What Should We Grow Today so We Make Money Tomorrow?
Reinforcement Learning for Small Farmers
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Greenhouse-in-a-box: an affordable, modular greenhouse that uses 90% less water, grows 7 times more food and gives farmers a steady dependable income.
Challenge

Develop an optimization-driven decision support system for this low-resource sector, with a holistic eye towards real-world and multi-agent considerations.
Decision support system

For example:

1. Plant **bottle brinjal** in December 2021

2. Plant **cucumber** in March 2022

3. Plant **beetroot** in July 2022

4. Plant **cucumber** in October 2022
current state
(crop, maturity, season, expected yield)

<table>
<thead>
<tr>
<th>current state</th>
<th>action</th>
<th>next state</th>
<th>...</th>
<th>next state</th>
</tr>
</thead>
<tbody>
<tr>
<td>(□, 0, ▪️, 0)</td>
<td>□️, 0, ▪️ +=1, 0</td>
<td>(🍅, 5%, ▪️ +=1, 50)</td>
<td>▪️, 1%, ▪️ +=1, 10</td>
<td>(🥔, 100%, ▪️, 10)</td>
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<tr>
<td>□️, 1%, ▪️ +=1, 10</td>
<td>▪️, 2%, ▪️ +=1, 10</td>
<td>...</td>
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profit ₹ 0 ₹ 0
The only possible action is to harvest. Tomorrow we will plant something new.
Markov Decision Process
Markov Decision Process

**State Space** \((\text{crop, maturity, expiry, date, flag})\)

**Action Space** \(\{N/A, \text{harvest, plant } c_1, \text{plant } c_2, \ldots\}\)

**Transition function** \(P_a(s, s')\)

**Reward function**

\[
r(s, a, s') = \begin{cases} 
< 0 & \text{if } a \text{ yields a constraint violation} \\
y(\text{crop}) & \text{if } a \text{ is } \text{harvest} \\
0 & \text{otherwise}
\end{cases}
\]
Reinforcement learning

\[ Q(s, a) = Q(s, a) + \alpha [R(s, a) + \gamma \max Q'(s', a') - Q(s, a)] \]
Solving for the optimal policy of actions

Goal: maximize expected total discounted reward

\[
\mathbb{E} \left[ \sum_{t=0}^{\infty} \gamma^t R_{a_t}(s_t, s_{t+1}) \right]
\]

\[
V(s) := \sum_{s'} P_{\pi(s)}(s, s') \left( R_{\pi(s)}(s, s') + \gamma V(s') \right)
\]

\[
\pi(s) := \text{argmax}_a \left\{ \sum_{s'} P_a(s, s') \left( R_a(s, s') + \gamma V(s') \right) \right\}
\]
Decision support system

Our algorithm produced this!

1. **Plant** bottle brinjal in December 2021
   Wait until bottle brinjal are fully grown, then harvest

2. **Plant** cucumber on March 12th, 2022
   Wait until cucumbers are fully grown, then harvest

3. **Plant** beetroot on July 16th, 2022
   Wait until beetroot are fully grown, then harvest

4. **Plant** cucumber on October 22nd, 2022
   Wait until cucumbers are fully grown, then harvest
Sometimes it goes wrong…

1. Plant **tomatoes** in December 2021
2. Plant **cucumbers** on April 24\(^{th}\), 2022
3. Plant **beetroot** on August 13\(^{th}\), 2022
4. Plant **cabbages** on November 11\(^{th}\), 2022
Sometimes it goes wrong…

1. Plant **tomatoes** in December 2021  
   Harvest a couple of times, but before they’re fully harvested…

2. Plant **cucumbers** on April 24\(^{th}\), 2022  
   Harvest a couple of times, but before they’re fully harvested…

3. Plant **beetroot** on August 13\(^{th}\), 2022  
   Rip them out of the ground in November so that you can plant…

4. Plant **cabbages** on November 11\(^{th}\), 2022
Sounds like we have a working decision support system that recommends crops.

So what are we working on this summer?
The **multiple** farmer universe

Is our recommendation still good?

- Income guarantees
- Avoid flooding the market with the same crop
- Fairness of recommendations

Improvements to the recommendation system

- Computational complexity
- Explainability
- Farmer risk profiles
Multi-agent reinforcement learning (MARL)

Each farmer is an agent motivated by their own rewards, and do actions to advance their own interests. In some MARL environments, these interests are opposed to the interests of other agents. We are in a unique position to provide small-scale coordination between agents.
Thank you