[p4] Optimal algorithm to determine pointing centers for PFS open-use programs

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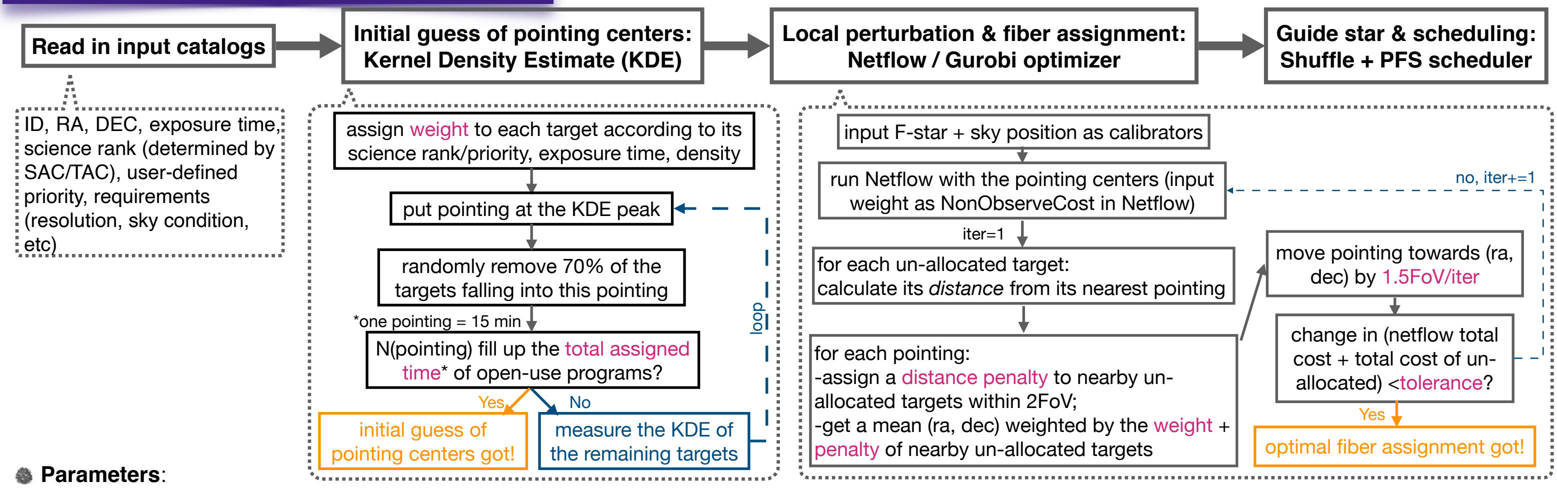
Introduction

Subaru Prime Focus Spectrograph (PFS) is a fiber-fed multiplex system, which enables acquisition of around 2400 spectra of objects simultaneously over a wide hexagonal field of 1.38 deg on the sky. Its innovative features are expected to help make great improvements in various science fields.

- **Operation Strategy**: to **share fibers among multiple open-use programs** in order to efficiently utilize all the fibers
- **Problem**: where to point the telescope?
  - **targets** from different programs can **vary significantly in spatial density/distribution, required exposure time, science priority,** etc
- In this project, we are going to develop an **"optimal" tiling algorithm for PFS open-use programs**:
  - to achieve high completeness in rank-A (highest science rank) samples
  - to maximize fiber allocation efficiency in each exposure (minimize wasted time)

PFS pointing Planner: a general flow-chart



Read in input catalogs

ID, RA, DEC, exposure time, science rank (determined by SAC/TAC), user-defined priority, requirements (resolution, sky condition, etc)

Initial guess of pointing centers: Kernel Density Estimate (KDE)

assign weight to each target according to its science rank/priority, exposure time, density

put pointing at the KDE peak

randomly remove 70% of the targets falling into this pointing

*one pointing = 15 min

N(pointing) fill up the total assigned time* of open-use programs?

Yes: initial guess of pointing centers got!

No: measure the KDE of the remaining targets

loop

Local perturbation & fiber assignment: Netflow / Gurobi optimizer

input F-star + sky position as calibrators

run Netflow with the pointing centers (input weight as NonObserveCost in Netflow)

iter=1

for each un-allocated target: calculate its *distance* from its nearest pointing

for each pointing:
-assign a distance penalty to nearby un-allocated targets within 2FoV;
-get a mean (ra, dec) weighted by the weight + penalty of nearby un-allocated targets

move pointing towards (ra, dec) by 1.5FoV/iter

change in (netflow total cost + total cost of un-allocated) <tolerance?

no, iter+=1

Yes: optimal fiber assignment got!

Guide star & scheduling: Shuffle + PFS scheduler

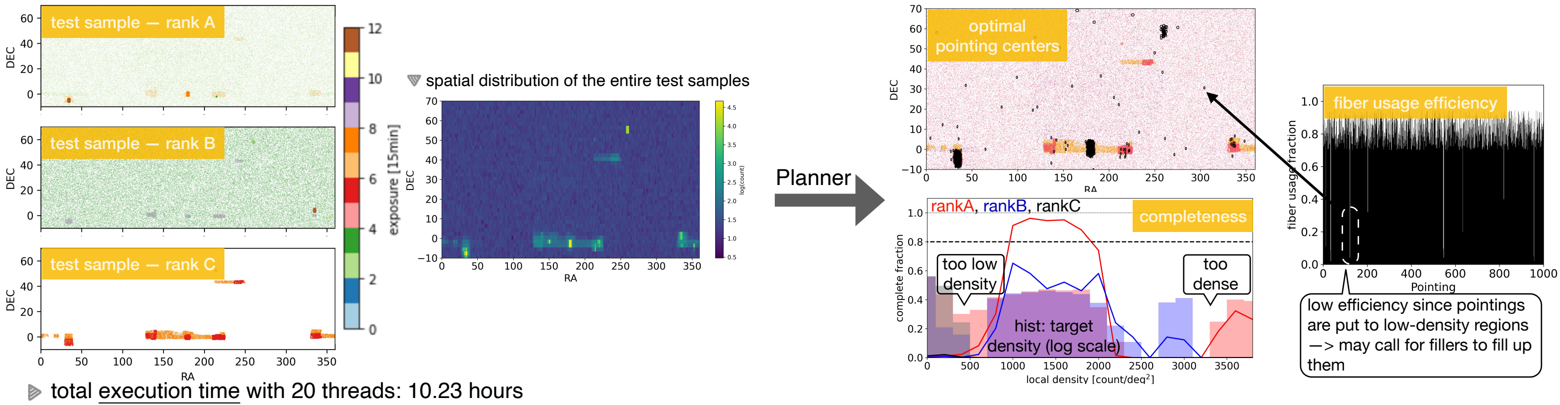
- **Parameters**:
  - total time allocated to open-use programs —> determined by SAC/TAC
  - weight: give **higher** weights to samples with **rank A** (highest science rank)**;** additional weights might be added to samples with shorter exposure time and higher local density (finish samples requiring short exposure time as soon as possible)

W1	**science rank**	**Rank A - P=3; Rank B - P=2; Rank C - P=1**	**W1=pow(a, P)**
W2	**exposure**	**N(exposure frame)**	**W2=pow(N, b)**
W3	**local density**	**N(target) in FoV**	**W3=pow(N, c)**

  - distance penalty: give **larger** penalty to targets **far** away from the pointing center —> prevent moving pointing too far away from its initial guess
  - combination between weight and distance penalty, moving step, tolerance, PA of each pointing, etc. —> optimizing all the parameters is still in progress…
- **Outputs**: pointing list + fiber assignment in each pointing

Simulation test: an example

- simulate 1000 pointings (one pointing=15min) over a set of test samples (weight scheme: a=10, b=-0.2, c=0)



low efficiency since pointings are put to low-density regions —> may call for fillers to fill up them

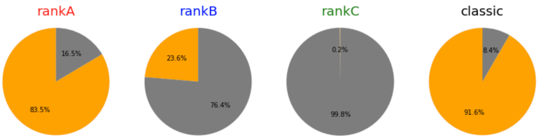
- total execution time with 20 threads: 10.23 hours
- complete fraction: **rank-A samples** in a proper range of spatial density can **achieve a completeness of >90%**
  - due to the fixed density of fibers (2394/FoV), samples with too-low or too-high density are hard to achieve a high completeness within the allocated time
  - PFS (queue mode) might not be suitable for isolated samples with too-low density or too-dense samples
- fiber usage efficiency: **72.2%** fibers are used on average

PFS pointing Planner: online version

- a **simplified version** of Planner can be provided to help users get an idea of expected completeness of their science samples
  - **one example:** user's science sample —> ~1900 per sq.deg, covering ~4 sq.deg, request 1 hour per target

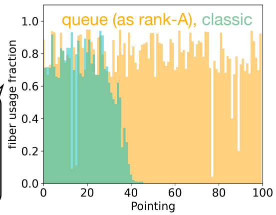
output: expected completeness if the user get rankA/rankB/rankC score in the queue mode or 5 nights (maximum for one program) in the classic mode

orange fraction: completed fraction



if user can get rank-A, the expected completeness can be as good as that got by the classic mode

usage of fibers is more efficient in the queue mode than the classic mode



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