Online Policies for Efficient Volunteer Crowdsourcing

How can we use nudging mechanisms to engage volunteers efficiently while avoiding excessive notifications?

Motivated by a collaboration with FOOD RESCUE US (FRUS)

Our Contributions:

• Introduce the online volunteer notification problem
• Develop online policies with constant factor guarantees
• Provide hardness results
• Test policies on datasets from FRUS

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Online Volunteer Notification Problem

- **V**: set of volunteers and **S**: set of task types
- **Task arrival**: At time t task *s* becomes available w. p. $\lambda_{s,t}$ ($\sum_{s \in S} \lambda_{s,t} \leq 1$)
- **Volunteer state** (active/inactive): Initially active.
- **Match prob.**: If active & notified about *s*, volunteer *v* responds w. p. $p_{v,s}$
  - If an active volunteer is notified, she becomes inactive for $\tau$ periods
- **Inter-activity time distribution**: $g(\tau)$

**Challenging Objective**: maximize expected # of completed tasks over *T* periods (submodular in notified subset)

**Goal**: design online notification policies that perform well compared to a “clairvoyant benchmark”

**Example**:
We can notify each volunteer every **two days** $\rightarrow g(2) = 1$
Summary of Theoretical Results

- Parameterized based on minimum discrete hazard rate of inter-activity time distribution:
  \[
  q = \min_{\tau} \frac{g(\tau)}{1 - G(\tau - 1)}
  \]

**Theorem [Lower Bound]:** There exists a non-adaptive randomized online policy that achieves at least \((1 - \frac{1}{e}) \frac{1}{2-q}\) of our benchmark.

**Theorem [Upper Bound]:** If \(q = 1/n\) for some integer \(n\), no online policy can achieve better than \(\min \left\{ \frac{1}{2-q}, 1 + q + \frac{q(1-q)(1-e^{-1})}{(1+q)\log(1-q)} \right\}\) of our benchmark.
Sparse Notification Policy (SNP)

**Key Idea:** Sparsify an ex-ante solution $x^*$ by solving a sequence of “low-dimensional” DPs

**Offline Phase:** Artificially rank volunteers. Starting with $v = 1$ and $t = T$,

$$y_{v,s,t} = \begin{cases} x^*_{v,s,t} & \text{Reward of notifying } v \text{ about } s \text{ at } t \\ 0 & \text{Reward of not notifying } v \text{ at } t \end{cases} \quad \begin{aligned} J_{v,t+1} \end{aligned}$$

$$p_{v,s} \prod_{1 \leq u \leq v-1} (1 - p_{u,s} y_{u,s,t}) + \sum_{t+1 \leq \tau \leq T} g(\tau - t) J_{v,\tau}$$

- Solution of higher ranked DP’s
- Expected future number of rescues completed by $v$ (if active at $\tau$)

$$J_{v,t} = \sum_{s \in S} y_{v,s,t} \text{ (Reward of notifying } v \text{ about } s \text{ at } t)$$

$$\quad + (1 - y_{v,s,t}) \text{ (Reward of not notifying } v \text{ at } t)$$

**Online Phase:** If task $s$ arrives at time $t$, notify volunteer $v$ with prob. $y_{v,d,t}$

**SNP vs. FRUS Current Practice**

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<thead>
<tr>
<th>Fraction of benchmark</th>
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<tbody>
<tr>
<td>SNP</td>
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<tr>
<td>Notify-1</td>
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<td>Notify-3</td>
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Graph showing comparison of SNP and FRUS current practice.