Time Delay Estimation in Gravitationally Lensed Photon Stream Pairs

Michał Staniaszek
Supervisor: Peter Tiňo

June 20, 2013

this is the abstract

1 Introduction

- explain the project in layman's terms

2 Background

- Ideas behind the project
- what it's useful for
- what gravitational lensing and time delay are

3 Photon Stream Simulation

In the early stages of the project, we developed a subsystem which could be used to generate simulated photon stream data to use for the development and testing of the rest of the project. The only property of the photons which we are interested in is their arrival time at our capture device, so the simulator should produce some vector $\Phi = [\phi_0, \ldots, \phi_N]\,, \phi_n \in \mathbb{R}$, where ϕ_n is the arrival time of the nth photon. In order to generate arrival times, we represent the source as some random variable X, which defines the average number of photons per unit time that arrive at the capture device.

The behaviour of X is modelled as a non-homogeneous Poisson process (NHPP) with continuous rate function $\lambda(t)$, where t is some point in time. The rate function can be specified either by providing an expression which is a function of t, or by sampling from a randomly generated function. Random functions are constructed by uniformly distributing M Gaussians across the interval $[t_0, T]$ in which arrival times are to be generated. Each Gaussian g_i is defined by its mean μ_i, its width σ_i, and its weight w_i, which determines its height. The means of successive Gaussians are separated by some distance Δt, such that $\mu_{m+1} = \mu_m + \Delta t,$ where $\mu_0 = 0$. Greater variation in the functions is introduced by sampling the weights w_i from a uniform distribution $U(-1, 1)$ and scaling them by some multiplier. A weighted sum of Gaussians

$$f(t) = \sum_{i=0}^{M} w_i \cdot e^{-(t-\mu_i)^2/2\sigma_i^2} \tag{1}$$

is used to compute the value of the randomly generated function f at some point t by summing the values of all Gaussians at that point.

Thus, the simulator creates a very simple model of a source object from which to generate photon arrival times.

Having defined or constructed $\lambda(t)$, we generate photon arrival times by thinning arrival times generated with inverse transform sampling.

4 Function Estimation

- Basic explanation of the IWLS estimator
- slightly more in-depth stuff for the development of our estimators

5 Time Delay Estimation

5.1 PDF Method

5.2 Area Method

6 Experimental Results

- general explanation of the experiments performed
- how was model selection done
- what sort of data were experiments performed on

7 System

- very brief explanation of the system features

8 Conclusion

- some suggestions for extensions