Design Science Research Paper Presentation

Stéphane Liem NGUYEN

University of Geneva

stephane.nguyen@etu.unige.ch

December 23, 2021

Overview

1. Author part
    - Problem definition
    - Additional motivations and previous works
    - Intuition for strategies
    - Idea of previous works' strategies
    - Methodology, reducing search space and implementation
    - Results and conclusion

2. Critic Part
    - Form
    - Content

Improved Bounds for the Symmetric Rendezvous Value on the Line [1]

Author part

Qiaoming Han
Donglei Du
Juan Vera
Luis F. Zuluaga

1. Author part
    - Problem definition
    - Additional motivations and previous works
    - Intuition for strategies
    - Idea of previous works' strategies
    - Methodology, reducing search space and implementation
    - Results and conclusion

2. Critic Part
    - Form
    - Content

Rendezvous problem?

- Rescue or meet someone urgently but limited (or no) visibility & no info on actual position of that person !

- Find optimal strategy used by two players: meet in least expected amount of time = rendezvous value:

$$3.25 = R^a = \min_{x_1, x_2} t(x_1, x_2) \leq R^s = \min_{x} t(x, x)$$

Problem

- On the Line !
  - No communication
  - Blind agent (extremely limited visibility)
  - Initial distance apart of 2
  - Velocity Bounded by 1
  - No protocol of the type: go meet at this rdv point

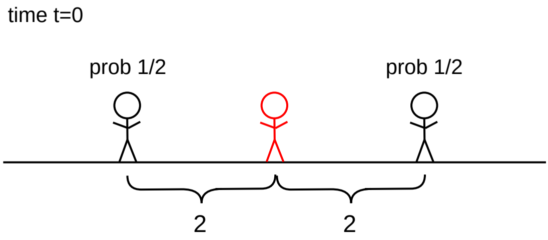


Figure: Rdv problem on the Line

Additional motivations. Our work

- Why Symmetric ? Unsolved for 26 years (introduced by Alpern in 1995)

- Improved bounds
- General frameworks for generating upper/lower bounds
- Provide theorems: reduced search space

Previous works

Table 1. Previous upper and lower bounds for R^s.

	Upper bound	Lower bound
Alpern (1995)	5.0000	—
Alpern and Gal (1995)	—	3.25
Anderson and Essegaier (1995)	4.5678	—
Baston (1999)	4.4182	—
Uthaisombut (2006)	4.3931	3.9546

Figure: Previous upper and lower bounds for R^s [1]

Intuition for strategies

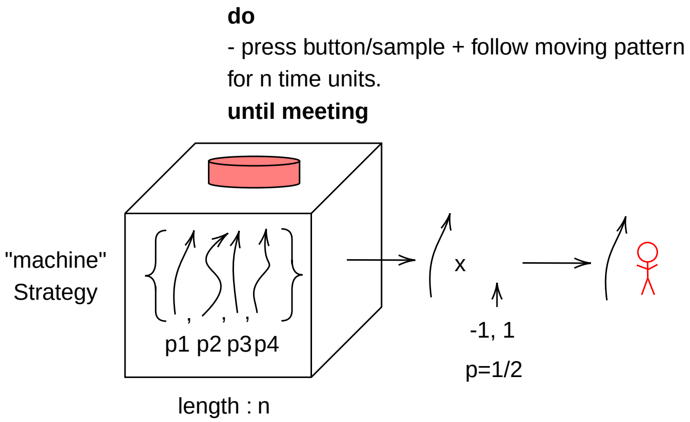
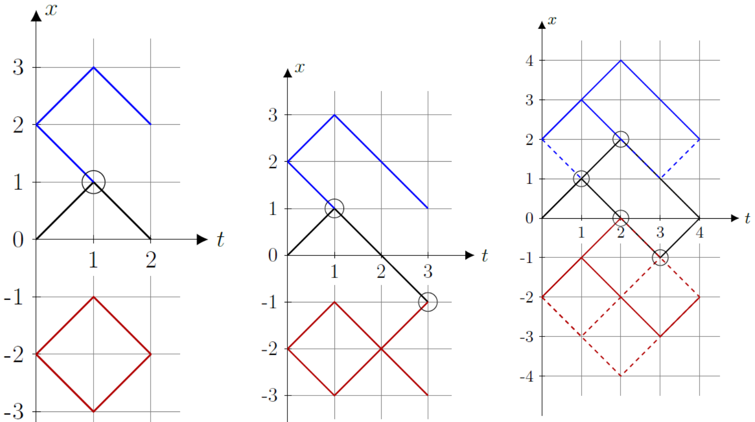


Figure: n-Markovian strategy - Repeating... until meeting

Our strategies and from previous work



(a) $R_2^s = 7$, $g_1 = \{1, -1\}, x_1 = 1$

(b) Stratégie d'Alpern $R_3^s = 5, g_1 = \{1, -1, -1\}, x_1 = 1$

(c) $R_4^s = 5.9441, g_1 = \{1, -1, -1, 1\}, g_1 = \{1, 1, -1, -1\}, x_1 \approx 0.1118, x_2 \approx 0.8882$

Figure: 3 examples of distance-preserving strategies [2]

Methodology

- Reduced search space (grid strat.) (theorems in paper)
- Upper and lower bounds to approach R^s:
  - Sub-problems fixed length n; optimal values: R^s_n and r^s_n
  - Fractional Quadratic Programming
  - SDP (for proofs of optimality)
- Lower bounds: different problem with revealed info (Alpern 2006)
- Conjecture based on numerical calculations that

$$R^s = \lim_{n\to\infty} R^s_n = 4.25$$

Reducing search space (upper bound)

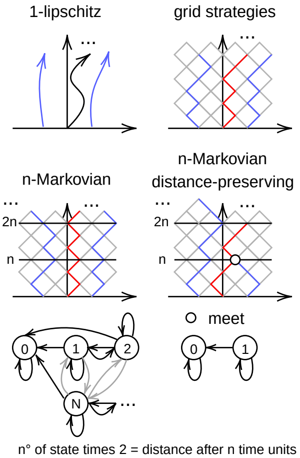
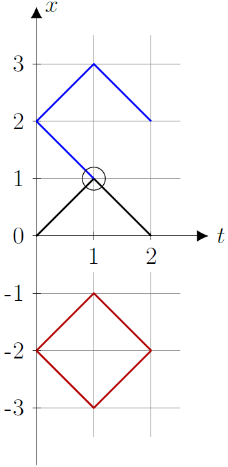
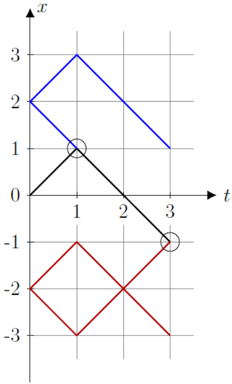


Figure: Last row: Absorbing Markov Chains for non distance-preserving and distance-preserving n-Markovian. Goal: minimize expected meeting time for fixed n, get $u_n \geq R_n^s \geq R^s$

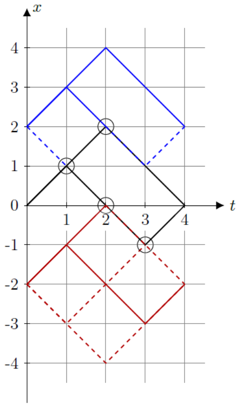
Examples of distance-preserving strategies



(a) $R_2^s = 7$, $g_1 = \{1, -1\}, x_1 = 1$



(b) Stratégie d'Alpern $R_3^s = 5, g_1 = \{1, -1, -1\}, x_1 = 1$



(c) $R_4^s = 5.9441, g_1 = \{1, -1, -1, 1\}, g_1 = \{1, 1, -1, -1\}, x_1 \approx 0.1118, x_2 \approx 0.8882$

Figure: 3 examples of distance-preserving strategies [2]

Implementation

- Matlab toolkit : Mathematical Programming & Matlab packages
  - QP
  - SeDuMi (Self-Dual-Minimization), DSDP5 (For Semi-Definite Programming)

Results

Table 2. Upper bounds for R^s.

n	u_n	Achieved no. of generators
1	∞^*	1
2	7.0000*	1
3	5.0000*	1
4	5.9441*	2
5	4.8827*	4
6	4.4634*	5
7	4.3490*	5
8	4.3209*	8
9	4.3044*	11
10	4.2866	18
11	4.2739	29
12	4.2678	38
13	4.2630	58
14	4.2595	89
15	4.2574	128
$\vdots$	$\vdots$	$\vdots$
∞	**4.25**?	∞?

(a) $u_n \geq R_n^s \geq R^s$

Table 3. Lower bounds for R^s.

n	l_n	Uthaisombut (2006)
1	3.0	2.0
2	3.2970	2.5
3	3.5869	3.0
4	3.8141	3.4375
5	3.9784	3.6458
6	4.0913	3.8326
7	4.1520	3.9546

(b) $l_n \leq r_n^s \leq R_U \leq R^s$

Figure: Improved bounds from $(3.9546, 4.3931)$ to $(4.1520, 4.2574)$ shown in [1]

Conclusion and conjecture

- Can work in reduced search space
- Improved previous bounds from $(3.9546, 4.3931)$ to $(4.1520, 4.2574)$.
- Conjecture based on numerical calculations that

$$R^s = \lim_{n \to \infty} R^s_n = 4.25$$

- Problem: Computational limits as n grows. Size : 2^{n-1}

Improved Bounds for the Symmetric Rendezvous Value on the Line [1]

Critic Part

Qiaoming Han
Donglei Du
Juan Vera
Luis F. Zuluaga

1. Author part
   - Problem definition
   - Additional motivations and previous works
   - Intuition for strategies
   - Idea of previous works' strategies
   - Methodology, reducing search space and implementation
   - Results and conclusion

2. Critic Part
   - Form
   - Content

Information on paper

Improved Bounds for the Symmetric Rendezvous Value on the Line

- **Technical** paper
- **Published In:** Operation Research **Journal**[1] (periodical)
  Volume 56, Issue 3, May-June **2008**, 270 pages
- pages 772-782 (counting from Issue 1)
- **Publisher:** Institute for Operations Research and the Management Sciences (INFORMS)
- **Cited:** 25 times (google scholar)
- **Authors** Qiaoming Han, Donglei Du, Juan Vera, Luis F. Zuluaga

[1] **Impact factor** 2020: 3.31. **Rank:** A* in CORE2020

Information on authors

Improved Bounds for the Symmetric Rendezvous Value on the Line

h-index from Web of Science[2]

- Qiaoming Han : 3
- Donglei Du: 10
- Juan Vera: 11 (21 in google scholar)
- Luis F. Zuluaga: 10 (18 in google scholar)

"h-index is based on the **Web of Science Core Collection** citations of the publications" - Web of Science[3]

[2] More informations on authors by clicking on the authors' names

[3] link to some information on WoS Core Collection

Quality of the abstract

Abstract

- 123 words (200 max by journal).
- Objective. "based on numerical calculations [...]"
- Active voice.
- Informative in general. A bit descriptive ? for the "important properties of problem".
  Maybe add why they're useful: properties reducing search space ?

Quality of the abstract

Abstract

5-"line" abstract

A notorious open problem in the field of rendezvous search is to decide the rendezvous value of the symmetric rendezvous search problem on the line, when the initial distance between the two players is two. We show that the symmetric rendezvous value is within the interval (4.1520, 4.2574), which considerably improves the previous best-known result (3.9546, 4.3931). To achieve the improved bounds, we call upon results from absorbing Markov chain theory and mathematical programming theory—particularly fractional quadratic programming and semidefinite programming. Moreover, we also establish some important properties of this problem, which could be of independent interest and useful for resolving this problem completely. Finally, we conjecture that the symmetric rendezvous value is asymptotically equal to 4.25 based on our numerical calculations.

Subject classifications: search and surveillance: rendezvous search; games/group decisions: teams; analysis of algorithms: suboptimal algorithms; symmetric rendezvous search; game theory; approximation algorithm; semidefinite programming relaxation.
Area of review: Optimization.

Figure: (field), reason for writing, problem, results, methodology, implications [1]

Quality of writing in general

- Well written but
- **Vocabulary:**
  - ($-$) "Complicated" vocabulary for me? n-Markovian, n-generator, Borel probability measure etc.
  - ($+$) **Compensated** by Appendix & intuition.
  - ($+$) Consistent.
  - ($+$) Introduced some **rigor** (proofs, theorems)
- Active voice and objective (proofs or conjecture based on numerical calculations)

Organisation - 1

- No SOTA/Related work section
  - Related works both in Introduction & Appendix – Introduction over 2 pages
  - Comparisons in Appendix (for different n).

- $R_6^s < u_6 = 4.4634$: The six-mixed generator is given below:

$$
\begin{aligned}
g_1 &= \{1, -1, -1, -1, 1, 1\}, & x_1 &\approx 0.2482,\\
g_2 &= \{1, -1, -1, 1, -1, 1\}, & x_2 &\approx 0.1561,\\
g_3 &= \{1, -1, -1, 1, 1, -1\}, & x_3 &\approx 0.1561,\\
g_4 &= \{1, -1, 1, -1, -1, -1\}, & x_4 &\approx 0.1867,\\
g_5 &= \{1, 1, -1, -1, -1, -1\}, & x_5 &\approx 0.2529.
\end{aligned}
$$

This result is slightly better than the upper bound 4.5678 of Anderson and Essegaier (1995), whose mixed six-generator is given below:

$$
\begin{aligned}
g_1 &= \{1, -1, -1, -1, 1, 1\}, & x_1 &\approx 0.4040,\\
g_2 &= \{1, -1, -1, 1, -1, -1\}, & x_2 &\approx 0.2120,\\
g_3 &= \{1, -1, 1, -1, -1, -1\}, & x_3 &\approx 0.1561,\\
g_4 &= \{1, 1, -1, -1, -1, -1\}, & x_4 &\approx 0.2279.
\end{aligned}
$$

Figure: Example of comparison in Appendix

Organisation - 2

- Link to implementation lost in the **middle of the paper** (p.7, p.9 out of 12 pages).
  $\rightarrow$ Maybe mention it earlier
- Well structured otherwise (personal opinion):
  - Introduction
  - Strategies, Grid Strategies, Distance-Preserving Strategies
  - Frameworks: Bounding (both upper then lower)
  - Concluding remarks with conjecture

Inspiration for the research (which pattern)

- "Historical approach" building theory/Generalizing from existing suboptimal solutions :
  - mathematical definition of problem on reduced search space
  - systematic way of getting bounds.
  - Lower bound inspired from previous related work with **different** problem with **revealed information** (lower meeting time).
- Methods taken from math. optimization : QP, SDP.
- "Divide and Conquer" : Lower bound & Upper bound. Fixed n's.
- Problem on the Line, not 3D !

Content

Negative Points

- **Broken link** to implementation $\Longrightarrow$ lack of information on implementation (algorithms ?).
- **No explanation** of how some quantities were computed (probabilities of meeting etc. Simulation ? Exact computation ?)
- **Not applicable in real life depending on situation/where it is applied** (same from related works on same problem) :
  - Maximum speed and suddenly switching direction.
  - Variance not taken into account
- **Unclear problems in previous works**, don't know that much about what was wrong !

Content

Positive Points

- Apart previously mentioned points: understandable concepts, no obvious mistakes (content)
- Step towards the solution: **Improved bounds of the rendezvous value**
- Clearly defined theorems, incrementally explained.

Evaluation/Validity of results

Evaluation through: Mathematical proofs & Benchmark (for some n)

- Proofs of theorems reducing search space
- Proof of optimality of bounds up to four digits for fixed n
- $(-)$ Higher n, not sure if really not stuck in valley?
- $(+)$ Conjecture backed up with numerical calculations.

The End

References

Figures without references come from author of the slides. The interpretation of the paper as well as the analysis do not necessarily correspond to the thoughts of the authors.

[1] Qiaoming Han, Donglei Du, Juan Vera, Luis F. Zuluaga, (2008)
Improved Bounds for the Symmetric Rendezvous Value on the Line.
Operations Research 56(3): 772–782.

[2] Stéphane Liem Nguyen, Pierre Leone, (2021)
Mise en oeuvre de méthodes d'apprentissage pour le problème de rendez-vous symétrique sur la ligne [Unpublished bachelor project]. University of Geneva.

Extra details on Evaluation/Validity of results

Evaluation through: Mathematical proofs & Benchmark (for some n)

- Proof of optimality of bounds up to four digits for fixed n
  - (upper) $\forall n \in \mathbb{N} \leq 9, 0 \leq u_n - R_n^s \leq 10^{-4}$
  - (lower) $\forall n \in \mathbb{N} \leq 7, 0 \leq r_n^s - l_n \leq 10^{-4}$ with $R^s \geq R_U \geq r_n^s$

  Based on $0 \leq a - opt \leq a - b \leq 10^{-4}$ with $a \geq opt$ and $a \geq b$