A Study of Spatial Exploration Patterns of Children

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Ultimate Goal

Cognitive development in children is based on exploration, part of which involves exploration of, and interaction with, the surrounding environment. There is an intuition that children with developmental delays like autism explore space in their surrounding environment using different motion patterns when compared to typically developing children. We propose to develop algorithms that can automatically track children in video and extract models of their exploratory motion, to enable measurement, mining, and quantitative analysis of the patterns of a child's exploratory behavior during unstructured, "free-play."

Current Work

Given a monocular, overhead video of a child engaged in free-play, we track the child across time to produce a time-stamped track map describing the child's exploration trajectory over time. We then perform quantitative analysis on the child's exploratory behavior by analyzing track globally emergent properties, and local-in-time properties.

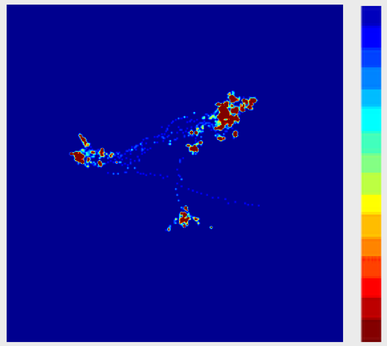
Future Work

- Applying our quantitative analysis to:
  - The same subject over time (longitudinal study)
  - Different subjects
  - Typically vs. atypically developing children
- Measuring correlation between quantitative measures
- Modelling motion of typically developing children, and motion of children possessing developmental delays.

Globally Emergent Properties

1. Time spent stationary vs. moving
2. How much space is explored
3. Geographical Distribution –> *Spatial Herfindahl Index*

$$SHI = \sum_j \left(\frac{E_j}{\sum_j E_j}\right)^2, \qquad E_j: freq\ of\ exploring\ region\ j$$



Blue: rarely explored

Red: frequently explored

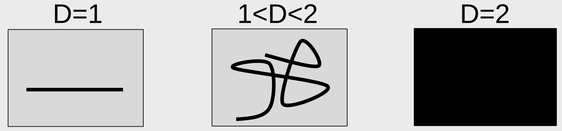
Heat Map of top-view tracked trajectories

4. Trajectory sharpness –> *Fractal Dimension*

$$D = Lim_{s\to 0}\ \log(n)/\log(1/s), \qquad n: \#\ regions,\ s: scale$$

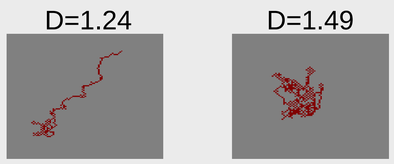
- Basic Idea – measure of space filling & roughness

D=1 | 1<D<2 | D=2



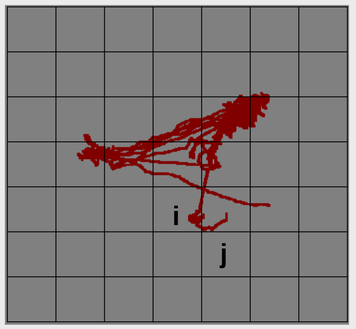
- Sample tracks

D=1.24 | D=1.49



Local-in-time Properties

1. Repetitive exploration patterns -> *Spatial Coefficient of Variation* (*SCV* higher value means more repetition of tracks)



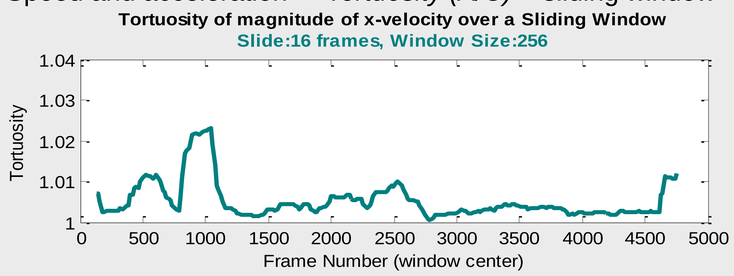
$$M = \begin{array}{c} \\ 1 \\ \\ 49 \end{array} \begin{array}{c} \begin{array}{ccc} 1 & & 49 \end{array} \\ \begin{pmatrix} \cdots & & \\ \vdots & M_{i,j} & \ddots & \vdots \\ \cdots & & \end{pmatrix} \end{array}$$

$$M_{i,j} = \#transitions\ i \rightarrow j$$

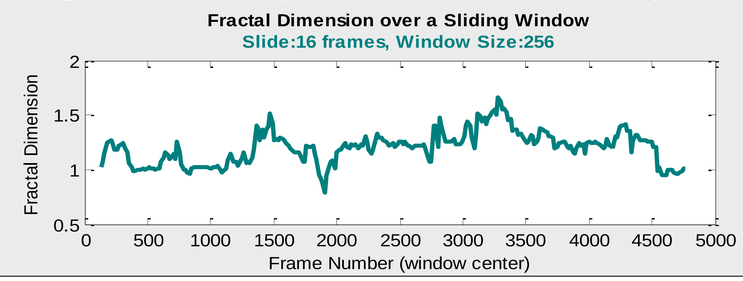
$$SCV = \sigma_M\ /\ \mu_M$$

2. How much children approach their anchor (parent)
   - Average distance from parent
   - Time spent in the vicinity of parent vs periphery
   - Latency to approach parent

3. Speed and acceleration -> *Tortuosity (A/C)* + sliding window



4. Roughness of trajectory –> *Fractal Dimension* + sliding window



References

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[2] M. Geyer, P. Russo, V. Masten. *Multivariate assessment of locomotor behavior: pharmacological and behavioral analyses.* Pharmacology Biochemistry and Behavior, *25*(1), 277-288, 1986.

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