Characterizing Human Mobility in Networked Virtual Environments
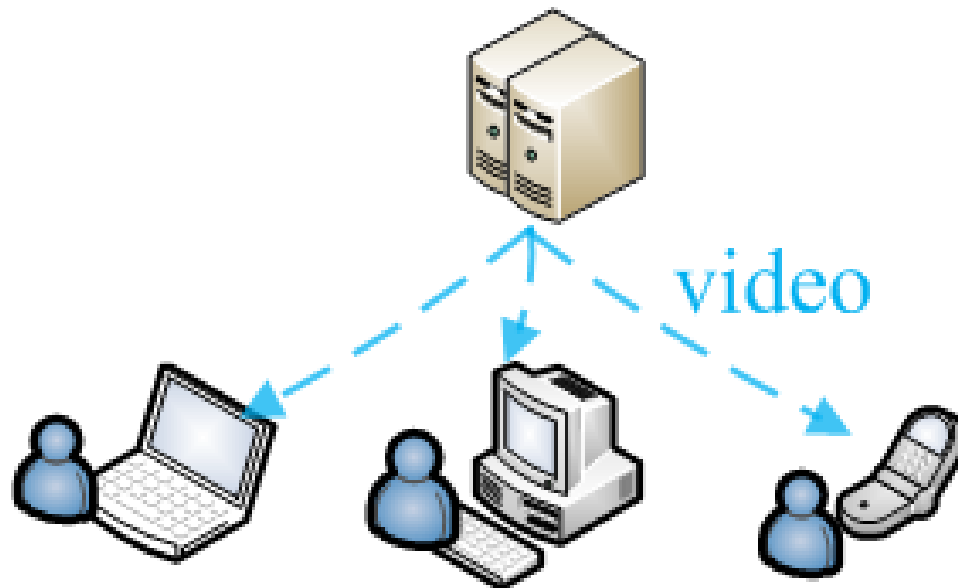
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The Netherlands**

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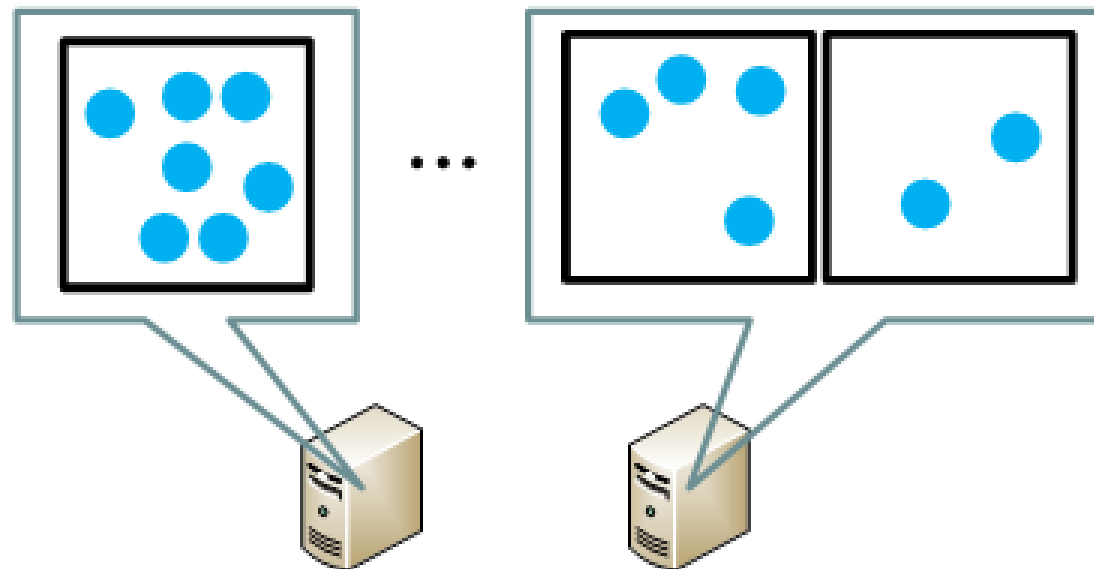Delft University of Technology

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Motivation 1/2

- Understanding the avatar mobility patterns in Networked Virtual Environments (NVEs)
  - To tune existing designs of NVEs
    1. Pre-fetching of NVE media contents according to movement

Motivation 1/2

- Understanding the avatar mobility patterns in NVE
  - To tune existing designs of NVEs
    1. Pre-fetching of NVE media contents according to movement
    2. Load balancing of workloads

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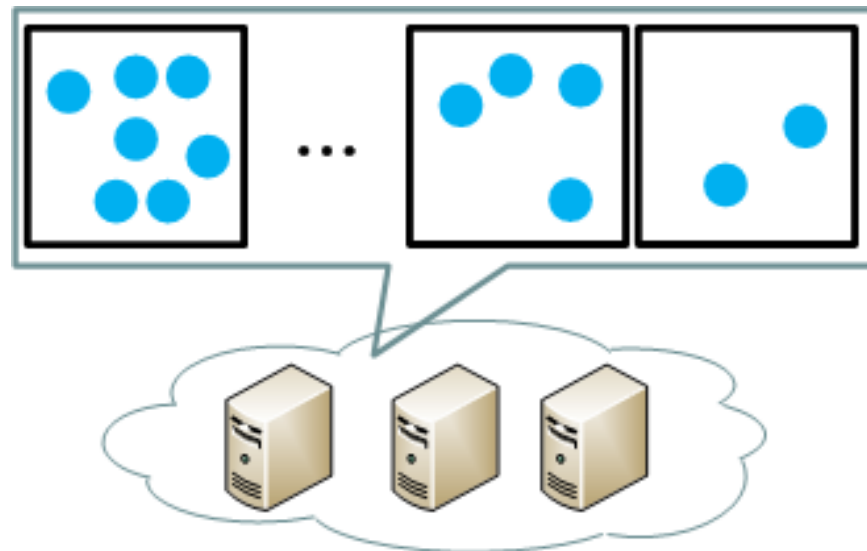Delft University of Technology

Motivation 1/2

- Understanding the avatar mobility patterns in NVE
    - To tune existing designs of NVEs
        1. Pre-fetching of NVE media contents according to movement
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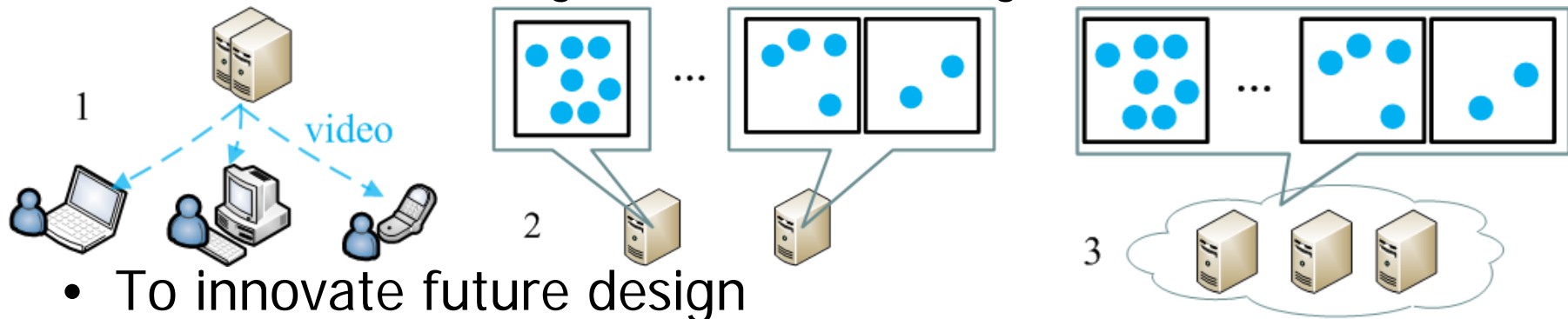   3. Resource leasing from cloud according to workloads
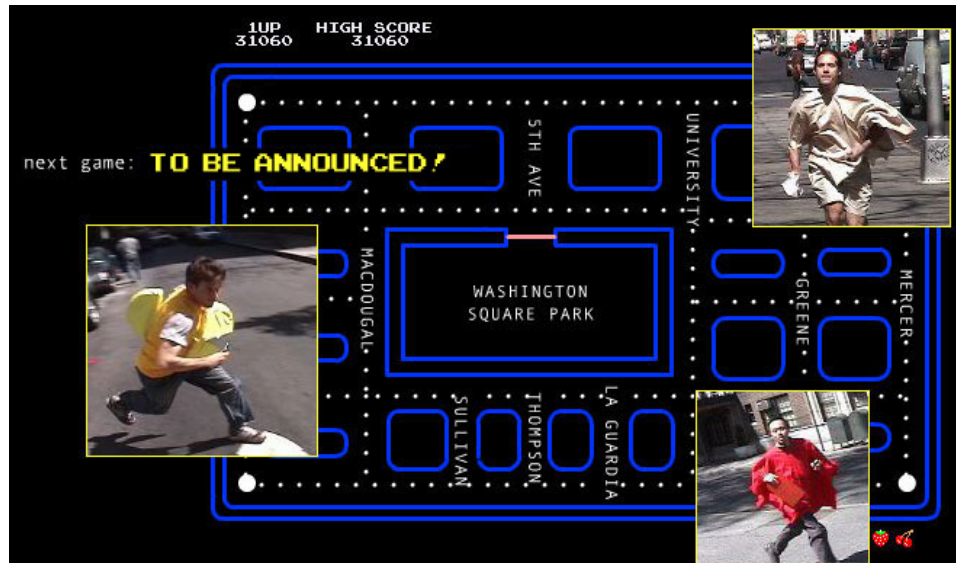
Motivation 1/2

- Understanding the avatar mobility patterns in NVE
  - To tune existing designs of NVEs
    1. Pre-fetching of NVE media contents according to movement
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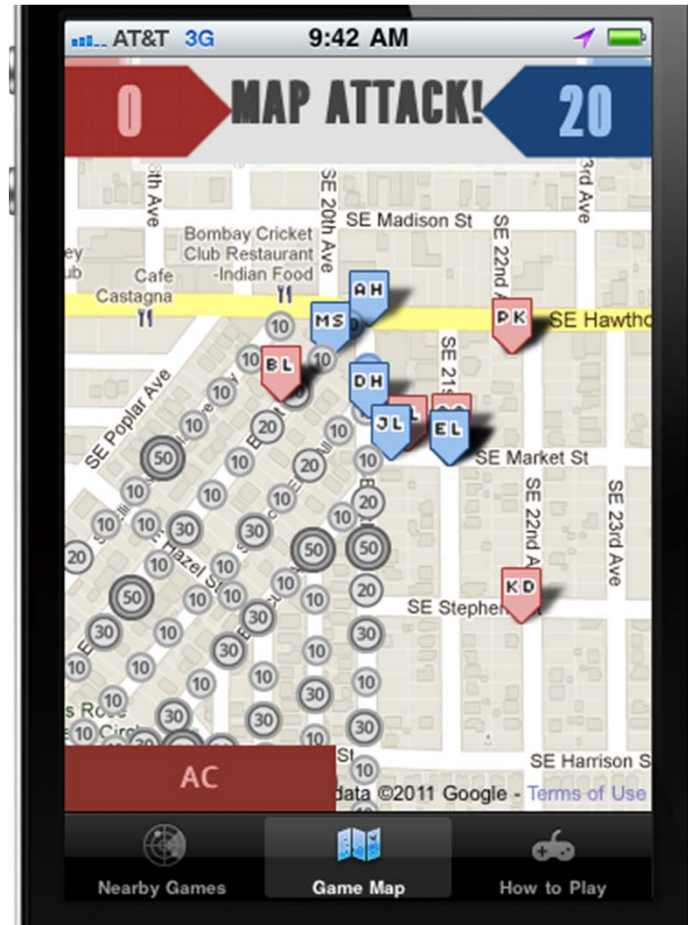   3. Resource leasing from cloud according to workloads

  - To innovate future design
- *Question*: *How similar are World of Warcraft and Second Life avatar mobility patterns?*

Motivation 2/2

- Increasing number of location based virtual environments

Pac Man Manhattan

Map Attack

- The real-world mobility affects the performance of NVEs

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Motivation 2/2

- Comparing the avatar mobility patterns with real-world human mobility patterns
  - Using the methods dealing with human mobility in real world to manage virtual world?
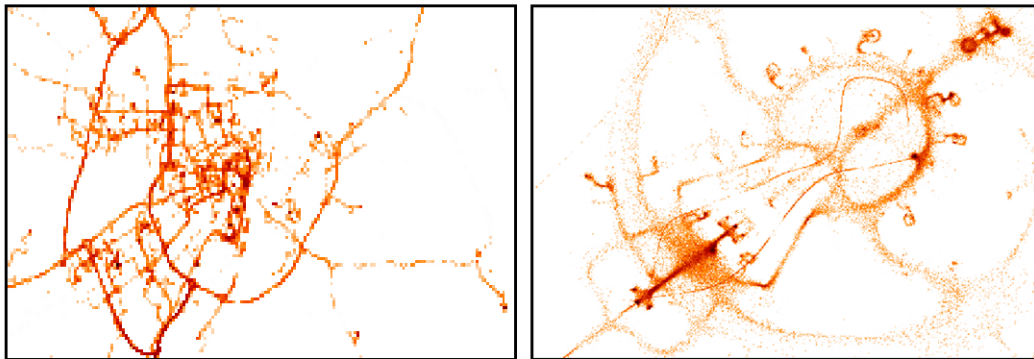 - Using the mobility models developed in real-world?

Figure 1: Mobility map for real (left) and virtual (right) cities.

- ***Question:*** *How similar are the characteristics of mobility in virtual and real world?*

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Agenda

- Datasets
- Characterization
- Implication and Limitation
- Conclusion

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Data Collection from Virtual world

- Using bots to read anonymized avatars' positions from different cities of World of Warcraft (WoW).

- 3 capital cities: StormwindCity, Ironforge, Orgrimmar from a normal playing sever

- StormwindCity from a role playing server.

Data acquired from real/virtual world

Dataset	World	Citizens	Space	Time	Granularity
WoW (ours)	Virt.	31,290	4 cites	2w	1s
SL	Virt.	26,714	4 zones	days	10s
GPS	Real	1,366	3 cities	1w	6s
GPS-2	Real	52	2 campuses	days	30s

Table 1: Dataset overview.

- 31,290 World of Warcraft avatars.
- 26,714 Second-Life avatars. Liang et al. 2009 (NUS)
  - 4 zones: Isis, Pharm, Ross, Freebies
- 1,366 persons' GPS positions. Bohte and Maat 2009 (TUDelft)
- 52 persons' GPS positions. Rhee et al. 2008, (NCSU and KAIST)

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Long-tail distributed flight length

- Flight: a straight line trip without pause or significant directional change.
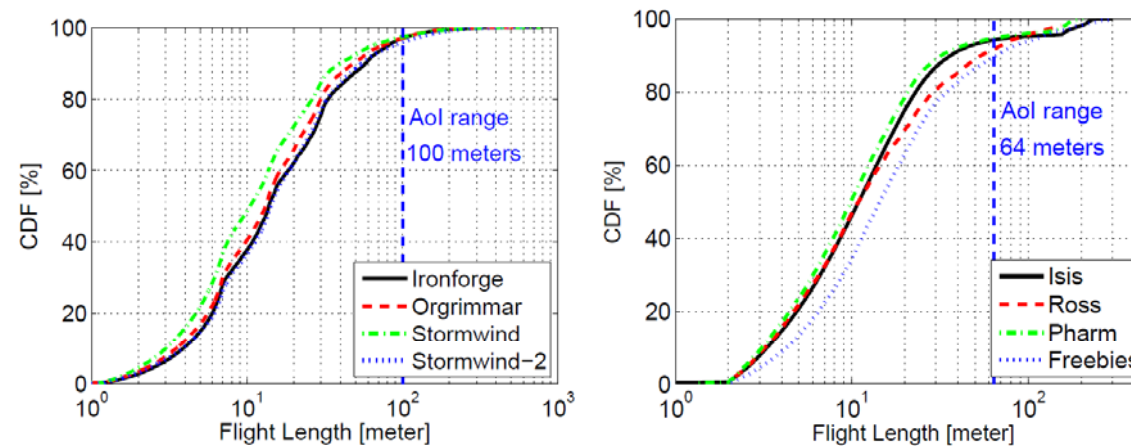

Figure 1: Flight length distribution of (left) the WoW dataset, and (right) the SL dataset (horizontal logscale).

- Most of the flights are shorter than the Area-of-Interest (AoI) range

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The distribution fitting of flight lengths: WoW vs GPS

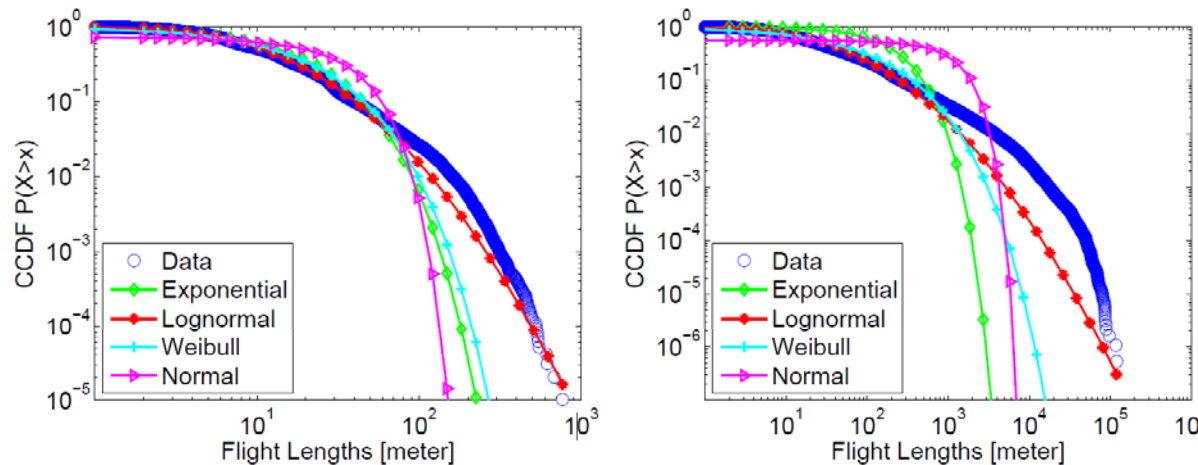- We fit the flight lengths against different distributions

Figure 2: Distribution fitting of (left) WoW dataset, and (right) the GPS dataset (all axes logscale).

- The flight lengths distributions for the two GPS datasets are longer than the two virtual world datasets

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Long-tail distributed pause duration

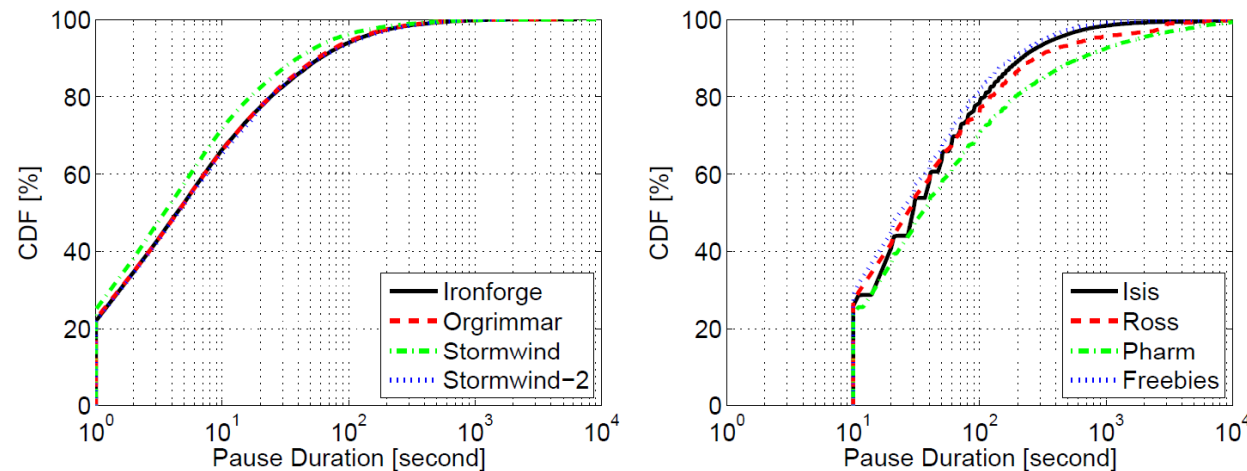- Pause duration: the time duration an individual does not move

Figure 3: Pause duration distribution of (left) the WoW dataset, and (right) the SL dataset (horizontal logscale).

- 80% of the pause durations of WoW is shorter than 30 seconds
- 80% of the pause durations of SL is shorter than 100 seconds

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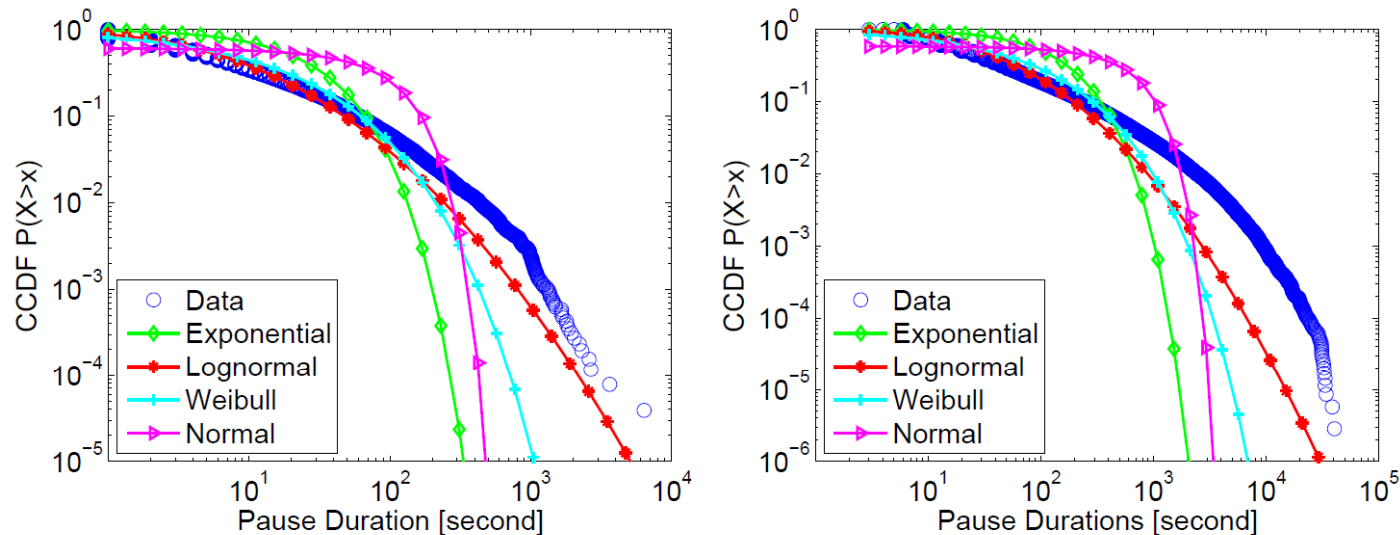# The distribution fitting of pause durations: WoW vs GPS

Figure 4: Distribution fitting of (left) WoW dataset, and (right) the GPS dataset. (all axes logscale.)

- The pause duration of the GPS dataset are longer than the virtual world data

Area popularity

- A person visited an area only if the person pauses at that area
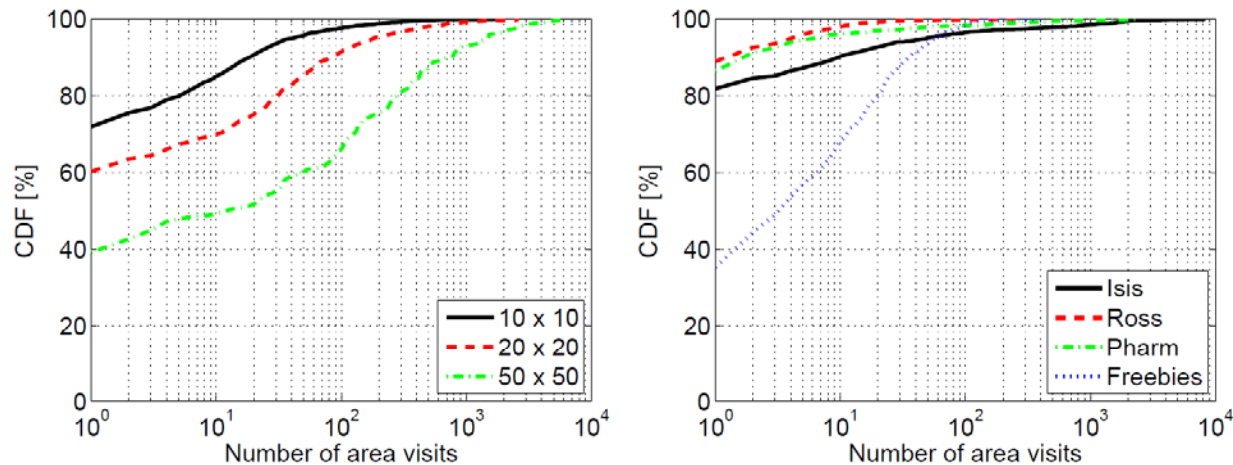

Figure 5: Number of area visits of (left) the WoW dataset, and (right) the SL dataset (horizontal logscale).

- The area popularity of virtual world is skewed
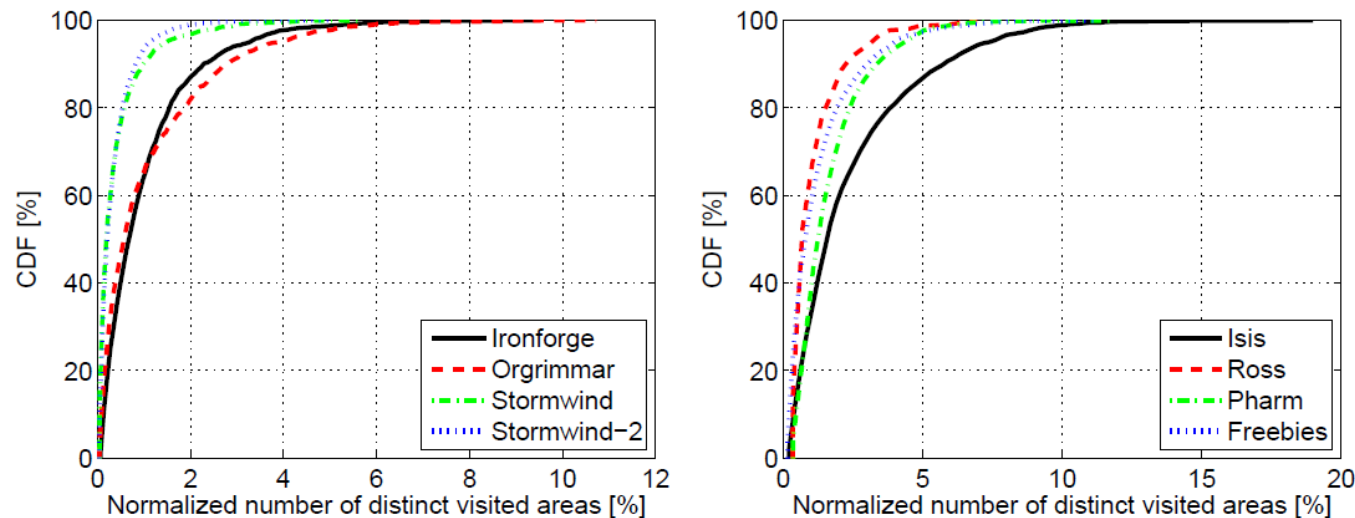
Limited number of visited areas

Figure 7: Percentage of distinct visited areas of (left) the WoW dataset, and (right) the SL dataset.

- Avatars/persons only visit a small set of the studied maps
- invisible movement boundary is present in both real and virtual worlds.

Personal preference in area visitation

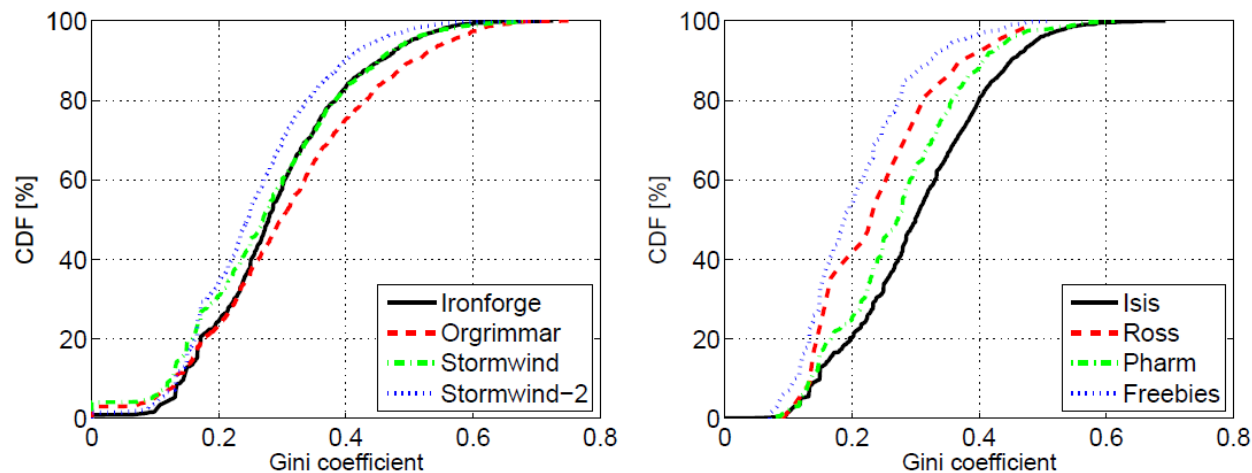- The Gini coefficient is used to quantify the inequality of personal preference

Figure 8: Gini coefficient of personal preference weight (left) the WoW dataset, and (right) the SL dataset.

- The probability of a user to visit a given area is skewed

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Implication

- Skewed area popularity
  - Caching of video/textures
  - Zone partitioning and load-balancing
- Peer-to-Peer NVE
  - Pick super nodes based on the personal preference or pause duration
  - Preference in area visitations: sharing rendered images among avatars

Limitations

- Bots
- City scenarios vs fighting scenarios
- Client side dataset collection
  - Coverage: temporal and spatial
  - Small scale

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Conclusion

- Long-tail distribution of flight lengths and pause durations
- Skewed popularity of areas
- Avatars only travel small parts of the virtual cities
- Different personal preferences for areas
- For GPS, the flight length is longer; and the personal preference to some areas is higher

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- Thanks for listening.
- Any questions, comments, suggestions?

- Siqi Shen S.Shen@tudelft.nl
- http://www.pds.ewi.tudelft.nl/~siqi/
- Data available at Game Trace Archive
  http://www.pds.ewi.tudelft.nl/~siqi/mobility/main.htm
  http://gta.st.ewi.tudelft.nl/

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