Power consumption of LED strip varies, but is generally quoted as around 5 – 7 W/m. For 49 poles, this gives a total peak power consumption of about 600 W to 900 W. Using Ohm's Law and the definition of electrical power:

$$V = IR$$

$$P = VI$$

and using 900 W as a worst case, the total current flow in THE·GRID is about 75 A at 12 V DC, although no single conductor carries the entire current.

E.2 Cabling Resistance and Voltage Drop

Cabling between the control tent and poles will be 2-core cable with an area of 0.5mm^2, or 5×10^{-7} m^2 per conductor. The resistivity of copper is 1.68×10^{-8} Ωm at room temperature. With a maximum cable length of around 20 m the total conductor length is 40 m, giving a resistance of 1.34 Ω. With a current of 1.46 A per pole, this gives a voltage drop of 1.96 V.

E.3 Cabling Self-heating

With a resistance of 0.0336 Ω/m and a current of 1.46 A, the power dissipated in a conductor will be:

$$\begin{aligned} P &= I^2 R \\ &= 71.6 \text{ mW/m} \end{aligned}$$

F Prototype Pole