Spatio-temporal Representation of Time-varying Pedestrian Flows

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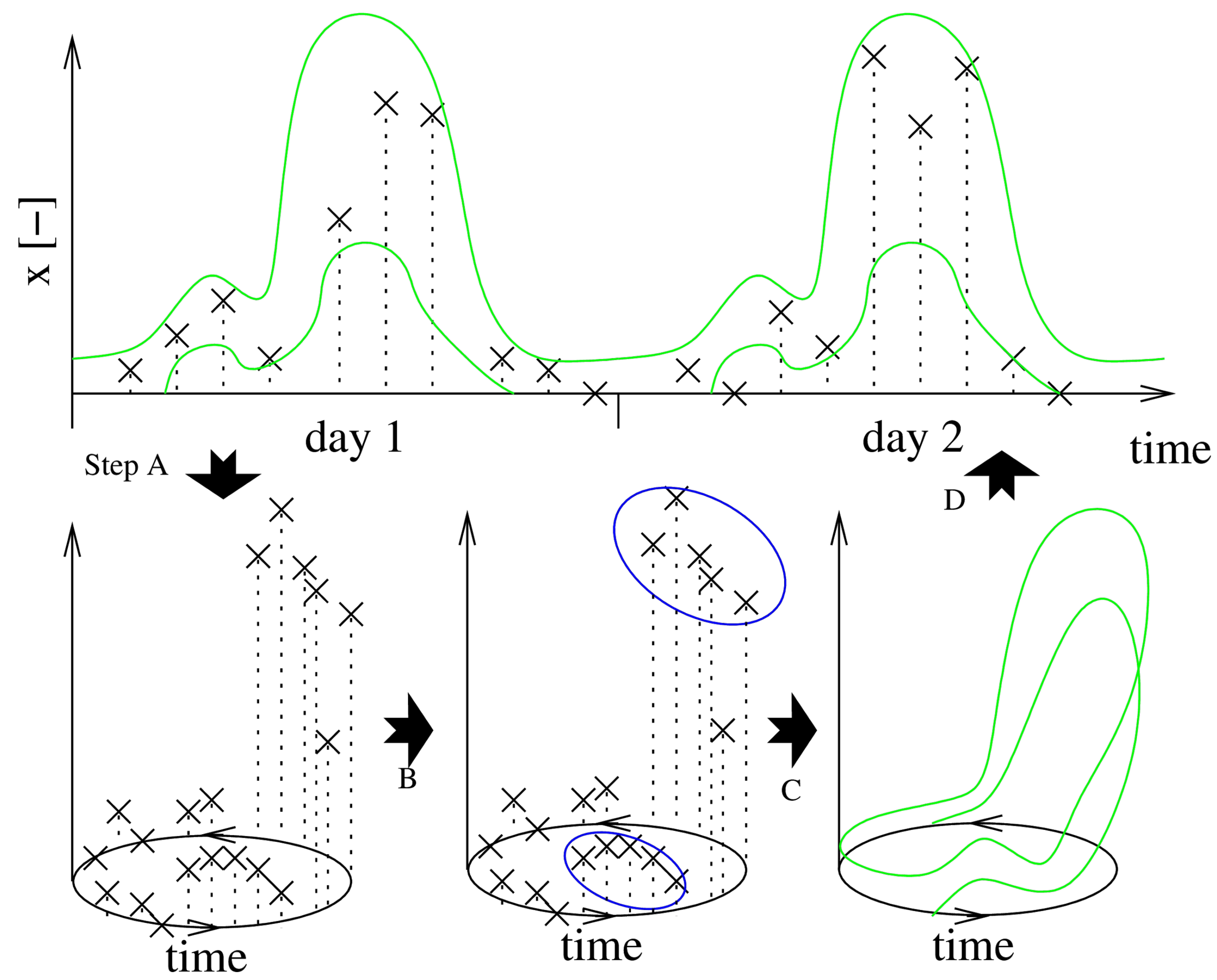
Introduction

- We introduce the concept of Warped Hypertime to help with mobile robots' pedestrian flow predictions.
- We represent the probabilistic distribution as a series of temporal dimensions wrapped in on themselves.
- This can be used to model temporally sparse information; in our case, when and how people will move through a given area.

Motivation

- We can allow our mobile robot to predict areas likely to be densely packed with people, and engage or avoid these crowds.
- By understanding the likely flow of traffic, the robot can move in a much more natural way through a crowd.
- This natural movement through people is important in the long term for having people accept robots as part of their lives.

Warped Hypertime



- apply the spectral decomposition method derived from the Frequency Map Enhancement [5],
- identify the most prominent temporal periodicities in the provided data,
- determine the parameters for the warped hypertime projection,
- split the dataset into occurrences and non-occurrences (that are mutually exclusive),
- project every measurement into a new constrained subset of multidimensional vector space, as described in [1],
- estimate the parameters of the distribution of each of these phenomena separately using an Expectation Maximisation algorithm (EM GMM)

To estimate the probability of the Bernoulli distribution of occurrences at one specific point, we compare the probabilities of occurrence and non-occurrence derived from these two distributions [7].

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Experiments

- The dataset was collected by the University Of Lincoln.
- The people presence was detected using a Velodyne 3D laser range finder attached to a mobile robot [6].
- During four weeks of measurement, we collected approximately 30,000 people detections daily.
- We compare the performance of proposed method to state-of-the-art algorithms STeF[2], DGM[3], CLiFF[4], while authors of them actively participated on the experiment.

Comparison

Method	Dynamics		Representation					Complexity	
Name	long-term	short-term	time	space	intensity	direction	speed	Memory [kB]	Train time [s]
WHyTe	✓	×	C	C	C	C	C	2	60
STeF	✓	×	C	D	×	D	×	140	20
DGM	✓	×	D	D	C	C	×	20	72
CLiFF	×	×	×	D	C	C	C	6k	$>10^4$
LSTM	×	✓	C	C	C	C	C	900	$>10^6$

C stands for the continuous, and D for the discrete representation of variables provided by method.

Prediction errors of the evaluated models and datasets

Testing sets	*Days*		*Nights*		*Days and nights*	
Criterion	*RMSE*	χ^2	*RMSE*	χ^2	*RMSE*	χ^2
WHyTe-0	0.49	23.0	0.46	0.9	0.48	23.9
WHyTe	0.49	23.4	0.00	0.2	0.40	23.6
STeF-0	0.65	10.0	0.07	16.0	0.53	26.0
STeF	0.57	10.6	0.02	8.1	0.46	18.7
DGM	0.70	25.5	0.83	0.0	0.75	25.5
CLiFF	0.60	15.5	0.16	9.2	0.50	24.7
LSTM	0.57	25.5	0.22	0.0	0.48	25.5

Outcome

- significant improvement in predicting the probability of occurrences over the other methods (20%+),
- STeF [2] and CLiFF [4] methods showed better prediction at estimating the conditional probability of flow directions,
- model created by proposed method WHyTe is smaller by magnitude(s) to its competitors

Ongoing work

- In the future work, we will evaluate the impact of compared methods to the robot's ability to predict the collision-free trajectories in a real world scenario.

References

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