Transformers for Robotics

Lecture 11

Current Paper Line-up

- Monday, October 21th, 2024
  - Paper 4: Stefan, Octo
  - Paper 5: Xuji, SceneSense: Diffusion Models for 3D Occupancy Synthesis from Partial Observation
  - Paper 6: Aritra, Deep Transformer Q-Networks for Partially Observable Reinforcement Learning
- Monday, October 28th, 2024
  - Paper 7: Himanshu, Set Transformer: A Framework for Attention-based Permutation-Invariant Neural Networks
  - Paper 8: James, Open World Symbolic Planning
  - Paper 9: William, Delicate Objects
  - Jensen, SAM/SAM2 papers

- Monday, November 4th, 2024
  - Paper 10: Carson, *Visio-tactile transformers for manipulation*
  - Paper 11: Peter, *From Pixels to Predictions: Spectrogram and Vision Transformer for Better Time Series Forecasting*
  - Paper 12: Naren, Waypoint Transformer: Reinforcement Learning via Supervised Learning with Intermediate Targets
- Monday, November 18th, 2024
  - Paper 13: Andy, Swin Transfomers
  - Paper 14: Lekai, Model Merge on LLM
  - Paper 15: -

Project

- Your final project is a 8-page paper following the format of the "Conference on Robotic LearningLinks to an external site." (CoRL).
- A valid final project for this class will require:
  - Articulate a clear hypothesis at the intersection of robotics and learning that is grounded in course content
  - Grounding of the proposed idea in the existing literature ("Introduction")
  - A detailed description of algorithms and tools used ("Materials and Methods"). These do not need to be original work, but sufficient for a beginning graduate student (you!) to reproduce the work
  - Experimental results (in-)validating your hypothesis ("Results")
  - A critical analysis of your experiments and outcomes ("Discussion")

Project: Heilmeier Catechism

- **What are you trying to do?**
  - Articulate your objectives using absolutely no jargon.
- **How is it done today, and what are the limits of current practice?**
  - This question addresses the state of the art and highlights the shortcomings of existing approaches.
- **What is new in your approach, and why do you think it will be successful?**
  - You need to explain what is innovative about your solution and why it is likely to succeed where others have failed.
- **Who cares?**
  - Identify the stakeholders who would benefit from the solution and why it matters to them.
- **If you're successful, what difference will it make?**
  - Explain the broader impact of your success, both practically and strategically.
- **What are the risks?**
  - Acknowledge the potential challenges and uncertainties that might prevent success.
- **How much will it cost?**
  - Estimate the financial investment required to complete the project.
- **How long will it take?**
  - Provide a realistic timeline for the project's completion.
- **What are the midterm and final "exams" to check for success?**
  - Define the measurable milestones and metrics that will be used to evaluate progress and ultimate success.

Project: Naren and Yutong

- **What are you trying to do?**
  Increase diffusion speed and robustness by limiting the horizon by *relying on safe waypoints* – make behavior cloning more robust when the space of demonstrated trajectories is left
- **How is it done today, and what are the limits of current practice?**
  Diffusion creates a long horizon of actions, but then re-creates it continuously to implement reactive control, which is computationally expensive
- **What is new in your approach, and why do you think it will be successful?**
  Instead of diffusing the entire trajectory at once, we break it down into intermediate waypoints
- **Who cares?** Imitation learning requires a lot of data, waypoints allow to chain smaller samples into many larger samples.
- **If you're successful, what difference will it make?** Better models from less data.
- **What are the risks?**
  - Acknowledge the potential challenges and uncertainties that might prevent success.
- **How much will it cost?**
  - Estimate the financial investment required to complete the project.
- **How long will it take?**
  - Provide a realistic timeline for the project's completion.
- **What are the midterm and final "exams" to check for success?**

  Midterm: giving a fixed set of waypoints use "task conditioning" (push-T vs kitchen)
  Final: "Franka kitchen" example in simulation with waypoints and compare computational cost and trajectory length

Project: Carson Kohlbrenner and Jay Vakil

- **What are you trying to do?**
  - Use VLM fine-tuning to make up for manufacturing variety in tactile sensors across datasets
- **How is it done today, and what are the limits of current practice?**
  - Tactile sensor suffer from large variability
- **What is new in your approach, and why do you think it will be successful?**
  - Pre-train on large dataset, fine tune on specific sensor after system integration
- **Who cares?**
  - Robots getting more tactile information (Gelsight, Digit)
- **If you're successful, what difference will it make?**
  - Explain the broader impact of your success, both practically and strategically.
- **What are the risks?**
  - Acknowledge the potential challenges and uncertainties that might prevent success.
- **How much will it cost?**
  - Estimate the financial investment required to complete the project.
- **How long will it take?**
  - Provide a realistic timeline for the project’s completion.
- **What are the midterm and final "exams" to check for success?**
  - Midterm: fine-tuning approach
  - Final: classify generalization ability of tactile models across different datasets

Project: Aritra and Himanshu

- **What are you trying to do?**
  - Improve learning under uncertainty in human-robot collaboration
- **How is it done today, and what are the limits of current practice?**
  - Tree-search solve POMDPs today, but don't scale well for large state spaces
- **What is new in your approach, and why do you think it will be successful?**
  - Use diffusions models to solve POMDP/belief MDPs, allows you to scale POMDPs to *larger* action spaces
- **Who cares?**
  - People solving POMPDs for robotics (because it needs trajectories)
- **If you're successful, what difference will it make?**
  - Solution quality will increase
- **What are the risks?**
- **How much will it cost?**
  - Estimate the financial investment required to complete the project.
- **How long will it take?**
  - Provide a realistic timeline for the project's completion.
- **What are the midterm and final "exams" to check for success?**
  - Midterm: simulator of HRI tabletop object removal task with tree-search for baseline
  - Final: compare with diffusion model and show that actions improve over tree search

Project: Stefan and William

- **What are you trying to do?**
  - Improve delicate object / contact-rich foundation models
- **How is it done today, and what are the limits of current practice?**
  - VLAs are trained without force, which is critical quantity for contact-rich manipulation
- **What is new in your approach, and why do you think it will be successful?**
  - Add force to transformer/diffusion VLAs by finetuning
- **Who cares?**
  - Imitation learning for contact-rich manipulation
- **If you're successful, what difference will it make?**
  - Better imitation learning with lesser data
- **What are the risks?**
  - Acknowledge the potential challenges and uncertainties that might prevent success.
- **How much will it cost?**
  - Estimate the financial investment required to complete the project.
- **How long will it take?**
  - Provide a realistic timeline for the project's completion.
- **What are the midterm and final "exams" to check for success?**
  - Midterm: deploy diffusion policy and finetune Octo as a baseline on the Deligrasp dataset w/o force
  - Final: ablations - train with only force, downsample the data, peg-in-hole,

Heilmeier: Max and Jensen

- **What are you trying to do?**
  - Blockstacking using VLM and LLM only.
- **How is it done today, and what are the limits of current practice?**
  - Symbolic planning with uncertainty handling results in a brittle bespoke solution
- **What is new in your approach, and why do you think it will be successful?**
  - All reasoning is done by the LLM, including handling noise, creating a new baseline that is truly open world.
- **Who cares?**
  - LLM-everything researchers and those who want to understand their limitations.
- **If you're successful, what difference will it make?**
  - True open world capability
- **What are the risks?**
  - LLM might not be able to understand physics and uncertainty
- **How much will it cost?**
- **How long will it take?**
- **What are the midterm and final "exams" to check for success?**
  - Midterm: VLM demonstration of block-stacking
  - Final: active perception and planning dataset

Project: Peter Kinder

- **What are you trying to do?**
  - Extend Spectrogram/ViT approach from univariate to multivariate timeseries for finance data forecasting
- **How is it done today, and what are the limits of current practice?**
  - Unable to include additional context such as macroeconomic trends such as GDP
- **What is new in your approach, and why do you think it will be successful?**
  - Macroeconomic data haven't been used so far
- **Who cares?**
  - Better stockmarket prediction, possibly other timeseries
- **If you're successful, what difference will it make?**
  - Better accuracy in time-series in prediction
- **What are the risks?**
  - Acknowledge the potential challenges and uncertainties that might prevent success.
- **How much will it cost?**
  - Estimate the financial investment required to complete the project.
- **How long will it take?**
  - Provide a realistic timeline for the project's completion.
- **What are the midterm and final "exams" to check for success?**
  - Midterm: full implementation of original paper
  - Final: ablation study with different timeseries on Yahoo timeseries

Project:James

- **What are you trying to do?**
  - Create a blockstacking dataset
- **How is it done today, and what are the limits of current practice?**
  - Robot foundation models record trajectories, images, and text descriptions, does not include 3D data and does not focus on entire sequences, which does not help with error correction (no negative examples)
- **What is new in your approach, and why do you think it will be successful?**
  - It contains negative examples and how to correct errors as they happen.
- **Who cares?**
  - Better train language-based foundation models where reasoning happens.
- **If you're successful, what difference will it make?**
  - Explain the broader impact of your success, both practically and strategically.
- **What are the risks?**
  - Acknowledge the potential challenges and uncertainties that might prevent success.
- **How much will it cost?**
  - Estimate the financial investment required to complete the project.
- **How long will it take?**
  - Provide a realistic timeline for the project’s completion.
- **What are the midterm and final "exams" to check for success?**
  - Midterm (after break): planner works and implements tower building
  - Final: 20 tower building sequences

Project:Xujia and Andy

- **What are you trying to do?**
  - Guess the 3D shape of an object by filling in the gaps using diffusion models
- **How is it done today, and what are the limits of current practice?**
  - Neural Radial Fields require shots from many perspective and a lot of compute, ScenseSense uses in-painting?
- **What is new in your approach, and why do you think it will be successful?**
  - You need to explain what is innovative about your solution and why it is likely to succeed where others have failed.
- **Who cares?**
  - Identify the stakeholders who would benefit from the solution and why it matters to them.
- **If you're successful, what difference will it make?**
  - Explain the broader impact of your success, both practically and strategically.
- **What are the risks?**
  - Acknowledge the potential challenges and uncertainties that might prevent success.
- **How much will it cost?**
  - Estimate the financial investment required to complete the project.
- **How long will it take?**
  - Provide a realistic timeline for the project’s completion.
- **What are the midterm and final "exams" to check for success?**
  - Midterm: Creating a dataset of 3D voxel data + RGB-D images of everyday objects in Webots
  - Final: Compare different conditioning methods for the diffusion to minimize error

Project:Lekai

- **What are you trying to do?**
  - Merge models for distributed reinforcement learning
- **How is it done today, and what are the limits of current practice?**
  - Using the Tedrake framework...
- **What is new in your approach, and why do you think it will be successful?**
  - Sharing the reward machines from local dataset/robot instead of transferring the entire model, as the information in the reward is actually sufficient.
- **Who cares?**
  - Less bandwidth, preserving privacy
- **If you're successful, what difference will it make?**
- **What are the risks?**
- **How much will it cost?**
- **How long will it take?**
- **What are the midterm and final "exams" to check for success?**
  - Midterm: Reproduce Tedrake framework using their minecraft benchmark
  - Final: compare with proposed approach

Heilmeier Questions

- **Who cares?** OTHER RESEARCHERS
- **What are the risks?** IF THERE ARE NO RISKS, IT'S NOT RESEARCH
- **How much will it cost?** IT HAS TO BE FREE
- **How long will it take?** YOU ONLY HAVE A FEW WEEKS. IF YOUR IDEA IS TOO BIG, WHAT IS THE FIRST STEP?
- **What are the midterm and final "exams" to check for success?** WHERE WILL YOU BE IN 4 WEEKS, WHERE IN 8?
- **If you're successful, what difference will it make?** CAN YOU TRAIN FASTER, USE LESS MEMORY, IMPROVE ACCURACY? WILL IT BECOME MORE EXPLAINABLE, MORE COMPACT, EASIER TO UNDERSTAND?

Project: In One Sentence	**Paper(s)**	**Members**
Pre-training/fine-tuning a (lightweight?) VLM from scratch	OpenVLA, tinyVLA, …	Jay Vakil, Carson Kohlbrenner
Diffusion with intermediate waypoints	Diffusion Policy, etc	Yutong Zhang, Naren Sivagnanadasan
Diffusion Models for Decision Making under Uncertainty	CleanDiffuser, DTQN	Himanshu Gupta, Aritra Chakrabarty
Training Robot Policies on Grasp Force Feedback	https://arxiv.org/abs/2403.07832	William Xie, Stefan Caldaru
ViT and spectrogram for multivariate time series forecasting	*From Pixels to Predictions: Spectrogram and Vision Transformer for Better Time Series Forecasting*	Peter Kinder
Block stacking with foundation models demo	Blox-Net: Generative Design-for-Robot-Assembly Using VLM Supervision, Physics Simulation, and a Robot with Reset	Max Conway, Jensen Lavering
Vision & Language Dataset of Robot Manipulation Actions	Entropy-Ranked Object Memory, Watson, Xie, Hasbini, Correll	James Watson
Diffusion model generate 3D octomap	SceneSense:Diffusion Models for 3D Occupancy Synthesis from Partial Observation	Xujia Zhang, Andy Ho
Robotic LLM Merge	Model Merging in LLMs	Lekai Chen