Feature-Based Dynamic Matching

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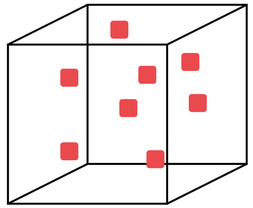
We study a dynamic matching problem in two-sided marketplaces with heterogeneous demand and supply

We assume a spatial structure on the type spaces and the matching quality functions.

Myopic policies like Greedy can result in highly sub-optimal performance

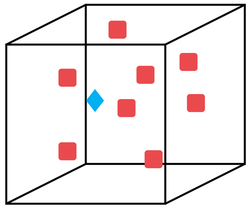
We design a simple and near-optimal simulation-based algorithm called SOAR

Model & Assumptions



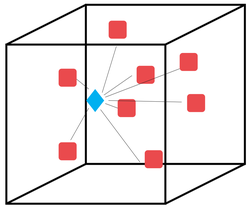
Platform has access to n supply units drawn i.i.d from Q

Each supply unit is a feature vector in a d-dimensional space

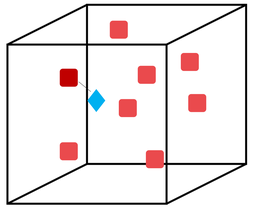


At time t, a demand unit drawn i.i.d from known P arrives

Each demand unit is a weight vector in a d-dimensional space

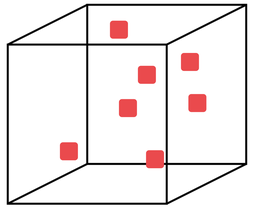


The platform must irrevocably match a demand unit to supply unit



The match quality is measured by quality function $\varphi(\blacklozenge,\blacksquare)$

Example of quality functions $\varphi(X,Y)=\langle X,Y\rangle, \varphi(X,Y)=-||X-Y||^p$



The demand and matched supply unit leave upon matching and the process repeats with $n-1$ supply units till the supply is finished

Performance Metric

Platform wants to minimize regret which is the difference between fluid optimal and expected average match quality with n supply units.

Meta Theorem

Let U_k^{off} denote the expected average matching quality when matching k demand and supply units drawn i.i.d from P and Q resp. Then the expected average matching quality under SOAR is given as

$$U_n^{\text{SOAR}} = \frac{1}{n}\sum_{k=1}^{n} U_k^{\text{off}}$$

Then the expected regret of SOAR is

$$\text{Regret(SOAR)} = \frac{1}{n}\sum_{k=1}^{n} (U^{\text{fluid}} - U_k^{\text{off}})$$

Near-Optimal Regret

demand and supply distributions are bounded

$\varphi(X,Y) = -||X-Y||^p$
($\varphi(X,Y)=\langle X,Y\rangle$ is a special case with $p=2$)

$\text{Regret(Hindsight Opt)} = \widetilde{\Omega}\left(n^{-\left(\frac{p}{d}\wedge\frac{1}{2}\right)}\right)$

$\text{Regret(SOAR)} = \widetilde{O}\left(n^{-\left(\frac{p}{d}\wedge\frac{1}{2}\right)}\right)$

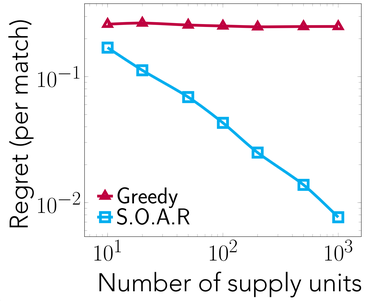
demand and supply distributions are smooth

$\varphi(X,Y) = -||X-Y||^p$
($\varphi(X,Y)=\langle X,Y\rangle$ is a special case with $p=2$)

$\text{Regret(Hindsight Opt)} = \widetilde{\Omega}\left(n^{-\left(\frac{p}{d}\wedge 1\right)}\right)$

$\text{Regret(SOAR)} = \widetilde{O}\left(n^{-\left(\frac{p}{d}\wedge 1\right)}\right)$

Numerical Performance



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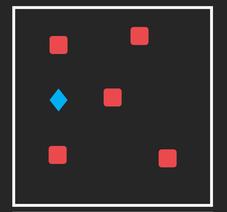
Research Question

How should a centralized platform dynamically match customers with heterogeneous demand and supply?

Answer: SOAR

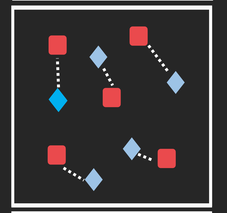
■ supply unit ◆ demand unit

given k supply units, a demand unit arrives

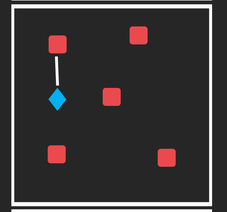


Simulate
a future demand scenario

Optimize
for the simulated scenario



Assign
based on optimal matching



Repeat
with remaining supply units