

Evolution of Altruism

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Cooperation/Altruism

- What is it?
- How does it arise in evolving systems? (It arises when it is adaptive... but when ***is*** it adaptive?)
- How does it *change* evolving systems? (When does it promote adaptation?)

Evolution of Altruism

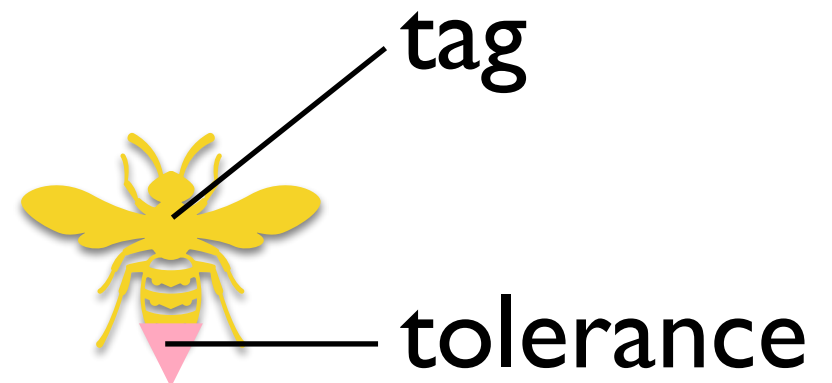
- Puzzles/challenges/results since Darwin
- Explanations of altruism toward:
 - Kin
 - Reciprocating partners
 - Agents with good reputations

Tag-Mediated Altruism

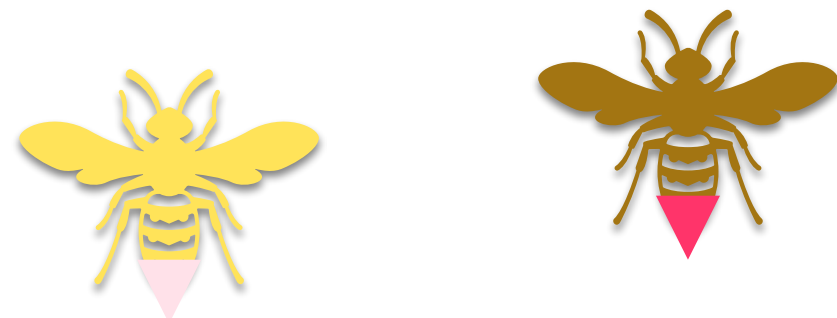
- Tags = arbitrary identifiers (Holland, 1995)
- Riolo *et al.* (*Nature*, 2001) showed that altruism based only on tag similarity can evolve in simple simulations.
- Roberts & Sherratt (*Nature*, 2002) claimed that Riolo *et al.*'s result held only when agents with identical tags were *required* to donate to one another.

Tags and Tolerances

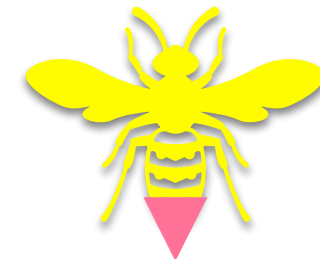
1. Donations when
 $\Delta\text{tags} \leq \text{tolerance}$



2. Reproductive
Tournaments



3. Mutation

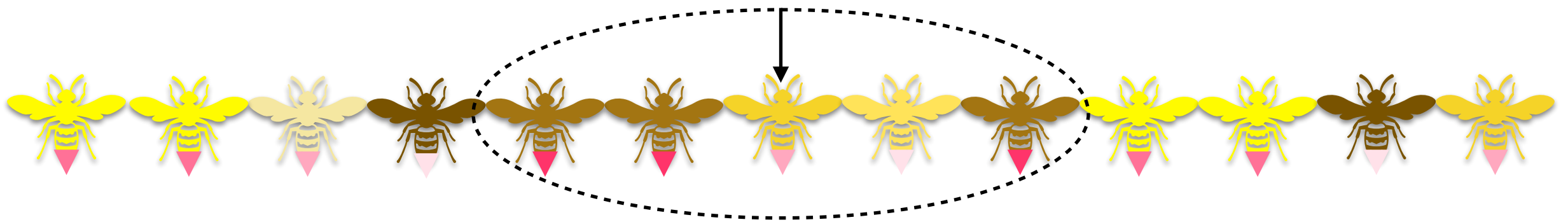


In Clojure

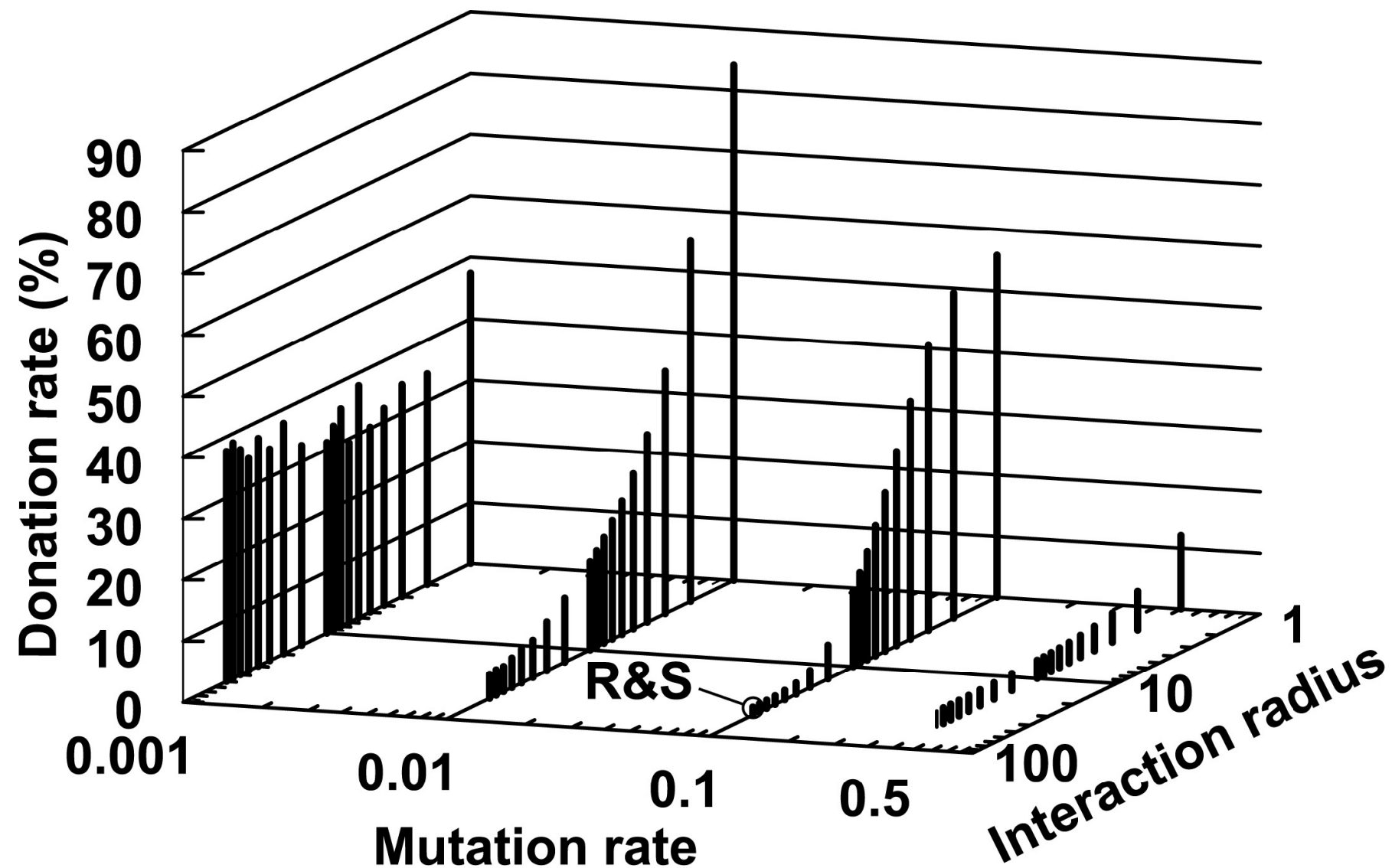
- Show worksheet
- Run with
 - Riolo et al. settings
 - Roberts and Sharratt settings

Genetic Stability and Territorial Structure

- Varied mutation rate.
- Varied “interaction radius” within a linearly structured population.



Genetic Stability and Territorial Structure



Spector, L., and Klein, J. Genetic stability and territorial structure facilitate the evolution of tag-mediated altruism. *Artificial Life*, Vol. 12, No. 4, pp. 553-560

Selfish Mimics

- One kind of defection.
- A selfish agent mutates to a tag value matching local cooperators.
- Like guessing a password.
- Longer passwords (multidimensional tags) should make this more difficult.

Multidimensional Tags

- Tag = $(t_1, t_2, t_3, \dots, t_n)$
- Distance = $\sqrt{\sum_{i=1}^n (t_1[i] - t_2[i])^2}$
- Earlier work by Hales and Edmonds, but not in a tag/tolerance framework.

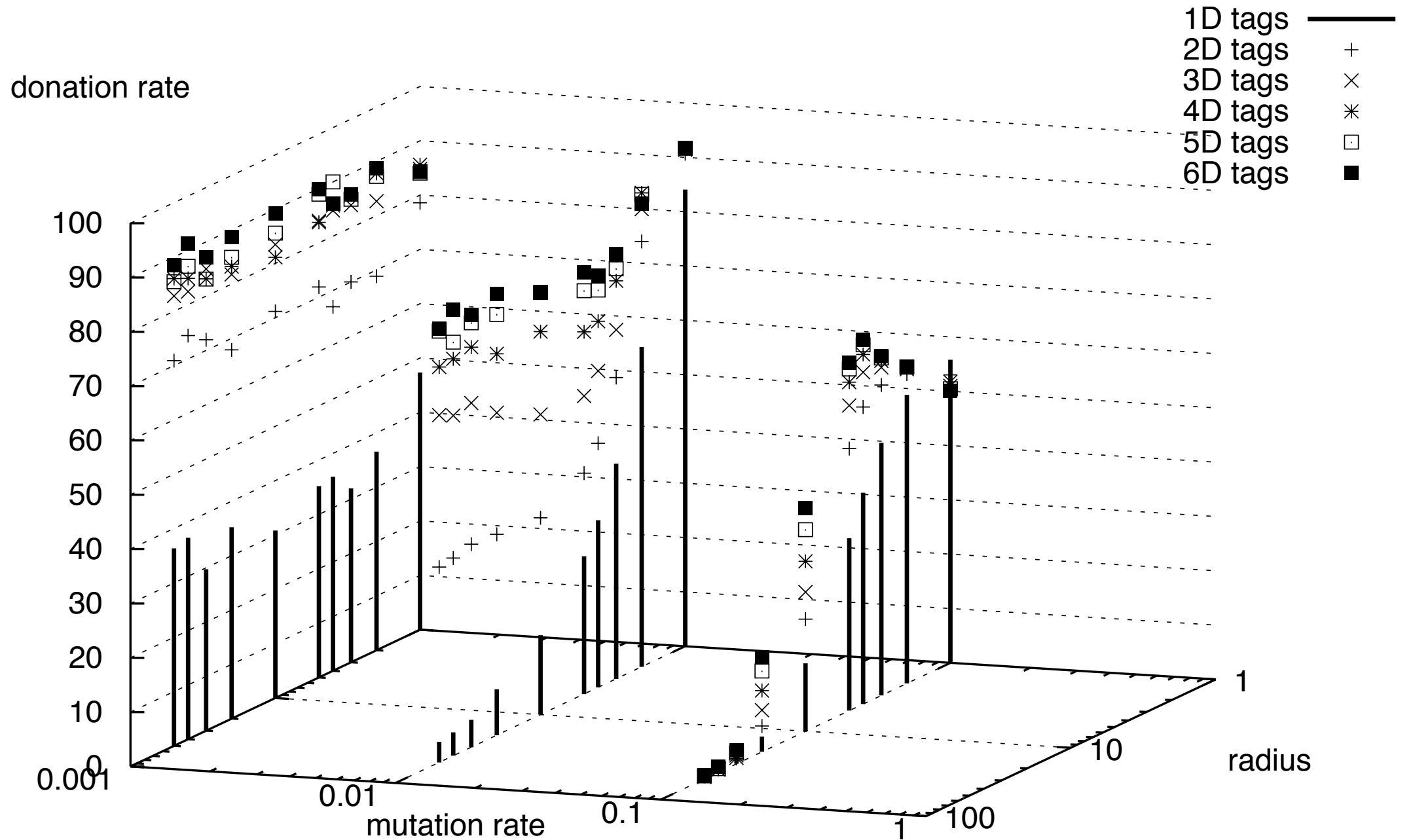


Fig. 1. Average donation rates as a function of mutation rate, interaction radius, and number of tag dimensions. For the data in this graph the cost (C) charged to a cooperating agent for each donation was 0.1, as in most of the prior research. Each plotted point represents the average of 92 independent runs.

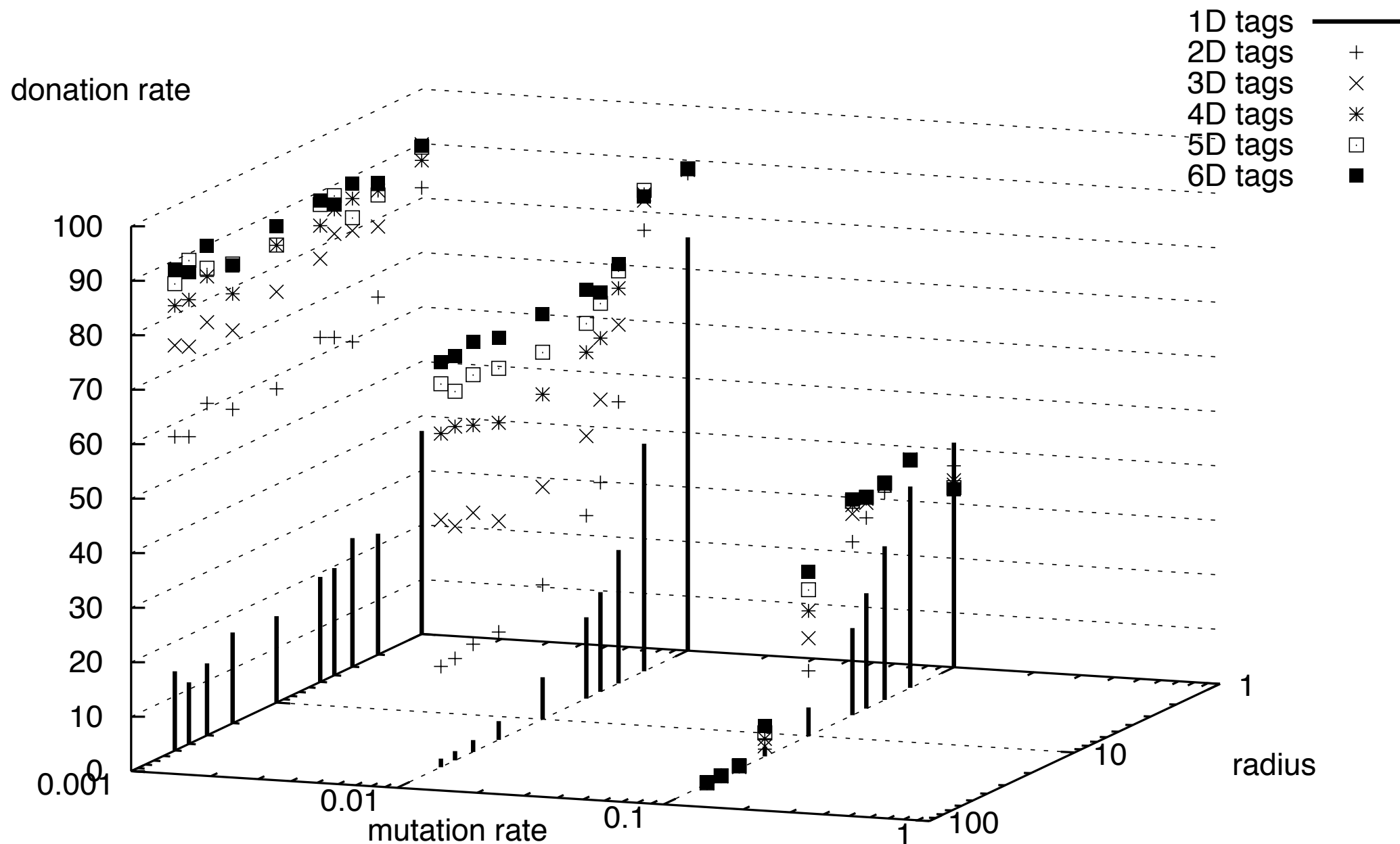


Fig. 2. Average donation rates as a function of mutation rate, interaction radius, and number of tag dimensions. For the data in this graph the cost (C) charged to a cooperating agent for each donation was 0.5, which is five times the cost used in most of the prior research. Each plotted point represents the average of 92 independent runs.

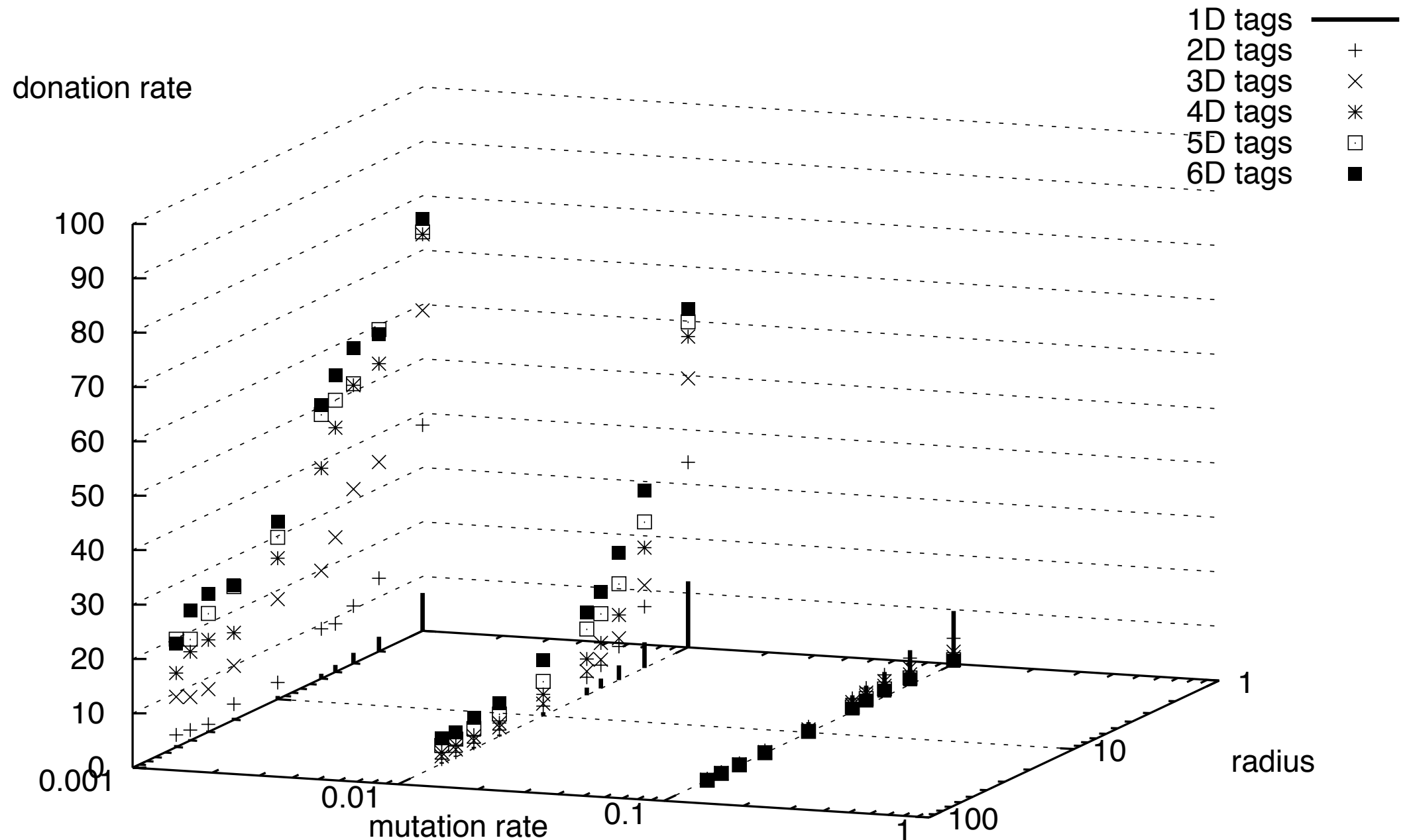


Fig. 3. Average donation rates as a function of mutation rate, interaction radius, and number of tag dimensions. For the data in this graph the cost (C) charged to a cooperating agent for each donation was 1.0, the same as the benefit to the recipient. Each plotted point represents the average of 92 independent runs.

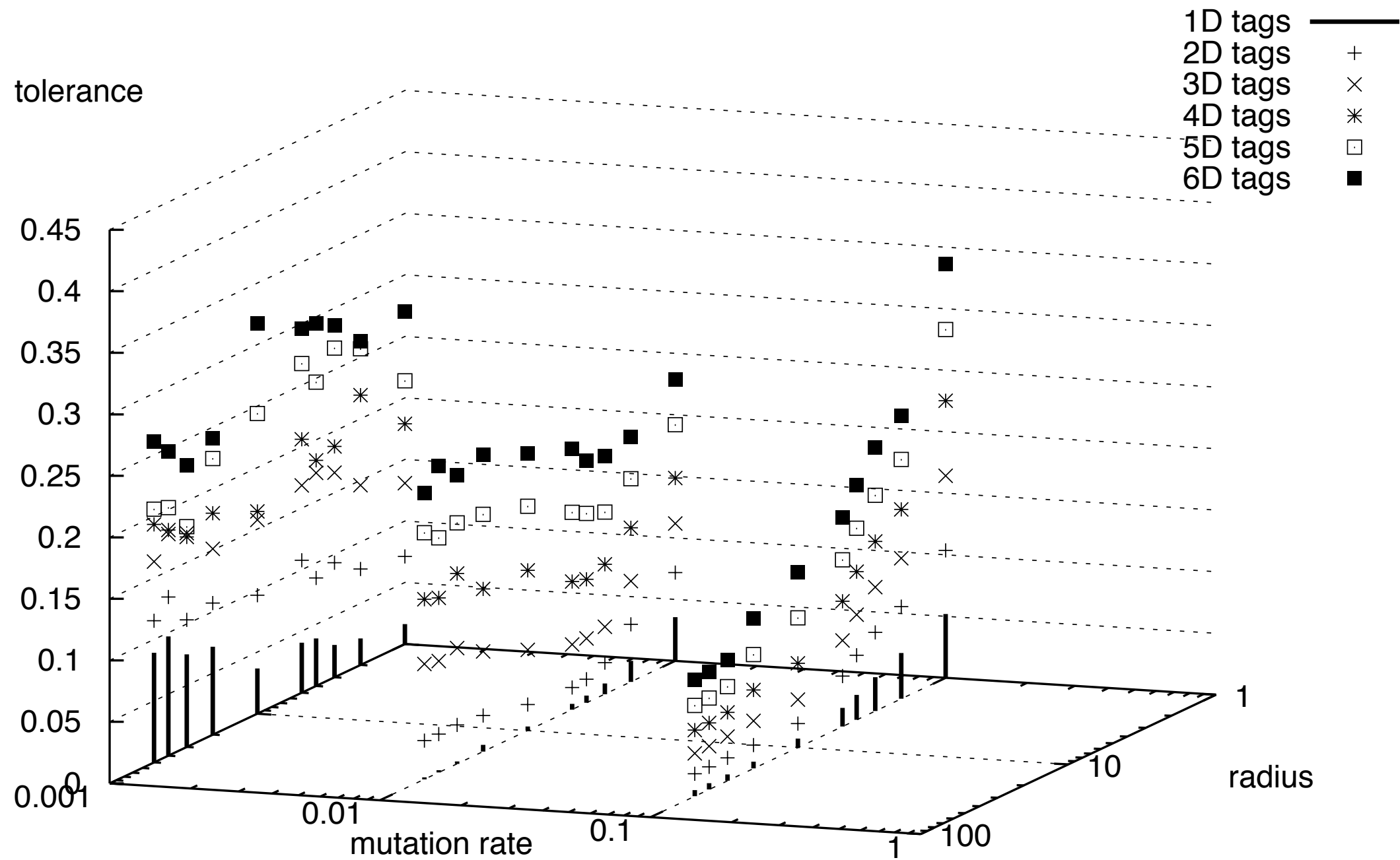


Fig. 4. Average tolerances as a function of mutation rate, interaction radius, and number of tag dimensions. For the data in this graph the cost (C) charged to a cooperating agent for each donation was 0.1, as in most of the prior research. Each plotted point represents the average of 92 independent runs.

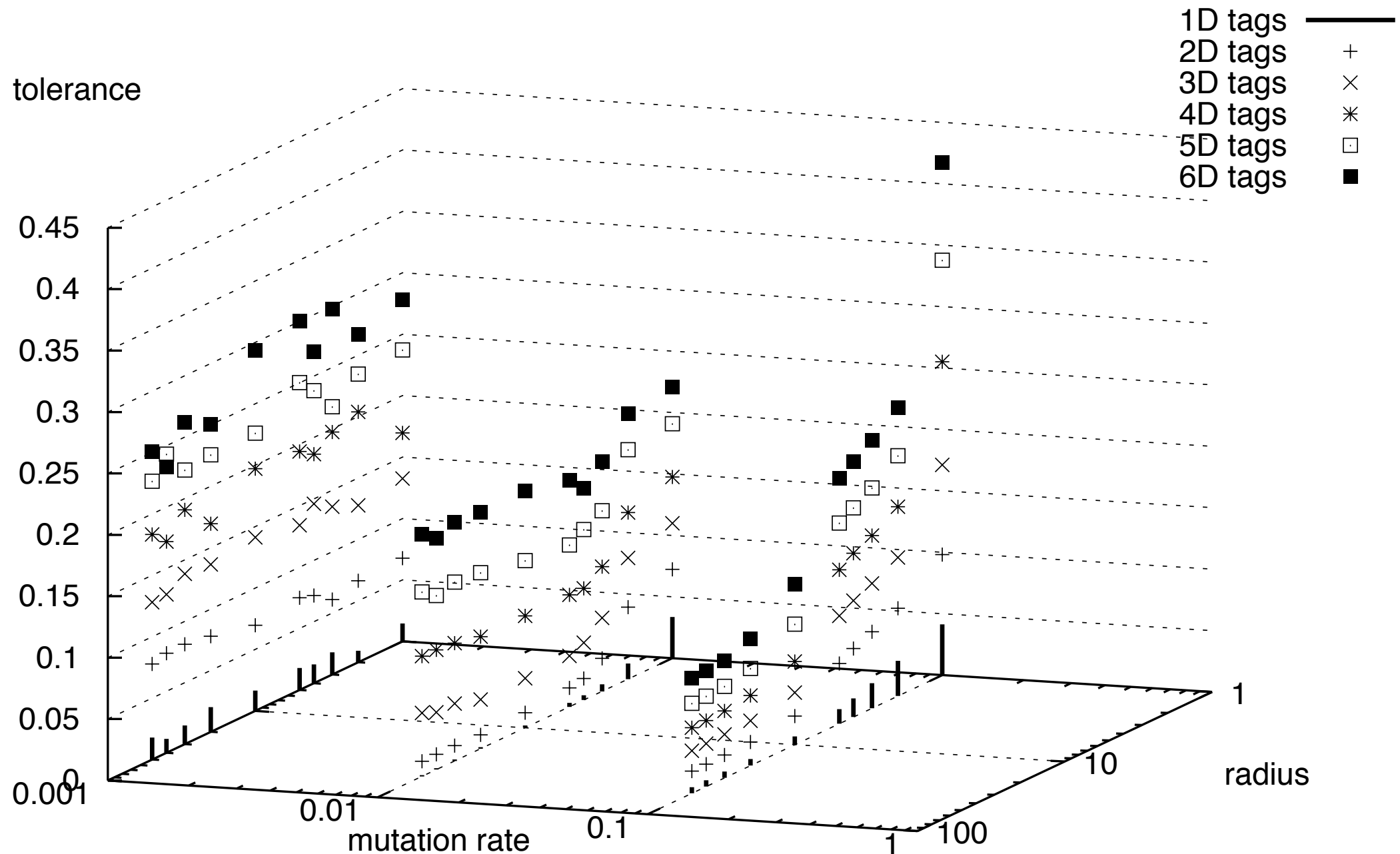


Fig. 5. Average tolerances as a function of mutation rate, interaction radius, and number of tag dimensions. For the data in this graph the cost (C) charged to a cooperating agent for each donation was 0.5, which is five times the cost used in most of the prior research. Each plotted point represents the average of 92 independent runs.

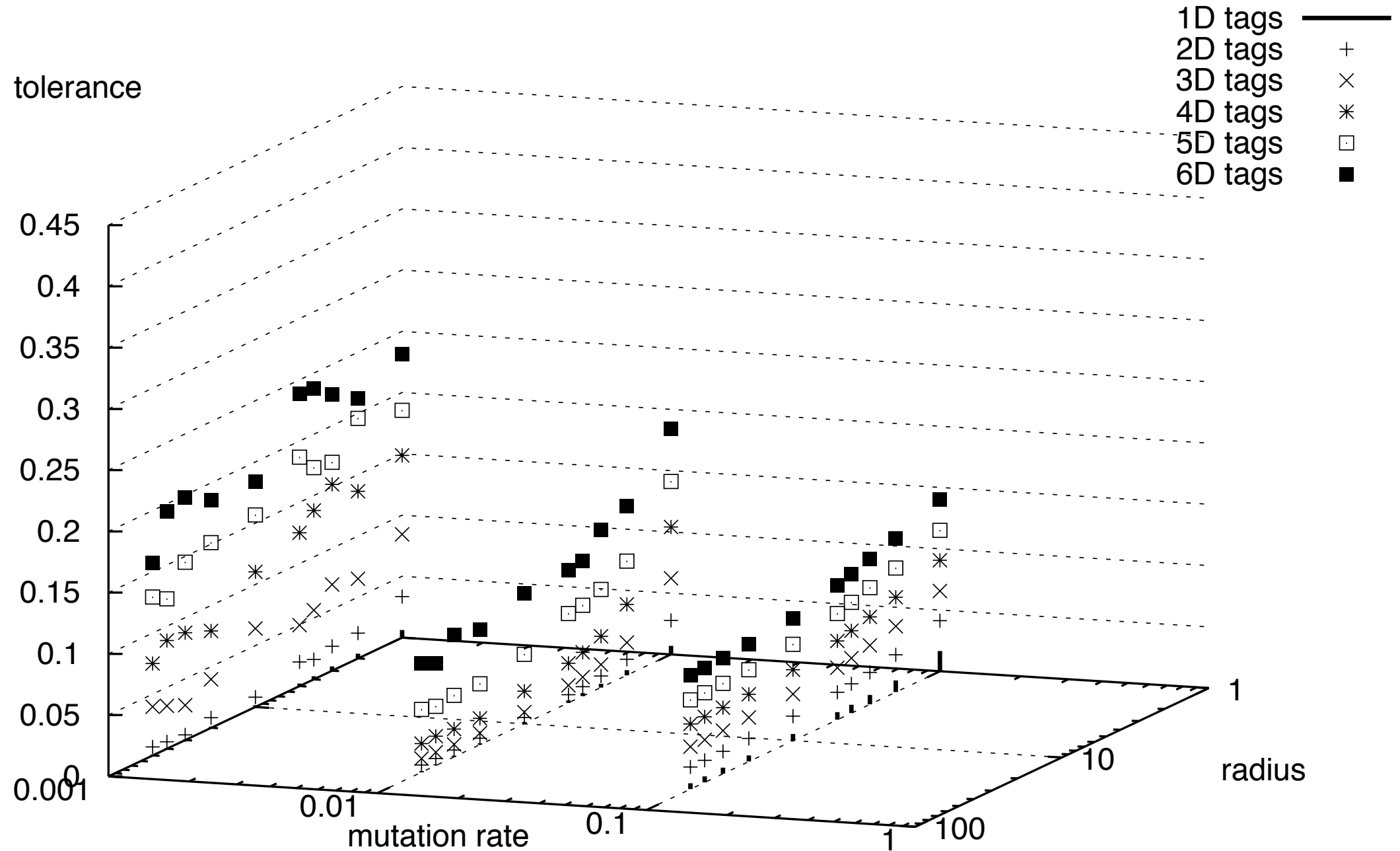
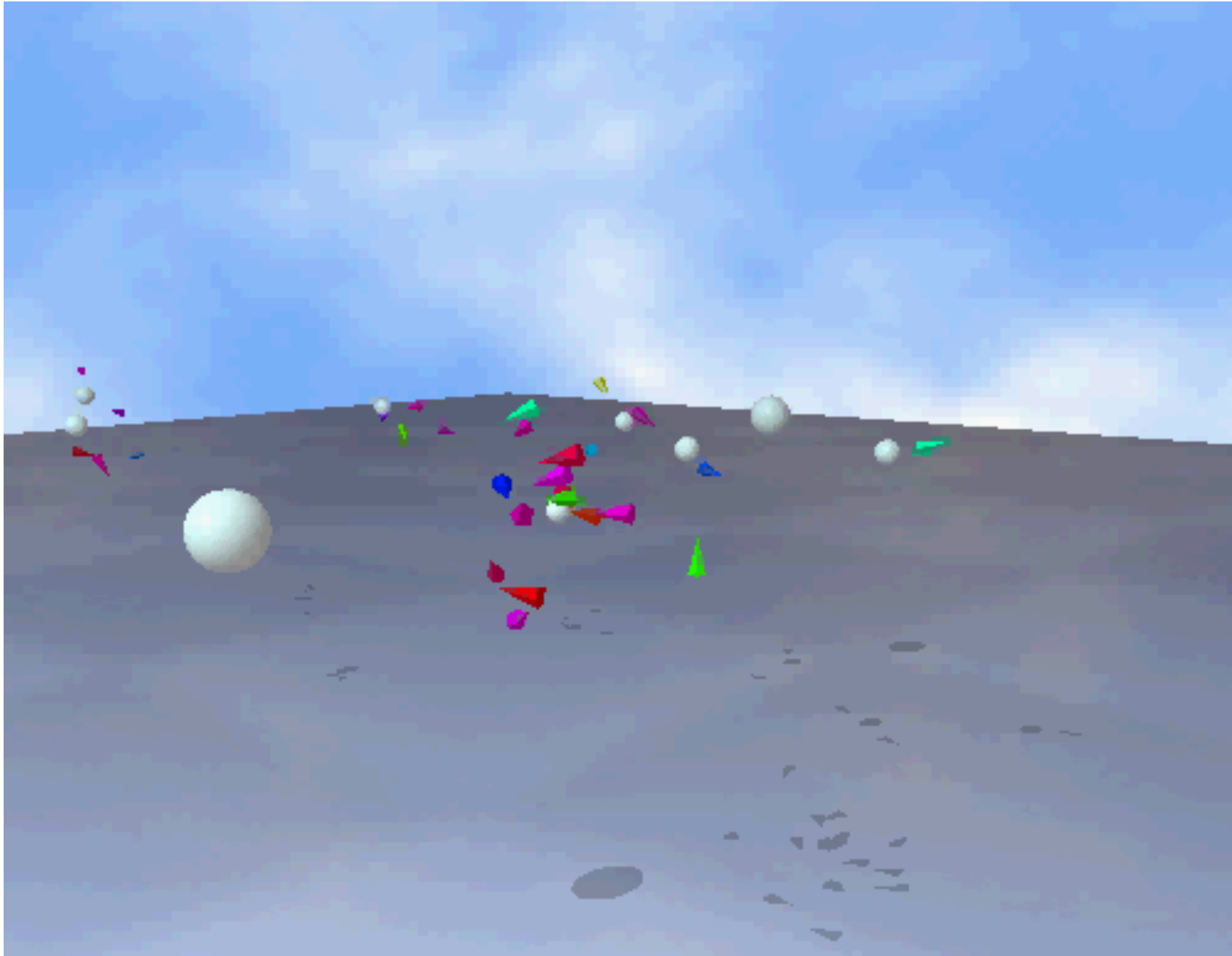


Fig. 6. Average tolerances as a function of mutation rate, interaction radius, and number of tag dimensions. For the data in this graph the cost (C) charged to a cooperating agent for each donation was 1.0, the same as the benefit to the recipient. Each plotted point represents the average of 92 independent runs.

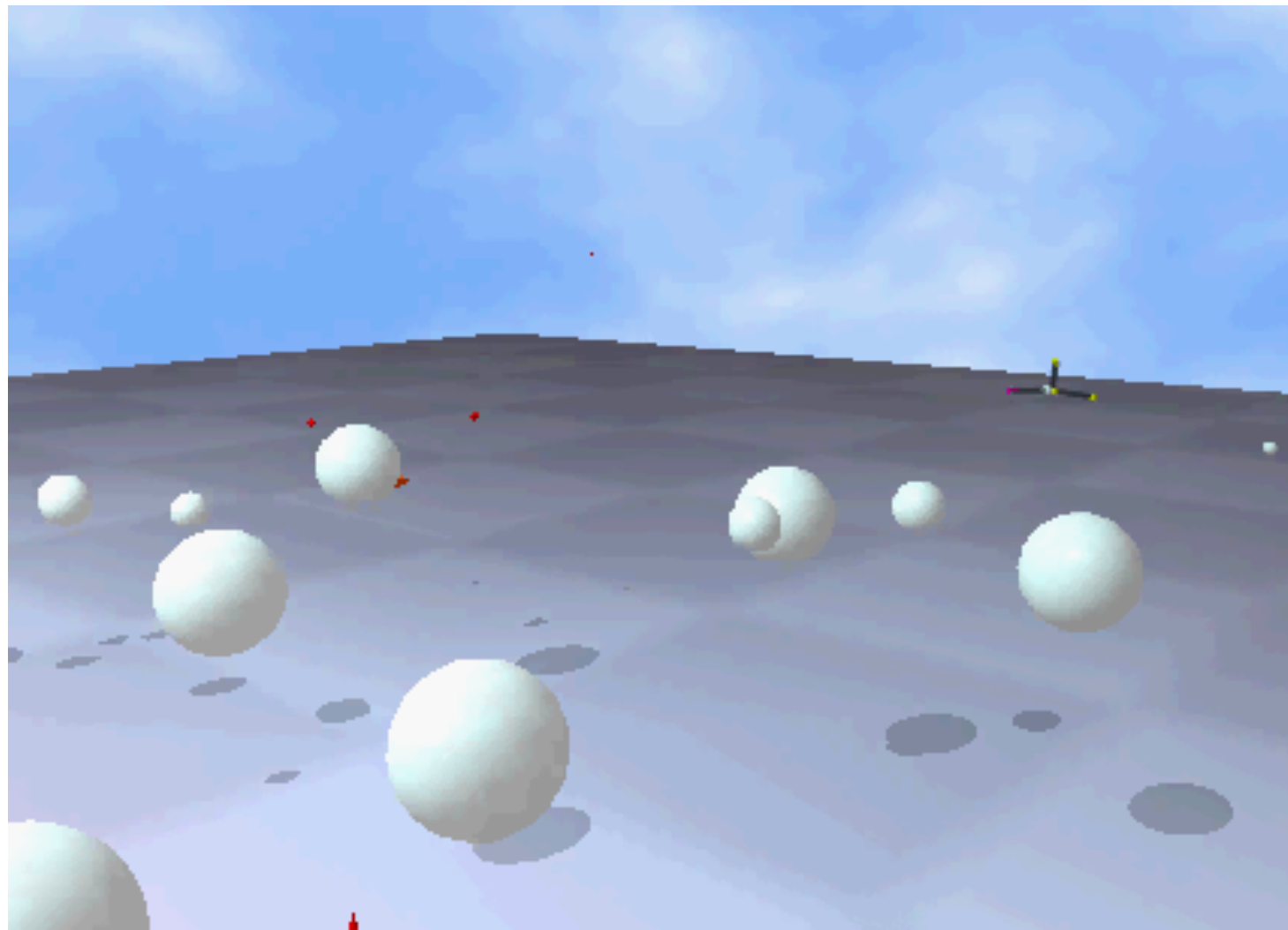
Multiagent Systems

- Cooperation and coordination are critical.
- Tags may provide effective and efficient team-member recognition and addressing.
- Multidimensional tags may enhance stability.

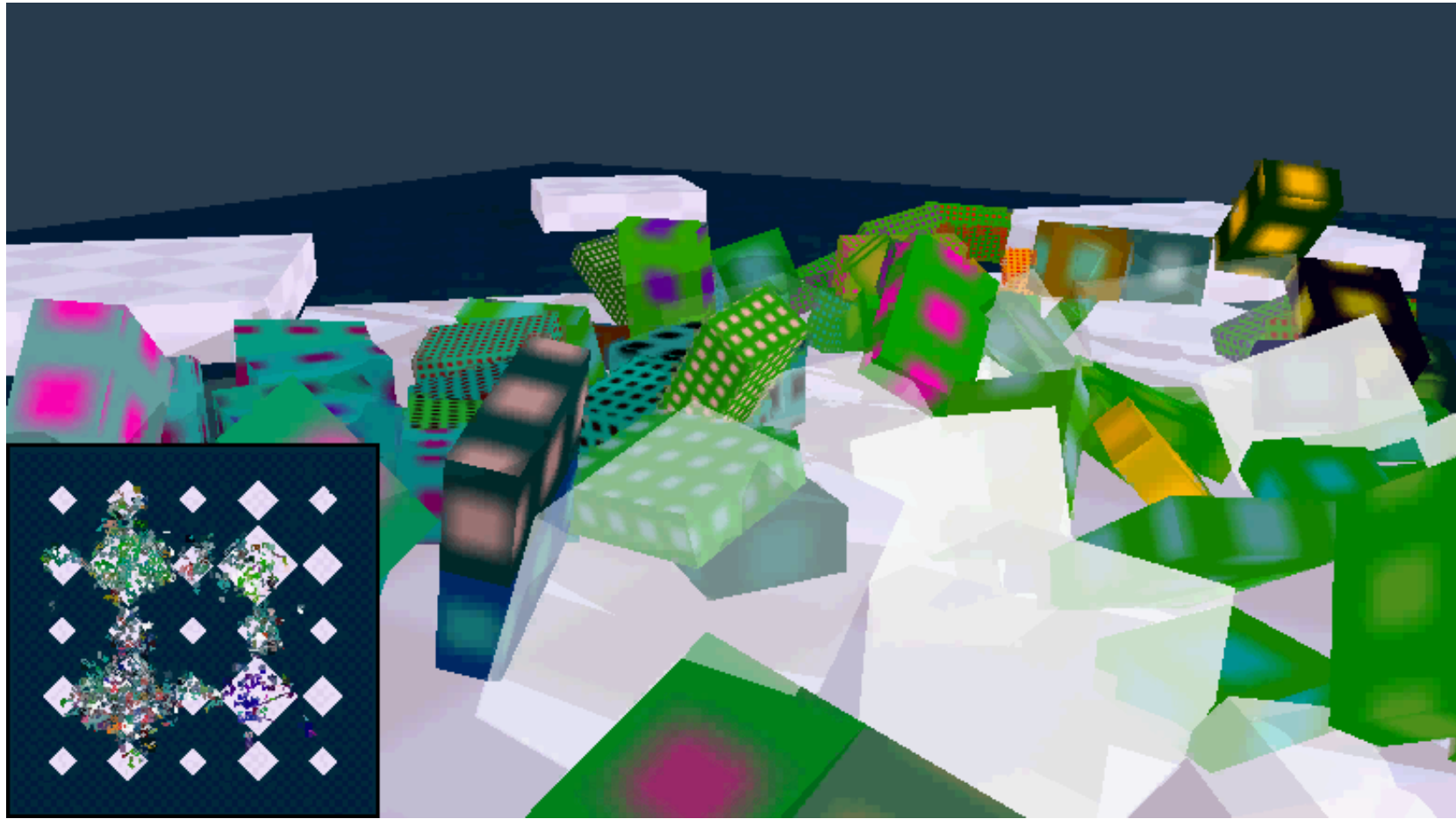
Cooperative Swarms



Visualizing Sharing



Multicellularity



Conclusions

- Cooperative exchanges build networks of interaction that can support the evolution of adaptive complexity.
- Multidimensional tags can enhance the evolvability of tag-mediated cooperation.