

1 Structured Light Coding

Some relevant reviews are [1].

1.1 Horn & Kiryati

One of early study of optimal structured light coding [2] generalizes Gray Code [3]. The authors draw inspirations from communication theory, where the projector projects unique temporal codes, received at each image plane through a noisy channel and subsequently decoded. Let there be K patterns and L code words, we want to encode $x \in [1 : L]$, the indices of vertical light planes, using some encoding scheme $f : [1 : L] \rightarrow \mathbb{R}^K$ such that nearest neighbor decoding $\hat{x}(y) = \arg \min_{x \in [1:L]} (f(x) - y)$ of a normalized noisy observation $y \in \mathbb{R}^K$ minimizes the probability of depth estimation error. In particular for the following forward model

$$\begin{aligned} y &= f(x) + n & \text{where} & & x &\sim \text{Cat}(1/L) \\ & & & & n &\sim p_n \\ & & & & y|x &\sim p_n(y - f(x)) \end{aligned}$$

We want to solve the following optimization problem,

$$\begin{aligned} \text{minimize}_f \quad \mathbb{P}(\text{depth estimation error}) &= \mathbb{E}_{x,y} [(x - \hat{x}(y))^2] \\ &= \sum_{x=1}^L p_x(x) \int p_{y|x}(y|x) (x - \hat{x}(y))^2 dy \\ &\propto \sum_{x=1}^L \int (x - \hat{x}(y))^2 p_n(y - f(x)) dy \end{aligned}$$

The paper suggest the use of space filling curves as the encoding function and established that Gray code is a special limiting case of the space filling curve. Note here we assume there is no *mutual illumination*, i.e. there is no interval reflection and so the projected codes $f(x)$ is proportional to observation y .

References

- [1] Joaquim Salvi, Jordi Pagès, and Joan Batlle. “Pattern codification strategies in structured light systems”. In: *Pattern Recognition. Agent Based Computer Vision* 37.4 (Apr. 1, 2004), pp. 827–849. ISSN: 0031-3203. DOI: [10.1016/j.patcog.2003.10.002](https://doi.org/10.1016/j.patcog.2003.10.002). URL: <http://www.sciencedirect.com/science/article/pii/S0031320303003303> (visited on 07/19/2019).
- [2] E. Horn and N. Kiryati. “Toward optimal structured light patterns”. In: *Proceedings. International Conference on Recent Advances in 3-D Digital Imaging and Modeling (Cat. No.97TB100134)*. Proceedings. International Conference on Recent Advances in 3-D Digital Imaging and Modeling (Cat. No.97TB100134). ISSN: null. May 1997, pp. 28–35. DOI: [10.1109/IM.1997.603845](https://doi.org/10.1109/IM.1997.603845).
- [3] K. Sato and Seiji Inokuchi. “Three-dimensional surface measurement by space encoding range imaging”. In: 1985.