## Towards More Realistic ANTS



Tobias Langner

## $n \times 3$





## Previous Work

- ANTS problem (Ants Nearby Treasure Search) introduced by Feinerman, Korman, Lotker, Sereni [PODC 2012]


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- Treasure located in optimal time $\approx D+D^{2} / n$


## Model



- Infinite integer grid with nest and food in distance $D$
- Goal: Starting at nest, find food fast


## Model



- In each step, ant can move one cell N, E, S, W or stay


## Model



- Communication within cells


## Model



- Communication within cells
- For each state: Is there an ant with this state?
- $\Rightarrow$ Finite message size


## Model



- Ants controlled by finite automaton


## Model



- Ants controlled by finite automaton
- Constant number of states independent of $n$


## Model



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How Many Ants Do We Need to Find the Food?


## Asynchronous and Deterministic



## Triangle Search

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## Triangle Search



## Triangle Search

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## Triangle Search



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## Triangle Search

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## Synchronous and Deterministic

Can we do better if the ants have a common sense of time?

## Diamond Search

Can we do better if the ants have a common sense of time?


## Diamond Search

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## Diamond Search



## Diamond Search

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## Diamond Search



## Diamond Search

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## Diamond Search



## Lower Bounds

Is this any good? Can we do better?

## One Ant

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## One Ant

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## One Ant

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## One Ant



## One Ant



## Two Ants

Observation: Ants have to meet infinitely often in states $\left(q, q^{\prime}\right)$.

## Two Ants



Observation: Ants have to meet infinitely often in states $\left(q, q^{\prime}\right)$.

## Two Ants



Observation: Ants have to meet infinitely often in states $\left(q, q^{\prime}\right)$.

## Two Ants



Observation: Ants have to meet infinitely often in states $\left(q, q^{\prime}\right)$.

## Two Ants

Observation: Ants have to meet infinitely often in states $\left(q, q^{\prime}\right)$.
Observation: Time between such meetings is constant.

## Two Ants



## Two Ants



## Two Ants



## Two Ants



## Two Ants

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|  |  |  |  |  |  |  | $\because$ | $\ldots$ |  | $\vdots$ | $\vdots$ |  |  |  |
|  |  |  |  |  |  |  | . . | C |  | $\ldots$ | $\vdots$ | : ${ }^{\prime}$ | $\cdots$ | : ${ }^{\prime}$ |
|  |  |  |  |  |  |  |  |  |  | . |  | $\ldots$ | : | $\vdots$ |
|  |  |  |  |  |  |  |  |  | $\vdots$ |  | . |  |  | $\vdots$ |
|  |  |  |  |  |  |  |  |  | ! . . | . . . |  |  |  | ... |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

## Two Ants



## Randomization



## Randomization



## Randomization



## Randomization



## Geometric Search

|  |  |  |  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  |  | F |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  | E |  |  |  |  |  |

## Geometric Search



## Geometric Search



## Geometric Search



## Geometric Search



## Geometric Search



## Geometric Search




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## Geometric Search




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## Geometric Search



## Geometric Search

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|  |  | F |  |  |  |  |  |  |  |  |
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|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  | E |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |

## Geometric Search

| 4 |  | $\ldots$ | $\ldots .$ |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 4 |  | $\ldots .$ | : |  |  |  |  | $\Delta$ |  |
|  |  |  |  | $\vdots$ |  |  |  |  | $\vdots$ |  |
|  |  |  |  | E. |  |  | ..... | . . | $\vdots$ |  |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  | - |  |
|  |  |  |  | $\vdots$ | - |  |  |  |  |  |

## Parallelization

|  |  |  |  |  | (c) |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | .. | © (E) |  | $\cdots$ |  |  |  |  |
|  |  | F | .. |  | ©(E) | $\because$ |  |  | $\because$ |  |  |
|  |  | . . |  | . . |  |  | ... |  | $\vdots$ | $\cdots$ |  |
|  | $\therefore$ |  | . . |  |  |  |  |  | $\because$ | : |  |
| © | © | © |  |  | N |  |  |  | © | © | © |
| $\vdots$ | $\cdots$ |  | $\cdots$ |  |  |  |  |  | . $\quad$ ' |  | $\therefore$ |
|  |  | $\because$ |  | $\cdots$ |  | ! | $\therefore$ |  |  | . |  |
|  |  |  | $\cdots$ | $\div$ | (6) | . |  |  | $\cdots$ |  |  |
|  |  |  |  | $\cdots$ | © |  | : |  |  |  |  |
|  |  |  |  |  | ( | $\ldots$ |  |  |  |  |  |

- Works in asynchronous deterministic setting
- Optimal speed-up, runtime $\approx D+D^{2} / n$


## Fault-Tolerance



- See talk at DISC by Jara Uitto: Fault-Tolerant ANTS


## Diamond Search in Real Life



## Thanks! <br> Questions \& Comments?



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