Thoughts on the Mani Project

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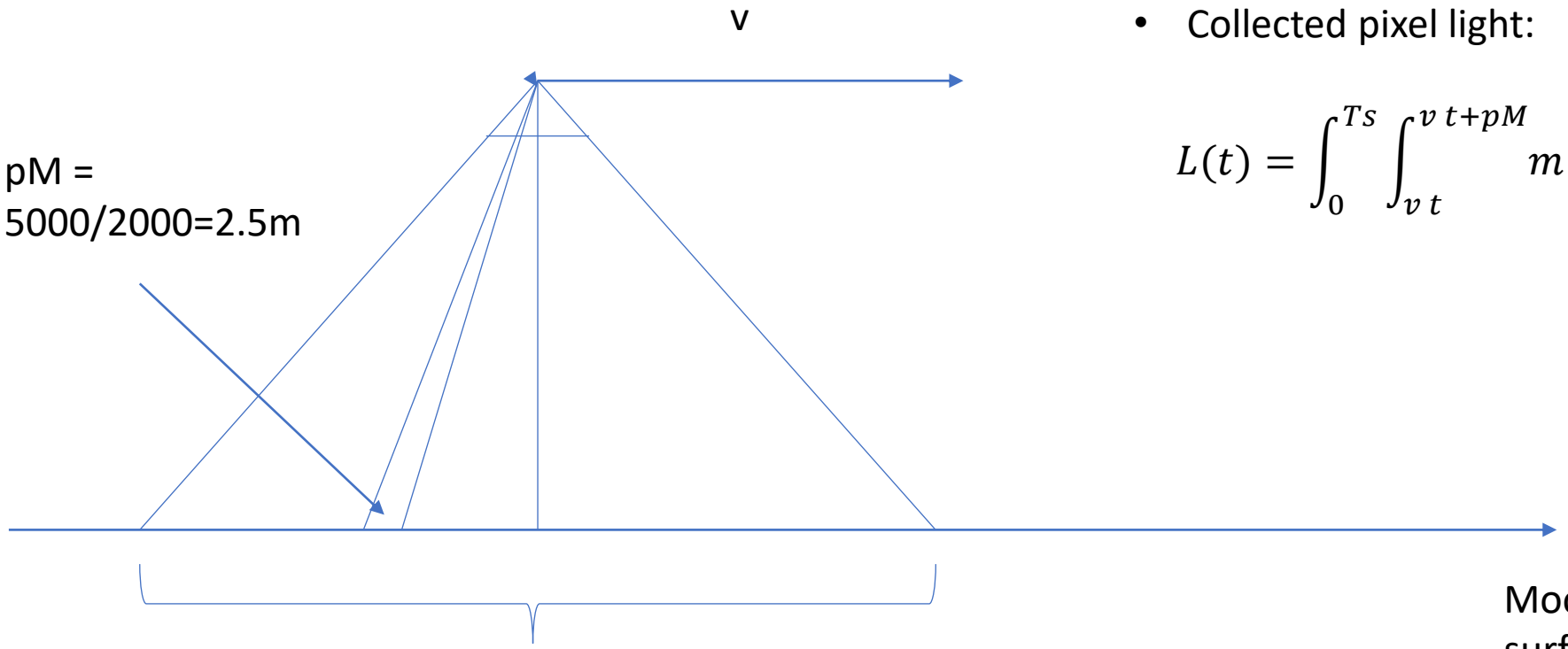
Example settings

- Camera
  - 2k X 2k pixels
  - Focal length 100mm
  - Shutter speed Ts=1mS
  - CCD dimensions: d X d = 1cm X 1cm

- Orbit
  - Altitude h = 50km
  - Orbital period: $T = 2\pi\sqrt{\frac{(50e3+1738e3)^3}{\mu=5e12}} \sim 111\ min$
  - Orbital speed: v = $2\pi\frac{1738e3}{T} = 1.6e3\frac{m}{s}$
  - Moon surface speed: 2π $1738e3$ / 27 / 24 / 60 / 60 = 4.7 m/s (negl)

Pixel input



- Moon surface light intensity: m(x)
- Collected pixel light:

$$L(t) = \int_0^{Ts} \int_{v\,t}^{v\,t+pM} m(x)\,dx\,dt$$

Pixel collected light

$$L(t) = \int_{t}^{t+Ts} \int_{v\,t\prime}^{v\,t\prime+pM} m(x)\,dx\,dt' =$$

$$\int \delta_{Ts}(t'-t) \int \delta_{pM}(x-vt')\,m(x)\,dx\,dt' =$$

$$\int m(x) \int \delta_{pM}(x-vt')\,\delta_{Ts}(t'-t)\,dt'\,dx$$

$$\delta_{pM}(x) = I_{0\leq x\leq pM}$$

$$\delta_{Ts}(t) = I_{0\leq t\leq Ts}$$

Pixel collected light

$$\int m(x) \int \delta_{pM}(x - vt')\, \delta_{Ts}(t' - t)\, dt'\, dx$$

$$\delta_{pM}(x) = I_{0 \le x \le pM}$$

$$\delta_{Ts}(t) = I_{0 \le t \le Ts}$$

$$\int \delta_{pM}(x - vt')\, \delta_{Ts}(t' - t) dt' \sim \delta_{pM + Ts\, v}(x - vt)$$

$$Ts\ v = 1e - 3\ * 1.6\ e3 = 1.6\ m$$

$$pM + Ts\ v = 2.5 + 1.6 = 4.1\ m$$

Fast sampling

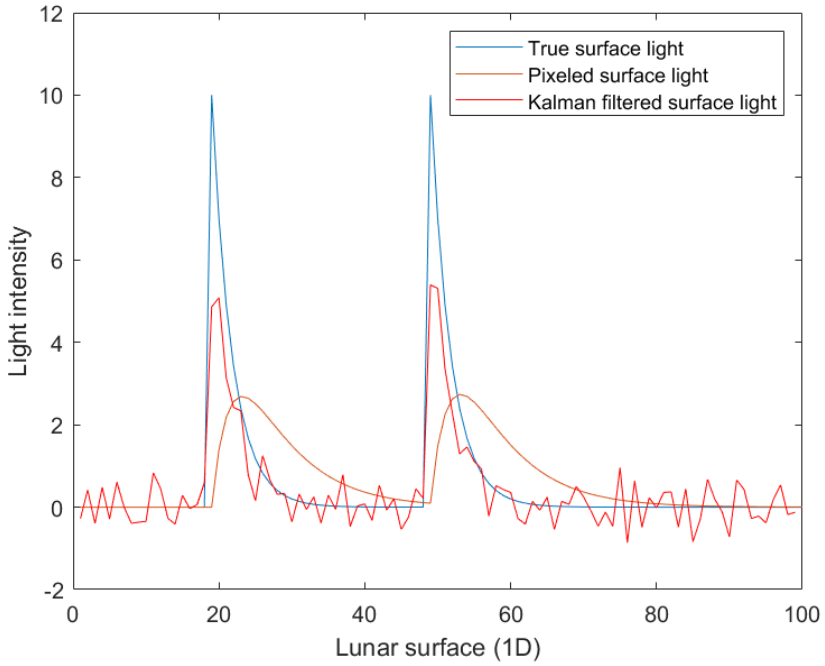
- Let Ts = 1e-4
- $pM + Ts\ v\ \sim pM = \ 2.5m$
- We sample m(x) each xS =16cm
- Each sample is $s(x) = k * \sum_{x'=x}^{x+2.5} m(x) = \frac{1}{16} * \sum_{x'=x+0*0.16}^{x+15*0.16} m(x)$
- $a^{16} = 0.1 \Rightarrow 16\log(a) = \log(0.1) \Rightarrow \log(a) = \frac{\log(0.1)}{16} \Rightarrow$
- $a = \exp\left(\frac{\log(0.1)}{16}\right) = 0.866$
- Equivalent IIR filer (1. ord AR):

$$s(x - 0.16) = a\ s(x) + (1 - a)\ m(x)$$

Kalman filtering

- $s(n+1) = a\, s(n) + (1-a)\, m(n)$ (Pixeled and blurred surface light)
- $m(n+1) = b\, m(n) + \varepsilon(n), \quad 0 \leq b < a$ (True surface light)

- $x(n) = \begin{bmatrix} m(n) \\ s(n) \end{bmatrix}$
- $x(n+1) = \begin{bmatrix} b & 0 \\ 1-a & a \end{bmatrix}$
- $y(n) = C\, x(n) = [0\ 1]\, x(n)$



ADCS

- Pointing accuracy: 0.1 grad = 0.0017 rad
- Pointing accuracy on lunar surface 0.0017*50e3 = 87 m !!

- IMU gyroscope precision 1e-3 grad/h = 5e-9 rad/sek
- Gyroscope on lunar surface: 2.4e-4 m (negl)

- What about lunar satellite positioning ??