[P02] PFS Pointing Planner (PPP): optimal tiling algorithm for PFS open-use programs

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Introduction

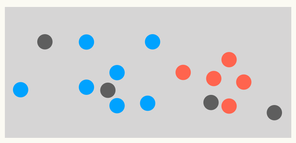
Subaru Prime Focus Spectrograph (PFS) is a fiber-fed multiplex system, which enables acquisition of around 2000 spectra of science objects simultaneously over a wide hexagonal field of 1.38 deg on the sky. Its innovative features are expected to help make great improvements in various science fields.

- to efficiently utilize all fibers, it plans to **share fibers** among multiple open-use programs
- Problem: **WHERE TO POINT the TELESCOPE?** —> different programs can have **different science priority, spatial density/distribution, exposure time,** etc.
- In this project, we develop **PFS Pointing Planner (PPP)** to **optimize pointing centers** for **PFS open-use programs.** It enables**:**
  - to achieve **high completion rate** for accepted programs, while keeping **high fiber usage fraction** in each pointing
  - to connect with **queue Planner** to optimize **scheduling** of pointings considering their **visibility and total priority**

PFS pointing Planner: a general flow-chart

Target DB — read accepted programs

ID, RA, DEC, exposure time, science grade (determined by SAC/TAC), inner priority (defined by PI), requirements (e.g., resolution)…



STEP1: Determine initial tiling pattern

assign **weight** to each target

*one pointing = 15 min

put pointing at the **Kernel Density Estimate (KDE) peak**

No, loop for the next **KDE peak**

achieve the **requirements**?

*e.g., average completion rate>80%

Yes

run Netflow with all the pointings

*weight is regarded as the cost of each target

estimate fiber assignment of targets

*use $U = T_{\mathrm{miss}} + T_{\mathrm{waste}}$

*incompletion rate:

$$T_{\mathrm{miss}} = \frac{1}{n(\mathrm{targets})} \sum_{i}^{\mathrm{target}} [(T_{i,\mathrm{request}} - T_{i,\mathrm{done}})/T_{i,\mathrm{request}}]$$

*un-used fiber fraction:

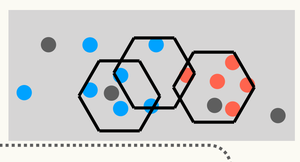
$$T_{\mathrm{waste}} = \frac{1}{n(\mathrm{point})} \sum_{i}^{\mathrm{point}} [n_{i,\mathrm{blank-fiber}}/2394]$$

minimal U?

Yes

INITIAL Pointing centers determined!

No, loop over different **weight**

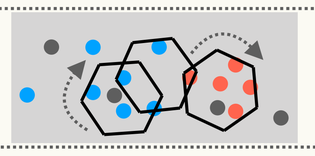


weight scheme

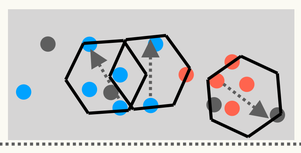
-higher weights given to Grade A programs

W1	Science grade	P1= 3 (grade A) or 2 (grade B)	W1=pow(a, P1+0.1*P2) initial guess: a=10
	internal user priority	P2= 0 (lowest) - 9 (highest)	
W2	requested exposure frame (e.g., 1 hour=4 frames)	N(exp)	W2=pow(N, b), initial guess: b=-0.1
W3	count of all targets in one FoV	N(target)	W3=pow(N, c) initial guess: c=-0.1
Final	have been already partially observed?	P3=1.5 (yes) or 1 (no)	P3*W1*W2*W3

STEP2: Optimize tiling pattern



or



separate pointings into different groups by clustering algorithm

*linking length = 1.38 deg (diameter of FoV)

For each group: optimize **PA** of pointings

For each group: **locally perturb** pointings to search for optimal solution

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

move the pointings towards (ra, dec)

run Netflow with new pointing centers

estimate fiber assignment of all targets

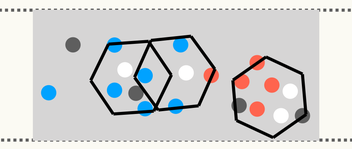
minimal U?

Yes

FINAL Pointing centers determined!

No, loop for the next **perturbation**

STEP3: Add fillers, F-stars, sky positions

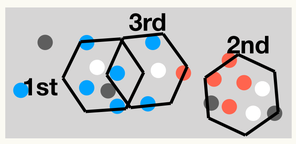


pick up pointings with fiber usage fraction <80%

add fillers with weight = 0.5*min(cost of accepted targets)

STEP4: Schedule pointings across the semester (Queue Planner)

visibility, total priority of pointings considered



YYYY/MM/DD xx:xx 1st
YYYY/MM/DD xx:xx 2nd
YYYY/MM/DD xx:xx 3rd
…

Final PFSdesign files

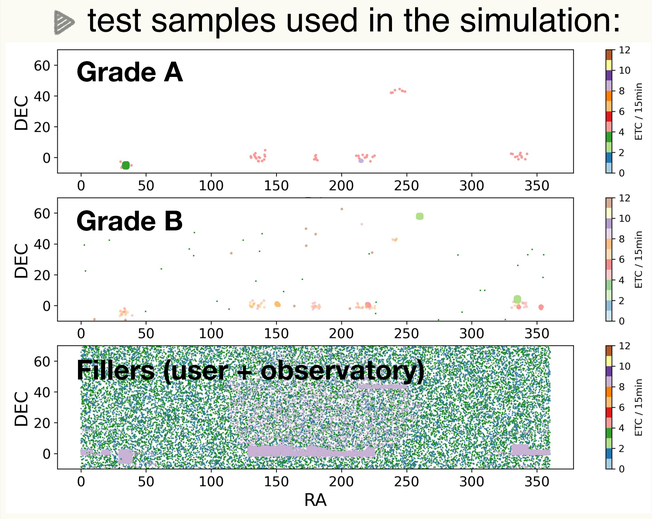
PPP: simulation results

PPP would optimize pointing centers for the whole semester

- **INPUT**: accepted programs; **requirements**
- **OUTPUT**:
  - final tiling pattern (incl. the **total number, center and PA** of pointings), **fiber assignment** of targets, **schedule** of pointings
  - format of output:

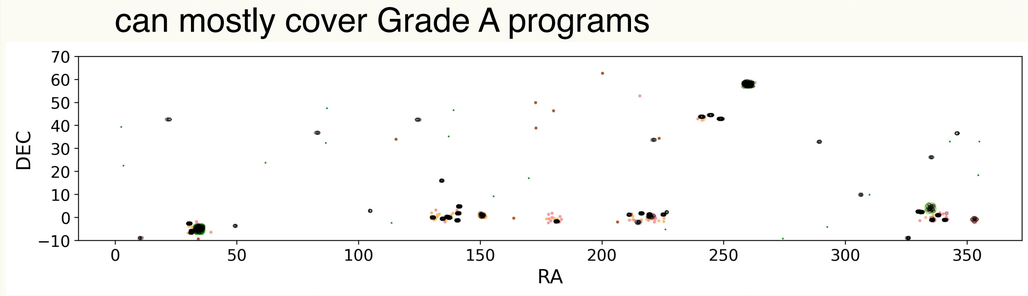
```
# point_1, center_ra1, center_dec1, PA1, obs_time1
fiber_1, obj_ID, obj_ra, obj_dec, grade, weight_final,…
…
# point_2, center_ra2, center_dec2, PA2, obs_time2
fiber_1, obj_ID, obj_ra, obj_dec, grade, weight_final,…
…
```

- We run simulation with PPP by
  - requiring **Grade A completion>90% & Grade B>65%**
  - test samples used in the simulation:

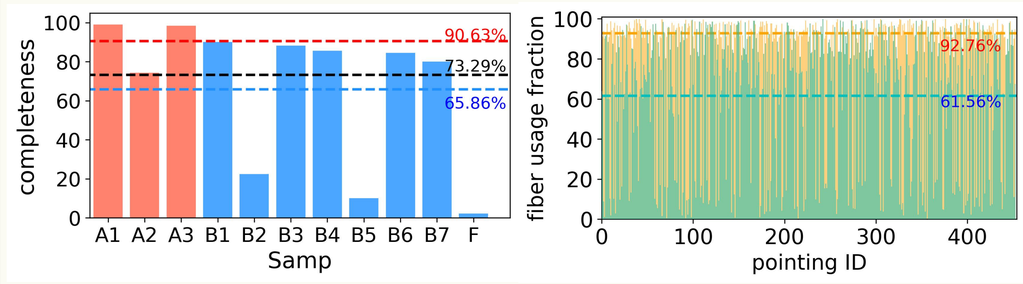


	type	count	N_exp
A1	galaxy	8500	9
A3	star	4500	4
A2	**QSO**	**35**	**5**
B1	galaxy	1500	6
B2	**galaxy**	**40**	**3**
B3	star	8000	5
B4	star	10320	3
B5	**QSO**	**10**	**12**
B6	cluster	20000	6
B7	cluster	10000	8

  - PPP outputs (execution time~15 hours):
    - ✻ **453 pointings** (453*15min~113 hours) are required, they can mostly cover Grade A programs



    - ✻ on average, the set requirement on **completion rate can be achieved**
      - ✻ for low-density programs
        - ✻ if Grade A (e.g., A2) —> able to complete >70%
        - ✻ elif Grade B (e.g., B2/5) —> hard to get high completion rate as targeting at them will highly reduce the fiber usage fraction



    - ✻ on average, the **fiber usage fraction can reach 60%** (Cyan histograms);
      - ✻ blank fibers can be assigned to fillers; after adding fillers, the fiber usage fraction can reach >90% (orange histograms)

PPP:online tool

A simplified version of PPP will be provided to help users get an idea of expected completion rate of their science programs

- users need to upload their science programs with RA, DEC, inner priority and requested exposure time
- **What will this online tool do?**
  - to simulate if the user program is given **Grade A/B in the queue mode**, or assigned to the **classical mode**
  - completion rate & fiber usage fraction in each case will be provided