HSFM- ΣNN: Combining a Feedforward Motion Prediction Network and Covariance Prediction

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Approach

Human beings tend to be **hardly predictable** on their decisions and motion. But properly predicted motion uncertainties can be used in many other fields.

HSFM-ΣNN - proposed **method** of pedestrians **motion prediction with uncertainty estimation**.

HSFM-ΣNN **combines** two different approaches: a model-based transition functions - **HSFM*** and a shallow **Neural Network** (NN) for covariance prediction.

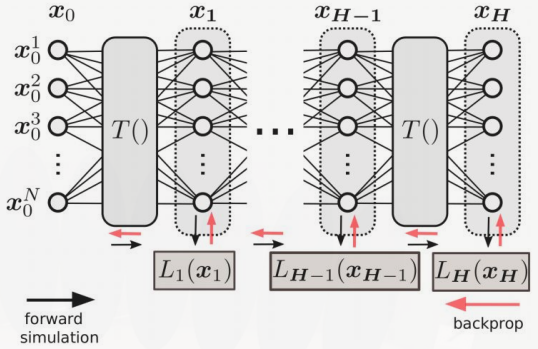

Fig.1 - The initial configuration x_0 propagates through several layers, each representing the transition function $T()$.

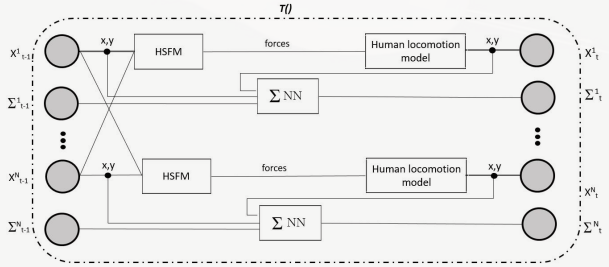

Fig.2 - Diagram of the proposed method, HSFM-ΣNN.

At each time-step the HSFM generates virtual forces, which are then integrated. Our approach combines this with a NN for covariance prediction.

*Mehta, D., Ferrer, G., Olson, E. (2018, May). "Backprop-MPDM(ICRA) (pp. 1740-1746)

*Farina, F., Fontanelli, D., Garulli, A., Giannitrapani, A., Prattichizzo, D. (2016, December). "When Helbing meets Laumond: the headed social force model" CDC conference (pp. 3548-3553)

Compared methods

A. Linearization and Covariance Forward-Propagation (**FP**)

$$x_{t+1} = T(\mu_t) + G_t(x_t - \mu_t)$$

B. Monte-Carlo(**MC**) Covariance Estimation

$$x_t^i \sim p(x_t), \quad i = 1, \ldots, N, \; x_{t+1}^i = T(x_t^i)$$

C. Neural Network(**ΣNN**) Covariance Prediction

Shallow NN

Method	percent of predicted values inside 1σ (Δ from expected)	percent of predicted values inside 3σ(Δ from expected)
LSTM	47.60 (-16.39)	69.74 (-28.25)
LSTM MC	37.16 (-26.83)	51.33 (-46.66)
HSFM MC	37.11 (-26.88)	60.98 (-37.01)
HSFM FP	6.06 (-57.93)	8.60 (-89.39)
HSFM-ΣNN	**58.79 (-5.20)**	**85.45(-12.54)**

Table.1 Comparison of calculated covariances

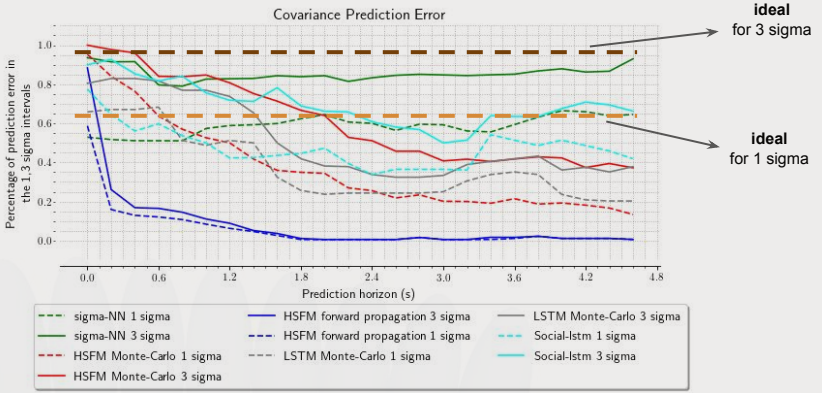

Fig.3 Evaluation of calculated covariances

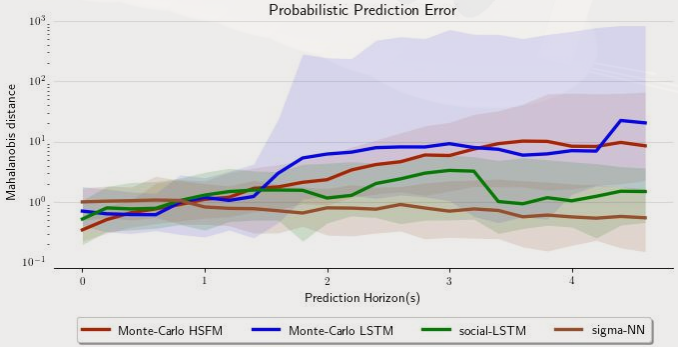

Fig.4 Mahalanobis distances

*Alahi, A., Goel, K., Ramanathan, V., Robicquet, A., Fei-Fei, L., Savarese, S. (2016). "Social lstm: Human trajectory prediction in crowded spaces"

Conclusions

- FP collapses - linearization error & vanishing gradients
- MC - expensive and underestimate uncertainties
- LSTM - degrades over time, underestimate uncertainties
- HSFM-ΣNN (proposed) - achieves consistent results, best predicted uncertainties

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