Improving Diversity and Preferred Assignment in Dickinson's First-Year Seminar Selection Process Using Optimization Models

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Introduction

- **Background:**
  Dickinson currently uses a process developed by Prof. Dick Forrester and Thanh To ('11) to assign students to First-Year Seminars (FYS) with the goal of assigning students to one of their top-ranked seminars while balancing the classes with regard to gender and the number of international students.

$$f_1(\mathbf{x}) = \text{Rank Value}$$

$$f_2(\boldsymbol{x}) = \sum_{k=1}^{m} (\text{MSEM}_k - \text{FSEM}_k)^2$$

= Gender Penalty

$$f_3(\boldsymbol{x}) = \sum_{k=1}^{m} (\text{USSEM}_k - \text{nonUSSEM}_k)^2$$

= Citizenship Penalty

Weighted Objective Approach:

$$\text{minimize} \sum_{i=1}^{3} w_i f_i(\boldsymbol{x})$$

- **Objective:**
  This study explores and develops enhanced methodologies for the FYS assignment process to outperform the current program and deliver more efficient and inclusive FYS assignments.

Reference

[1] Forrester, R., and K. Hutson, "Balancing Student and Faculty Preferences in the Assignment of First-Year Seminars," *Decision Sciences Journal of Innovative Education*, Vol. 12, 2014.
[2] Forrester, R., K. Hutson, and T. To. "Improving the Quality of the Assignment of Students to First-Year Seminars," *OR Insight*, Vol. 26, 2013.
[3] To, T. "Mathematical Techniques for Assigning First Year Seminars, *Honors Thesis*, 2011.

Methods

Linearization of Quadratic Objectives

METHOD 1

Minimize the total deviations arising from imbalances in gender and the number of international students.

- $\sum_{k=1}^{n} |MSEM_k - FSEM_k|$ = Gender Penalty.
- $\sum_{k=1}^{n} |USSEM_k - nonUSSEM_k|$ = Citizenship Penalty.

```
for k in SEMINARS:
    model.addConstr(w_gender[k] >= MSEM[k] - FSEM[k])
    model.addConstr(w_gender[k] >= FSEM[k] - MSEM[k])
for k in SEMINARS:
    model.addConstr(w_citizenship[k] >= US_SEM[k] - NonUS_SEM[k])
    model.addConstr(w_citizenship[k] >= NonUS_SEM[k] - US_SEM[k])
```

METHOD 2

Minimize the largest imbalances in gender and international student representation.

- $g \geq |MSEM_k - FSEM_k|$ where g represents the largest gender imbalance in FYS.
- $c \geq |USSEM_k - nonUSSEM_k|$ where c represents the largest imbalance in number of international students in FYS.

```
# Add constraints for Gender Penalty
for k in MSEM:
  # Minimize the Gender Penalty
  model.addConstr(gen_penalty[k] >= MSEM[k] - FSEM[k])
  model.addConstr(gen_penalty[k] >= FSEM[k] - MSEM[k])
  model.addConstr(g >= gen_penalty[k])
```

Model: Hierarchical Optimization

- This model orders multiple objectives based on the priorities of each objective and ensures objectives at higher priorities are optimized to a greater extent.

```
zU_Rank = model.getObjective().getValue()
model.addConstr(f_rank <= 0.999999999 * zU_Rank, "Rank")
model.addConstr(g <= 1.0000000001 * zU_Gender, "Gender")

model.setObjective(g, GRB.MINIMIZE)
model.optimize()
```

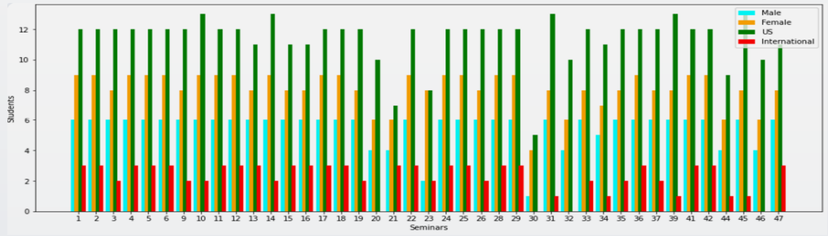
Results

Existing Dickinson FYS Assignment Program

Program run-time: Approximately 10 minutes

Assignment results:

- First-choice: 48.75%
- Second-choice: 29.39%
- Variance: 0.66% (gender); 0.75% (student type)



Hierarchical Implementation

Program runtime:
Approximately 1 second

Method 1 Assignment results:

- First-choice: 56.27%
- Second-choice: 28.67%
- Diversity Variance: 1.68% (gender); 38.1% (student type)

Method 2 Assignment results:

- First-choice: 56.27%
- Second-choice: 28.67%
- Diversity Variance: 0.94% (gender); 38.1% (student type)

Conclusion

- This study exemplifies how institutions can optimize course assignments while prioritizing diversity and inclusivity.
- Hierarchical optimization offers Dickinson more flexibility to adjust the assignment process in alignment with institutional objectives.
- The reduction in runtime enables the potential for adjustments and further optimization.
- **Future Work**: Integrate the current assignment model with the hierarchical optimization model to further increase efficiency.