Multiple Target Discovery and Coverage with Mobile Wireless Sensors

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Mobile sensor/robot deployment
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Scenario of environmental monitoring

• There are one or more targets in the field of interest at unknown locations

• All available sensors are placed in the vicinity or each other around the gathering point - base station

• The goal is to observe/cover as many targets as possible and transfer gathered data to the base station in multi-hop manner
Environment exploration problem

- Unknown deployment field

- Where are the targets and how many of them?

- Connectivity preservation
Target coverage problem

- Distributed solution to cope with the scalability issues
- Connectivity preservation throughout the deployment
- Minimized number of relay sensors, maximized number of covering sensors
Connectivity preservation

\[ d_{\text{max}} = \min\{ (r_C \cos \alpha_i + \sqrt{d_i^2 - r_C^2 \sin^2 \alpha_i})/2, i \in \text{RNG}(u) \} \]
Virtual force based movement

Movement vector \( \vec{F} = \vec{F}_B + \vec{F}_T + \vec{F}_N \)
Deployment algorithm

Phase = Discovery;
repeat
   Calculate the $RNG(u)$;
   if Phase == Discovery then
      $$\vec{F} = \vec{F}_D = -C_{BJ} - \sum_{i=1}^{n_{RNG}} C_N \frac{j_i}{d_i^2};$$
      if Target is discovered then
         Add $T_i(x, y)$ in the neighborhood table;
         Share $T_i(x, y)$ information with neighbors;
   else
      if Covering the target then
         $$\vec{F} = \vec{F}_C = \frac{C_T}{d_T^2};$$
      else
         $$\vec{F} = \vec{F}_C = C_{BJ} \frac{j_B}{d_B^2} + \frac{C_T}{d_T^2} j_T + \sum_{i=1}^{n_{RNG}} C_N d_i j_i;$$
      end
   end
   $$d_{max} = \min\{ \frac{r_C \cos \alpha + \sqrt{d_i^2 - r_C^2 \sin^2 \alpha}}{2}, i \in RNG(u) \};$$
   if $d(u, RNG(u)) == 2r_s$ then
      Phase = Coverage;
   end
until Target is covered;
Discovery
Discovery
Discovery
Coverage
Coverage
Coverage
Percent of covering sensors

![Graph showing the percent of covering sensors versus the number of sensors for different numbers of targets. The graph includes lines for 1 to 5 targets, each represented by a different color and symbol.](image-url)
Percent of complete coverage

Number of targets: 1
2
3
4
5

Number of sensors

Percent of complete coverage

0  20  40  60  80  100

20  25  30  35  40
Conclusions - Pros

- Distributed asynchronous algorithm for target coverage which maximizes the number of covering and minimizes the number of connectivity sensors

- The same principle used both for exploration and coverage

- The connectivity between sensors is preserved all throughout the deployment

- The network adapts itself to the indoor environment shape
Conclusions - Cons

- Coverage phase convergence - does it always form a tree?
- What happens if a node dies?
- Mobile targets?
Thank you!