

Roto-translated Local Coordinate Frames for Interacting Dynamical Systems

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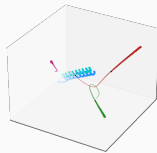
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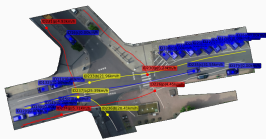


Interacting systems are everywhere

- Colliding particles
- N-body systems
- Molecules
- Motion capture
- Traffic scenes



3D Charged particles [5]



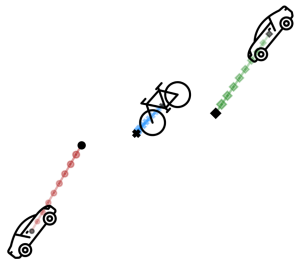
Traffic scenes, InD [1]

[5] Thomas Kipf et al. "Neural relational inference for interacting systems". In: *ICML*. 2018

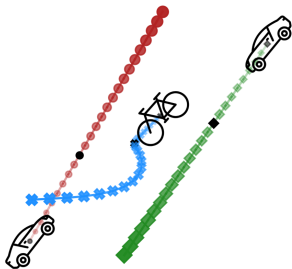
[1] Julian Bock et al. "The inD dataset: A drone dataset of naturalistic road user trajectories at german intersections". In: *2020 IEEE Intelligent Vehicles Symposium (IV)*. 2020

Future forecasting

Past

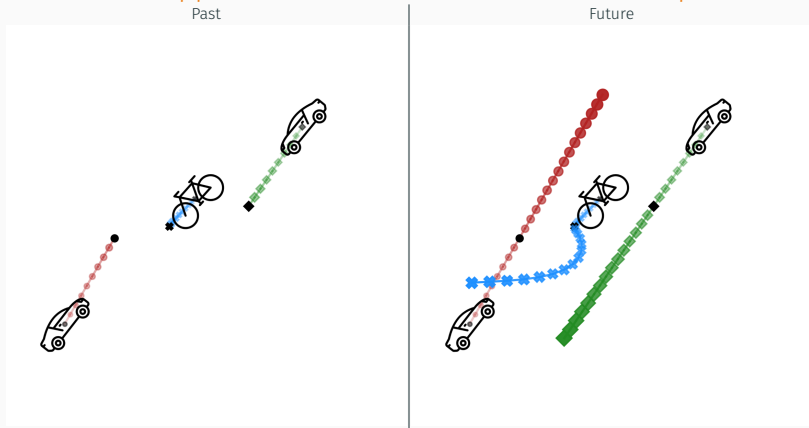


Future



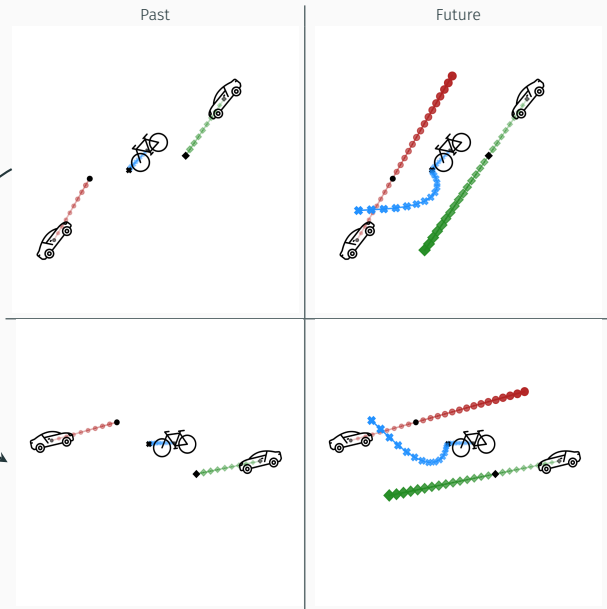
Motivation

What happens when we rotate/translate the inputs?

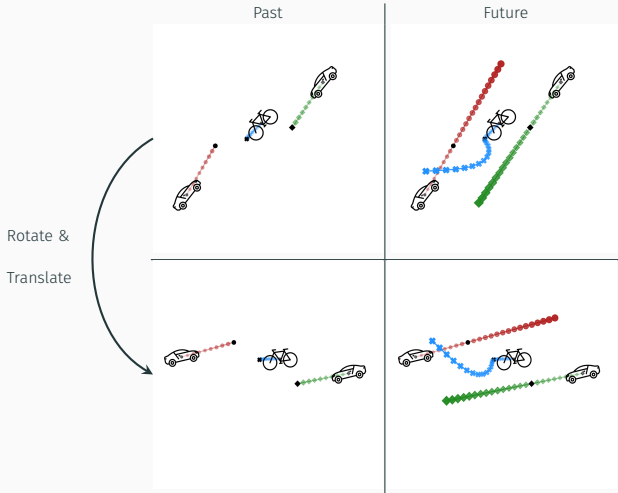


Motivation

Rotate &
Translate



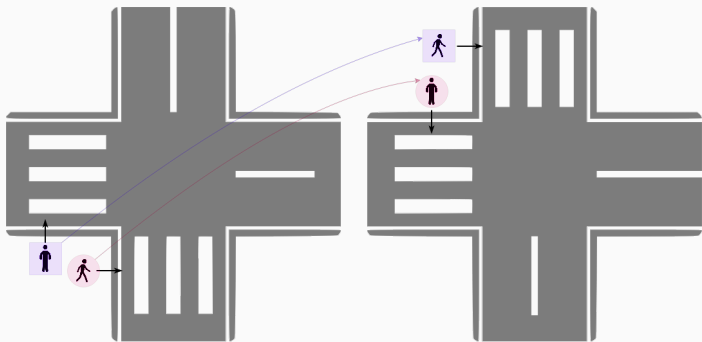
Motivation



Rototranslation equivariance

Dynamics do not change under rotations and translations

Motivation



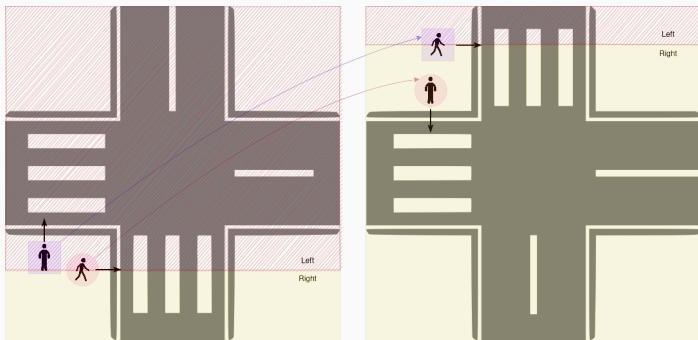
Ego-centric perspective

Objects operate in ego-centric and asymmetric views of the world

Global coordinate frames

Graphs embedded in arbitrary global coordinate frames

Motivation



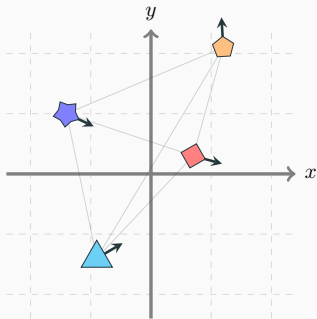
Ego-centric perspective

Objects operate in ego-centric and asymmetric views of the world

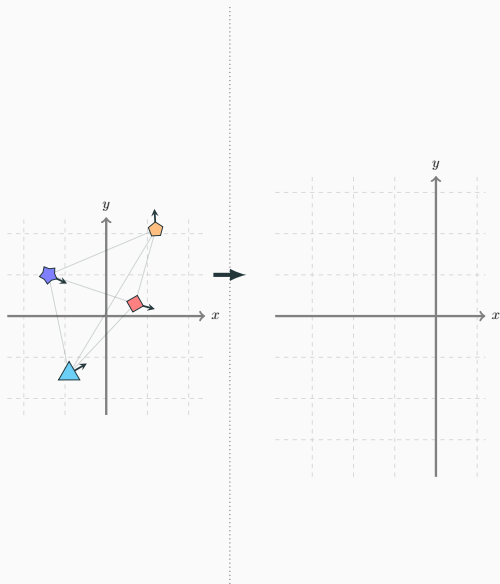
Global coordinate frames

Graphs embedded in arbitrary global coordinate frames

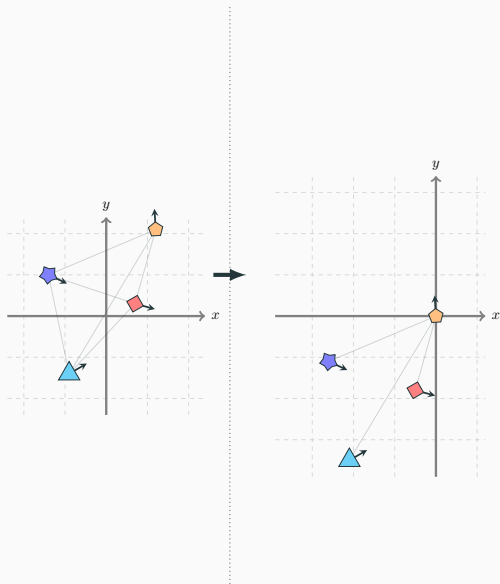
Local coordinate frames



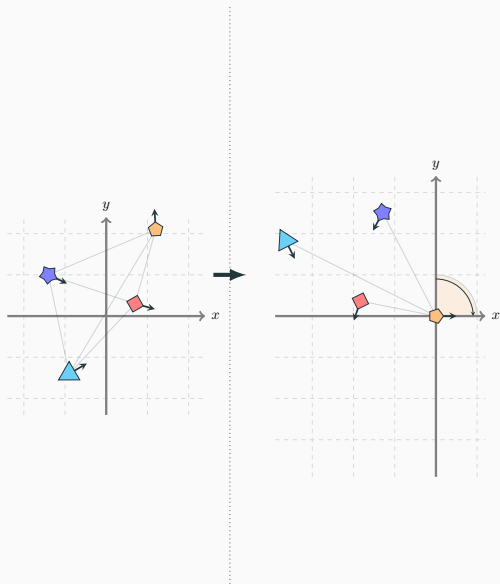
Local coordinate frames



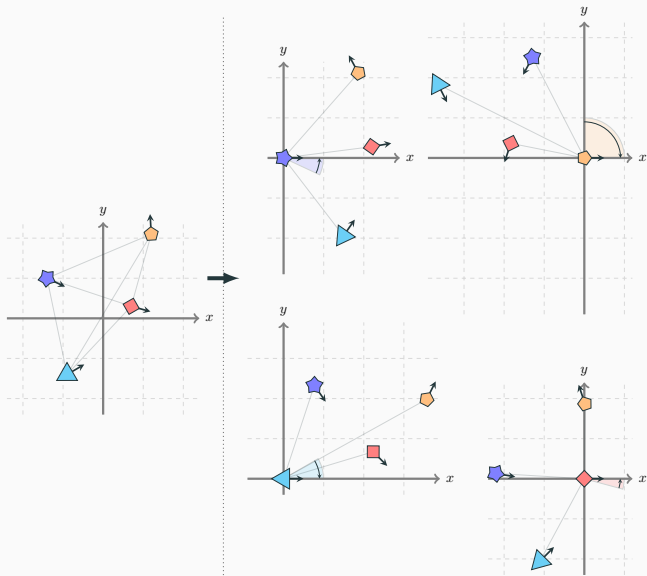
Local coordinate frames



Local coordinate frames



Local coordinate frames



Local coordinate frames as Neural relational inference models

\mathbf{x}_{t-1}

\mathbf{x}_t

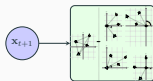
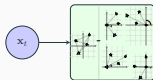
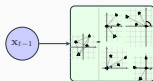
\mathbf{x}_{t+1}

[4] Diederik P Kingma and Max Welling. "Auto-encoding variational bayes". In: *ICLR*. 2014

[5] Thomas Kipf et al. "Neural relational inference for interacting systems". In: *ICML*. 2018

[3] Colin Graber and Alexander G Schwing. "Dynamic Neural Relational Inference". In: *CVPR*. 2020

Local coordinate frames as Neural relational inference models

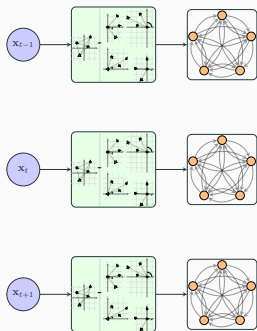


[4] Diederik P Kingma and Max Welling. "Auto-encoding variational bayes". In: *ICLR*. 2014

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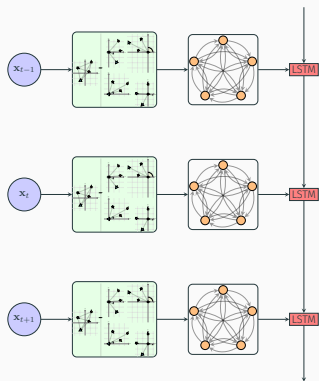


[4] Diederik P Kingma and Max Welling. "Auto-encoding variational bayes". In: *ICLR*. 2014

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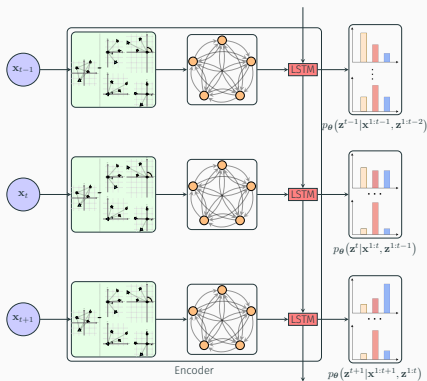


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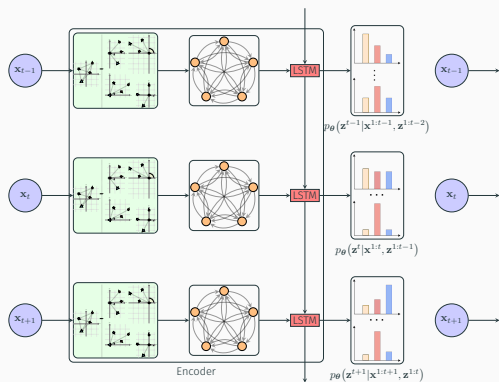


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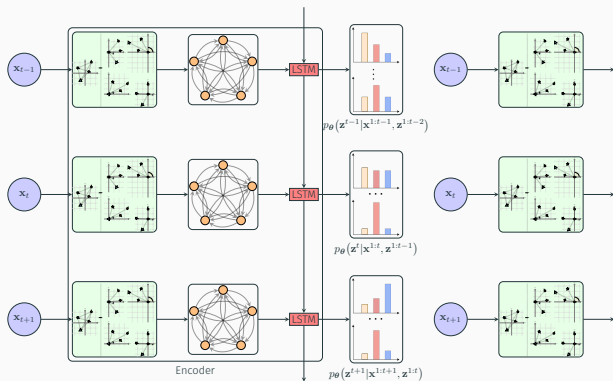


[4] Diederik P Kingma and Max Welling. "Auto-encoding variational bayes". In: *ICLR*. 2014

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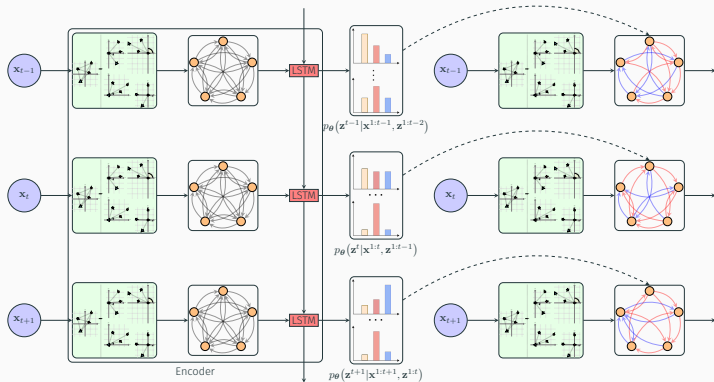


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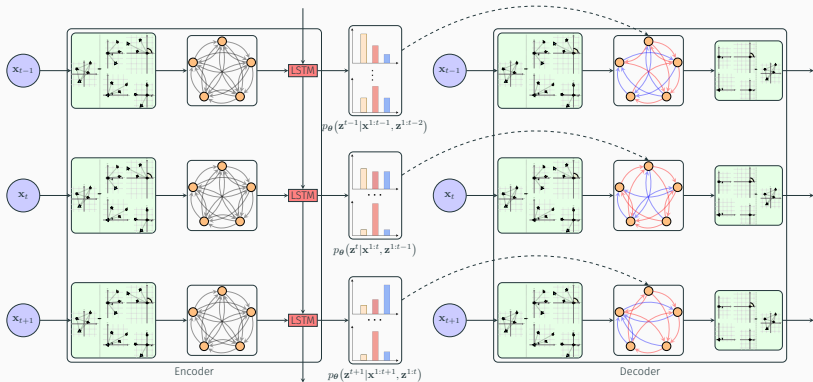


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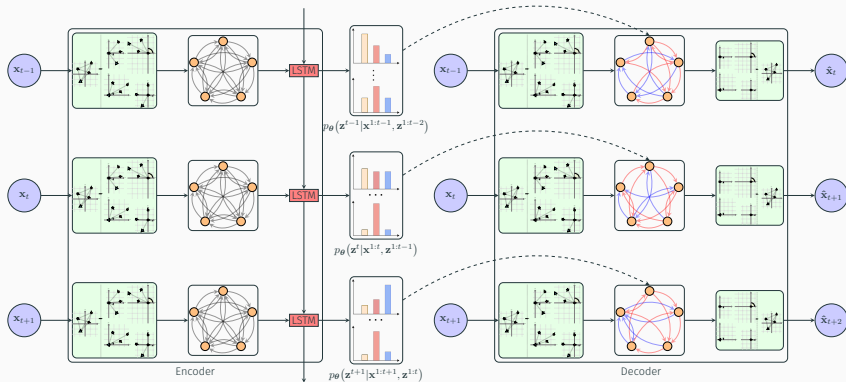


[4] Diederik P Kingma and Max Welling. "Auto-encoding variational bayes". In: *ICLR*. 2014

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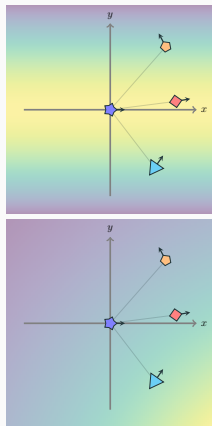
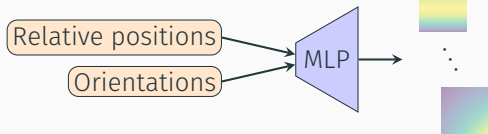
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[5] Thomas Kipf et al. "Neural relational inference for interacting systems". In: *ICML*. 2018

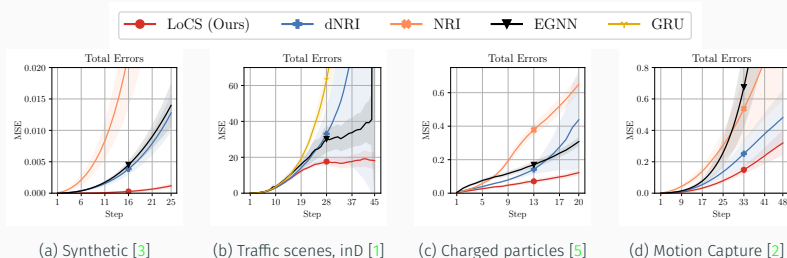
[3] Colin Graber and Alexander G Schwing. "Dynamic Neural Relational Inference". In: *CVPR*. 2020

Anisotropic continuous filtering in local coordinate frames

Directionality in graphs \implies Anisotropic filtering



Results



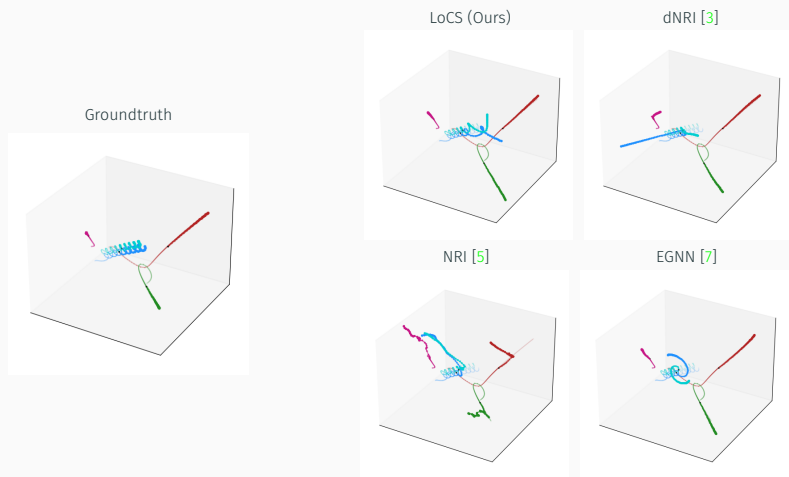
[3] Colin Graber and Alexander G Schwing. “Dynamic Neural Relational Inference”. In: *CVPR*. 2020

[1] Julian Bock et al. “The inD dataset: A drone dataset of naturalistic road user trajectories at german intersections”. In: *2020 IEEE Intelligent Vehicles Symposium (IV)*. 2020

[5] Thomas Kipf et al. “Neural relational inference for interacting systems”. In: *ICML*. 2018

[2] CMU. *Carnegie-Mellon Motion Capture Database*. 2003. URL: <http://mocap.cs.cmu.edu>

Qualitative results - charged particles



[5] Thomas Kipf et al. "Neural relational inference for interacting systems". In: *ICML*. 2018

[3] Colin Graber and Alexander G Schwing. "Dynamic Neural Relational Inference". In: *CVPR*. 2020

[7] Víctor García Satorras, Emiel Hooigemboom, and Max Welling. "E(n) Equivariant Graph Neural Networks". In: *ICML*. 2021

Conclusion

- Local coordinate frames for all objects
- Invariance/equivariance to global roto-translations
- Anisotropic continuous filters in local coordinate frames
- Demonstrate effectiveness on a range of 2D/3D settings
- Source code will be available at:
<https://github.com/mkofinas/locs>

- [1] Julian Bock et al. “The inD dataset: A drone dataset of naturalistic road user trajectories at german intersections”. In: *2020 IEEE Intelligent Vehicles Symposium (IV)*. 2020.
- [2] CMU. *Carnegie-Mellon Motion Capture Database*. 2003. URL: <http://mocap.cs.cmu.edu>.
- [3] Colin Graber and Alexander G Schwing. “Dynamic Neural Relational Inference”. In: *CVPR*. 2020.
- [4] Diederik P Kingma and Max Welling. “Auto-encoding variational bayes”. In: *ICLR*. 2014.
- [5] Thomas Kipf et al. “Neural relational inference for interacting systems”. In: *ICML*. 2018.

- [6] Danilo Jimenez Rezende, Shakir Mohamed, and Daan Wierstra. “Stochastic backpropagation and approximate inference in deep generative models”. In: *ICML*. 2014.
- [7] Víctor Garcia Satorras, Emiel Hoogeboom, and Max Welling. “E(n) Equivariant Graph Neural Networks”. In: *ICML*. 2021.
- [8] Martin Simonovsky and Nikos Komodakis. “Dynamic edge-conditioned filters in convolutional neural networks on graphs”. In: *CVPR*. 2017.