An Autonomous Adaptive Scheduling Agent for Period Searching

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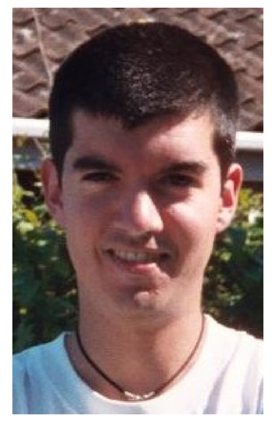

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Abstract

What is the best way to practically observe undersampled, periodic, time-varying phenomena using a network of robotic telescopes? We implement an autonomous software agent that uses an optimal geometric sampling technique to cover the period range of interest, but additionally implements proactive behaviour that maximises the optimality of the dataset in the face of an uncertain and changing operating environment. The agent has been successfully demonstrated using the three 2m robotic Faulkes North, Faulkes South, and Liverpool Telescopes.

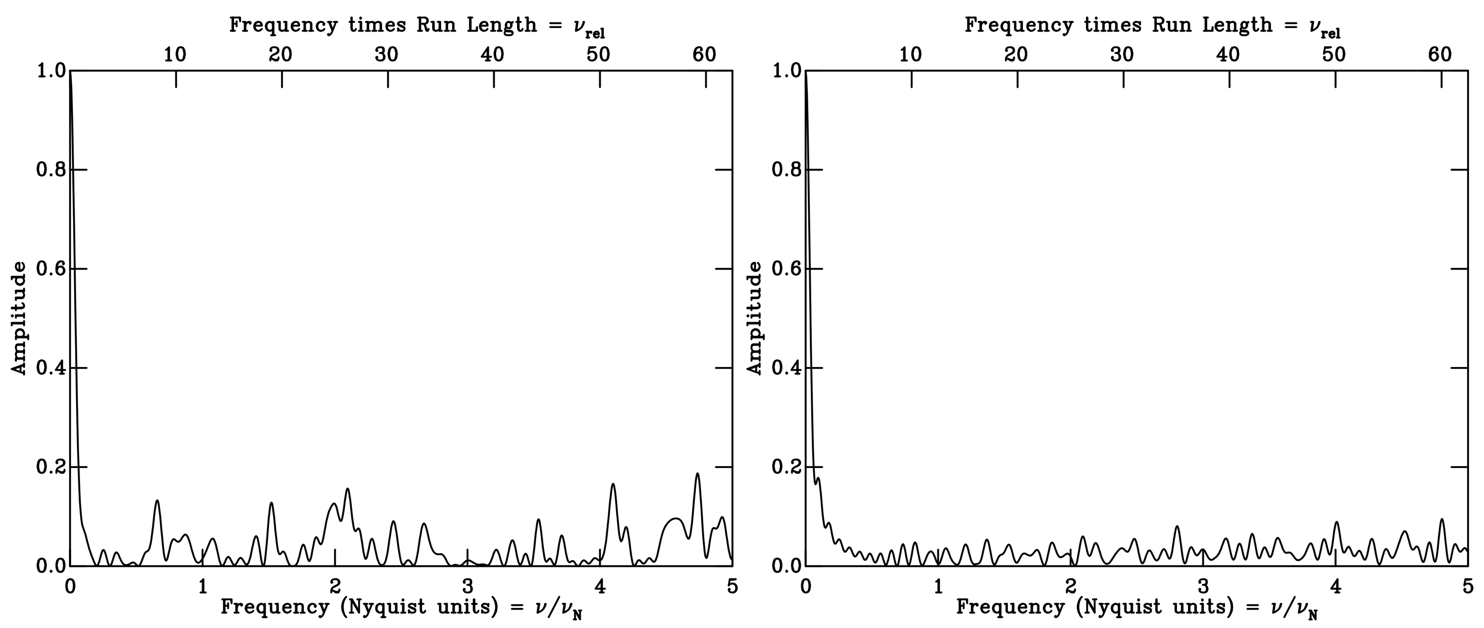
The Problem

Imagine a classic time-domain problem: a survey of variability in star-forming regions. Especially in the youngest clusters, a large fraction of the cluster members are T-Tauri stars that can exhibit significant variability due to rotational modulation of features at the stellar surface. However the range of periods among cluster members is large, ranging from a few hours to many days. Additionally, aliasing, particularly as a consequence of diurnal sampling, is usually a problem for data obtained in the "classical paradigm", where an on-site observer performs observations using a single telescope.

A robotic network spread across longitude can break this aliasing pattern, but datasets are typically undersampled with respect to shorter periods in the range of interest. Given this limited number of observations, *when* should the observations be made to maximise this alias breaking?

Optimal Sampling

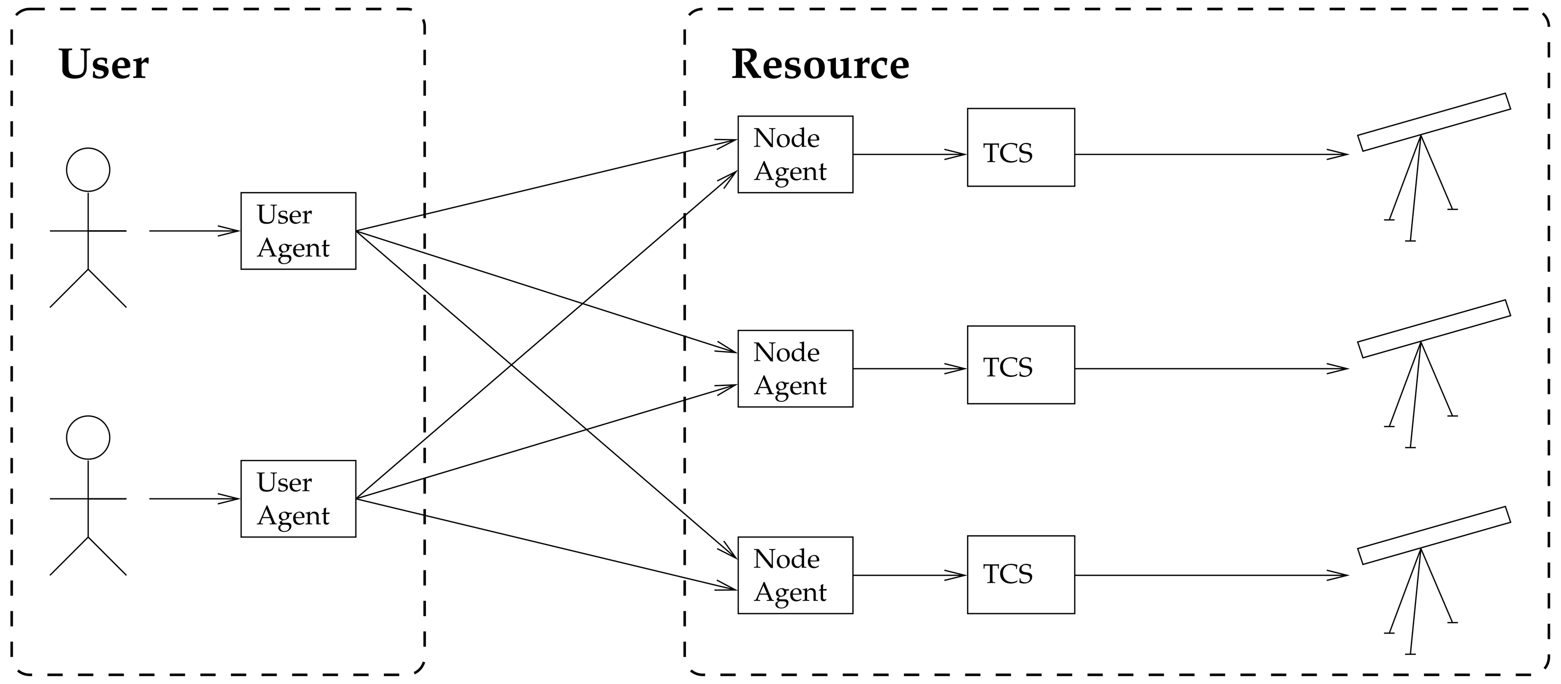
Given a limited number of observations, the optimal geometric sampling technique determines the best time to make individual observations in order to achieve similar sensitivity to periods across the full range of interest.



The two plots above show the window functions for a set of observations randomly placed in time (*left*), and a set of observations placed according to the optimal sampling scheme described in Saunders et al. (2006) (*right*). Structure arising from the choice of timestamp is clearly reduced by a correct choice of sampling times. Of particular importance is the property that as long as the set of gaps between observations remains unchanged, observations may be arbitrarily reordered (Saunders et al., 2006). In practice, this property is fully exploited by the adaptive algorithm to react to unpredictable events such as weather and telescope downtime.

The eSTAR Project

The eSTAR project[1] (Allan et al., 2004, 2008) is an agent-based software system that aims to establish an intelligent robotic telescope network for efficient and automated observing. The system comprises *user agents* that run an observing programme on behalf of an astronomer, and *embedded agents* that provide the interface to observational resources such as telescopes.

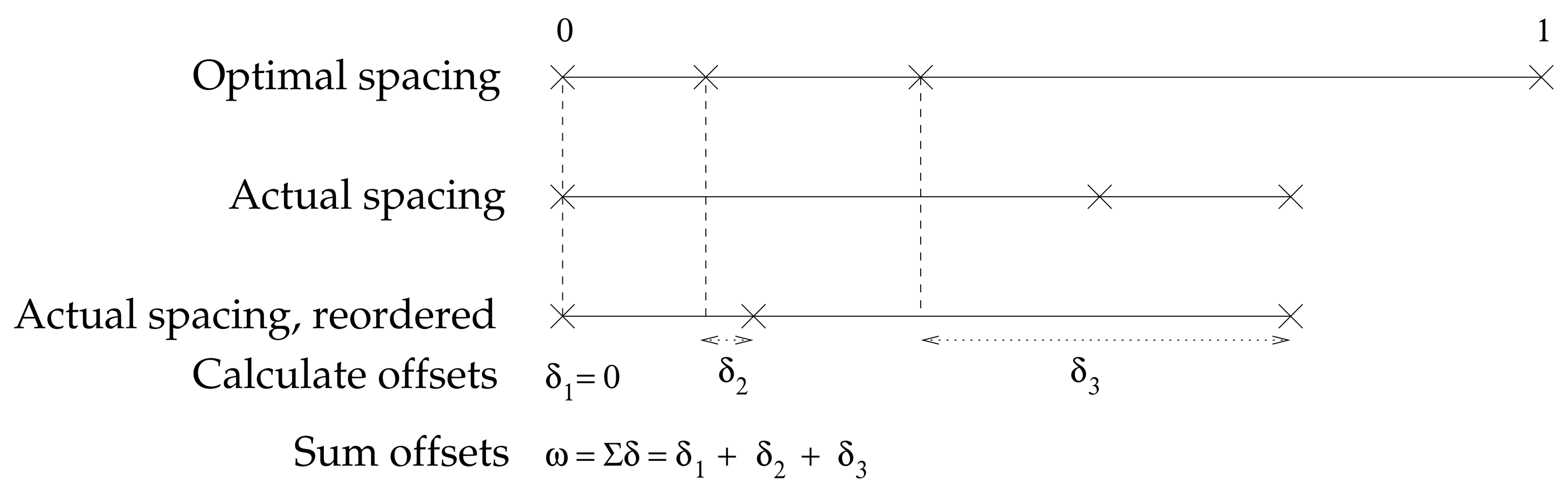


The observing process follows the HTN[2] protocol (Allan et al., 2006), which has three basic steps:

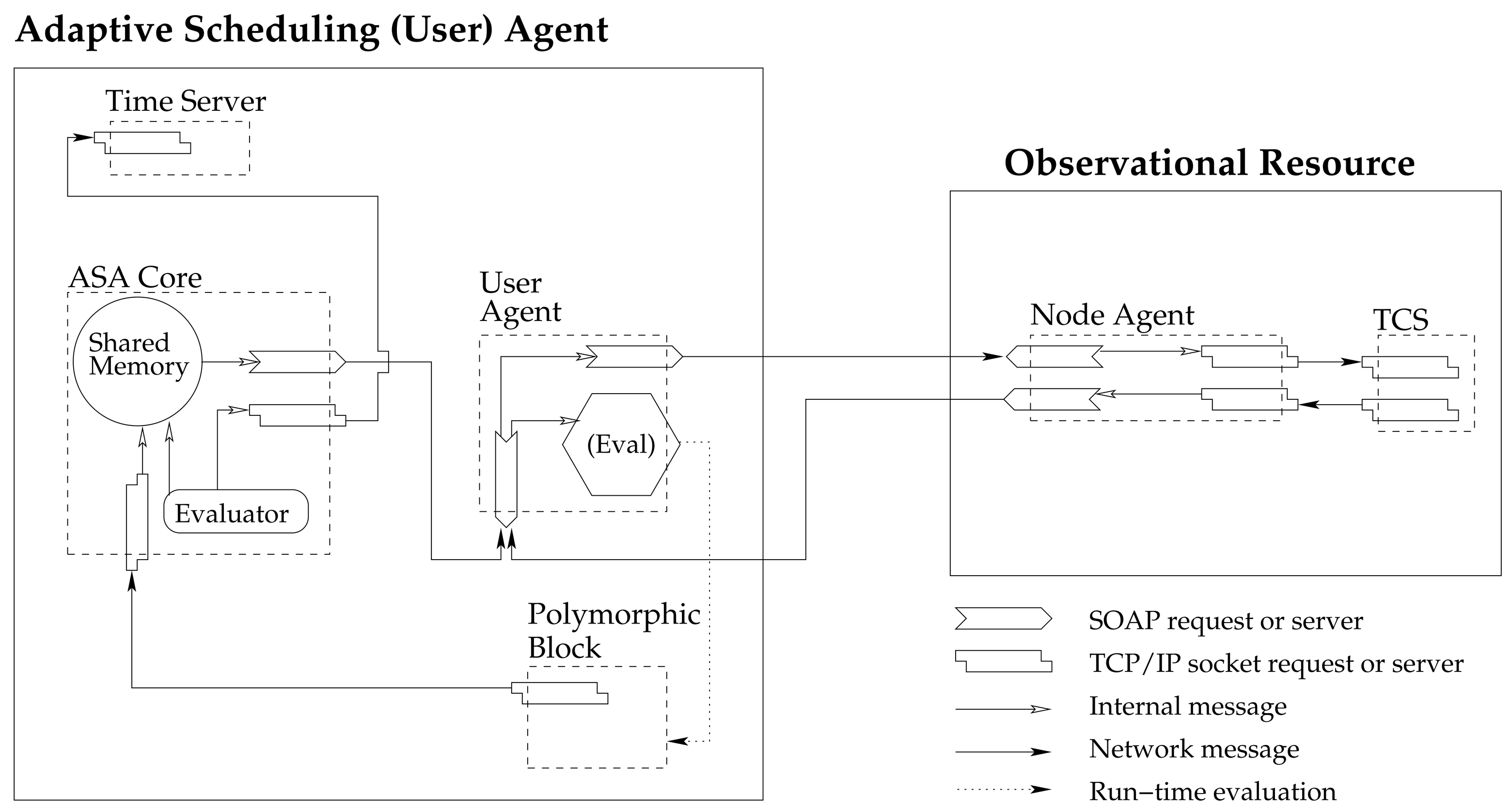
1. **The user agent requests a score from the node agent at each telescope for a future observation.** A score is a kind of probability of success: A high score indicates the telescope believes the observation is likely to succeed, while a score of 0 indicates the request will certainly fail.
2. **The user agent submits the observation request to the highest scoring telescope.** The observation is queued at the telescope by the dispatch scheduler for that telescope.
3. **At the requested time, the observation either succeeds or fails.** The node agent reports the status of the observation to the user agent, which can use this information to choose the position of the next observation in the time series.

An Adaptive Algorithm

The agent implements an adaptive algorithm which determines the optimality of the series for a range of possible future timestamps. The optimality of the time series is a function of the set of gaps between observations. The existing gaps are used to determine the best subsequent point to minimise structure in the window function. By calculating this value dynamically as each observation is processed, the agent is able to respond flexibly to the actual conditions at the telescope. Full details are presented in Saunders et al. (2008).



The internal architecture of the adaptive scheduling agent is depicted in the diagram below. A multi-threaded core implements the adaptive evaluation engine. Requests are made using a web service submission mechanism, while a TCP/IP socket connection listens for observation feedback information. Date/time information is abstracted by a time server, which can be accelerated to allow fast simulations to be performed. RTML[3] (Pennypacker et al., 2002; Hessman, 2006) document construction and HTN protocol negotiations are handled by a user agent web service running on the local machine. Asynchronous messages tigger a response from the agent core, allowing the agent to receive observation feedback as the run progresses.



Results

To prove the concept, the agent was given autonomous control of an observing run of a periodic variable with a well known period. The agent successfully improved the quality of the time series compared to a control run of fixed positions that was run concurrently. For full details, see the forthcoming paper of Saunders et al. (2008), or the detailed discussion in Saunders (2008).

References

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[1] www.estar.org.uk
[2] Heterogeneous Telescope Networks: www.telescope-networks.org
[3] Robotic Telescope Markup Language