A Tiny Guide for beginners in Multi-Agent Systems Research
--Whom to be followed, what to do and how to do at the beginning as a researcher

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(This note introduces some resources where you can read papers from, mainly in multi-agent research)

There are three big factions for general Multi-Agent Systems Research
1. University of Massachusetts (UMass) Gang, having the Legend Prof. Victor R. Lesser, the father of Multi-Agent, covering almost all important topics in this area
2. Reasoning Gang, mainly on reasoning (logic)
3. Carnegie Mellon University (CMU) Gang, mainly on planning, learning, and robotics

Question: Why we need to define different factions?
A short answer: Because we are researchers, we need to know them so that we can create something new!

A long answer:
Below is an illustration structure.

different backgrounds -> different knowledge -> different approaches -> different outputs
|_____|
|
Similar Targets / Problems

By defining different factions, we could have a multi-dimension view to formulate the similar (even the same) questions. For example, people use Back Propagation (BP) algorithm in deep learning. It is actually a feedback design to train neural networks.

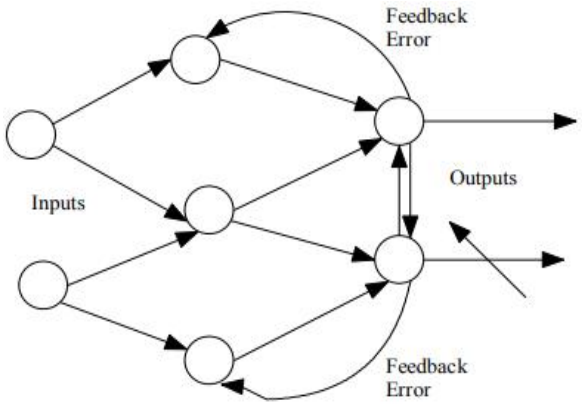

Fig1. Back Propagation (Feedback) in an Easy Neural Network Example

While feedback design is wildly used in Control for many years.

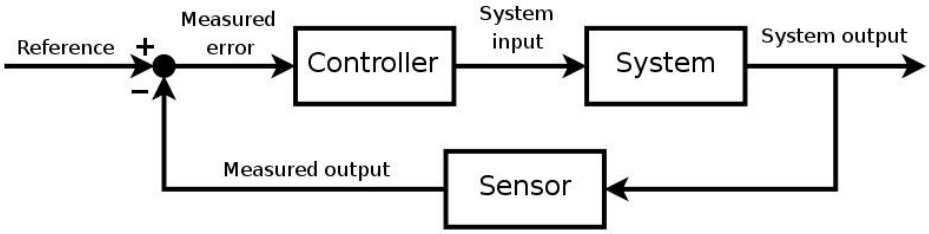

Fig2. Back Propagation (Feedback) in an Easy Neural Network Example

So it kind of transferring one method in one approach (Control in this case) to another approach (Deep Learning in this case). And the similar/same target in this case is to solve a kind of Dynamic Programming problems.

Also, by transferring knowledge from one field (approach) to another field (approach), people create fruitful new methods and new knowledge. For example, Claude Elwood Shannon borrowed the entropy in statistical thermodynamics to define the “amount of information” in information theory, a.k.a. Shannon Entropy. People take ideas in Evolutionary Biology to create Genetic Algorithm. Researchers mimic the thermodynamics model from annealing in metallurgy to create Simulated Annealing algorithm. Being inspired by Pheromone in Biology, Marco Dorigo proposed Ant Colony Optimization algorithms.

Actually, most new knowledge and methods are created in this way.

Fortunately, Multi-Agent Systems is such an area that includes many approaches. You can read my survey below to have a glimpse of three of them.

My superficial survey in Multi-Agent Systems:
https://github.com/klyw1998/Multi-Robot-Systems/blob/main/Survey_Future%20work%20in%20multi-agent%20systems%20research%20with%20probably%20approaches.pdf

With my explanation above, I am sure that you could understand a little bit deeper about research in Multi-Agent Systems. Taking Multi-Agent Deep Reinforcement Learning (MADRL) approach as an example, it includes four areas, Multi-Agent System, Deep Learning, Reinforcement Learning, and Game Theory. In this case, new knowledge in one area could boost new knowledge in the whole MADRL approach.

Defining different factions and learning from them is to form your own knowledge base for different approaches, which could make a huge difference in this area. This is why we need to define different factions and learn from them.

Unfortunately, more and more groups are realizing this. But we are not that late!

Some general research areas:

Learning, Reinforcement Learning, Deep Learning, Deep Reinforcement Learning, Multi-Agent Deep Reinforcement Learning, Multi-Agent Systems, Multi-Robot Systems, Robotics, Control, Optimization, Decision Making, Planning, Mechanism Design, Reasoning, Logic, Game Theory, Complexity, Security, Verification

Recap of three big factions for general Multi-Agent Systems Research
1. University of Massachusetts (UMass) Gang, general Multi-Agent Systems
2. Reasoning Gang, mainly on reasoning (logic)
3. Carnegie Mellon University (CMU) Gang, mainly on planning, learning, and robotics

Whom to be followed:

Some Multi-Agent Labs:
(F means Faction; blank means No Faction or No Extra)

Institute	Professor	PhD thesis	Main Research Area	Background	F	Extra
Oxford	**Shimon Whiteson**	**Adaptive Representations for Reinforcement Learning**	**Deep Reinforcement Learning**	**PhD in UT Austin**	**3**	**Legend Peter Stone's student**
UTA	**Peter Stone**	**Layered Learning in Multi-Agent Systems**	**Learning, Multi-Agent Systems, and Robotics**	**PhD in CMU**	**3**	
CMU	**Howie Choset**	**Sensor Based Motion Planning_The Hierarchical Generalized Voronoi Graph**	**Robotics, Planning, and Mechanism Design**	**PhD in Caltech**	**3**	
USC	**Sven Koenig**	**Goal-Directed Acting with Incomplete Information**	**Decision Making, Planning, Robotics**	**PhD in CMU**	**3**	
Oxford	**Michael Wooldridge**	**The Logical Modelling of Computational Multi-Agent Systems**	**Logic, Computational Complexity, and Game Theory**	**PhD in University of Manchester**	**2**	**A legend in Oxford; First-generation multi-agent systems researcher in British; Head of Department of Computer Science at Oxford from 2014-2021**
Cambridge	**Amanda Prorok**	**Models and Algorithms for Ultra-Wideband Localization in Single- and Multi-Robot Systems**	**Multi-Agent Systems, Robotics, Learning, Planning, and Control**	**PhD in EPFL**		**Best Thesis in Computer Science, Automation, Telecommunications**
Imperial College	**Alessio R. Lomuscio**	**Knowledge Sharing among Ideal Agents**	**Verification for Multi-Agent Systems, Logic**	**PhD in University of Birmingham**	**2**	
UCL	**Jun Wang**	**Relevance Models for**	**Learning,**	**PhD in Delft**		

		Collaborative Filtering	(Multi-agent) Reinforcement Learning, and Control	University of Technology		
Edinburgh	Stefano Vittorino Albrecht	Utilising Policy Types for Effective Ad Hoc Coordination in Multiagent Systems	multi-agent systems, reinforcement learning, game theory, and Decision Making	PhD in Edinburgh	3	Legend Peter Stone's postdoc
NTU	Bo An	Automated Negotiation for Complex Multi-Agent Resource Allocation	Computational Game Theory, Security, Multi-Agent Optimization And Learning	PhD in UMass	1	Legend Victor R. Lesser's student; Winner of AAMAS 2010 Dissertation Award
IIIS, Tsinghua University	Chongjie Zhang	Scaling Multi-Agent Learning in Complex Environments	Deep Reinforcement Learning, Multi-Agent Systems, Reasoning and Planning	PhD in UMass	1	Legend Victor R. Lesser's student; IIIS (Yao Class) is the best research institute in Great China
Stanford	Yoav Shoham	Reasoning about Change	Game Theory and Logic (Reasoning)	PhD in Yale	2	A legend in Stanford; Prof. Fangzhen Lin's advisor; First-generation multi-agent systems researcher in US
NEU at Boston	Christopher Amato	Increasing Scalability in Algorithm for Centralized and Decentralized Partially Observable Markov Decision Process: Efficient Decision-Making and Coordination in Uncertain Environments	Multi-Agent Systems, Robotics, Reasoning, Game Theory and Learning	PhD in UMass	1	

Also, there are some researchers who are from Control background, and some of their work are also shinning in Multi-Agent Systems:

Institute	Professor	PhD thesis	Main Research Area	Background	Extra
UC Riverside	Wei Ren	Consensus Seeking, Formation Keeping, and Trajectory Tracking in Multiple Vehicle Cooperative Control	Multi-Agent Systems and Control	PhD in Brigham Young University	
Caltech	R. M. Murray	Robotic Control and	Control	PhD in UC	A legend in Caltech;

		Nonholonomic Motion Planning		**Berkeley**	**Prof. Ling Shi's advisor**
Harvard	**Na Li**	**Distributed Optimization in Power Networks and General Multi-agent Systems**	**Learning, Optimization, and Control**	**PhD in Caltech**	**Student of another Caltech Legend, Prof. John Doyle**

What to do and how to do?

I believe many of you are pursuing or undergoing a Master of Philosophy (which is a two-year thesis master, not a two-year taught master, and not a one-year master of science) or Doctor of Philosophy. As for it is about something of philosophy, the goal and the only goal is to expand the human knowledge base by publishing conference papers, journal papers, and also your thesis paper.

From this point, all your work should lead you to the only goal and define you as a researcher at the same time, if not, you are kind of wasting of your time which would never come back again.

Well, someone may say I just want to go to industry areas after graduation, not everyone is needed as a professor. The sad point is that, if your goal is not to keep going in research after graduation, you will die soon academically, mentally, and physically. The support is the truth that all systems have their inner inertia, including human beings (we call this kind of inertia laziness). 99.99% of people can not achieve their goal precisely because of inner inertia. If you are the 00.01% of people who can realize all your goals, why not go to play Olympics? So learning to set a higher goal which could lead you to the proper result.

Now I guess you have a basic definition of research. Well, know to what to do is very hard. As far as I know, most Chinese students don' t know or pretend they know what to do in their research. It is really a tragedy! To solve this is hard, it is like formulating a problem before solving it. Usually you formulated the problem in a proper way, solving it is a piece of cake (just usually, sometimes some problems are very easy to formulate but very hard to solve). For me, the reason why I choose this area (Multi-Agent System) is that it matches my knowledge base, it could give me positive feedback to keep me forward and make me happy, and I have the confidence to beat most of my colleagues in this area all over the world (this kind of confidence is based on my work and knowledge).

I hope you know or you will know soon about what to do in your research, then you should learn to choose. The reason is that you only have very limited time. Maybe you are building a system, 95% of the time is useless as it is to build something which already exists. If so, you may rethink the value of your work. Sometimes, what you are doing could make you busy, stimulate your nervous system, and give you positive feedback, but are somehow a little bit useless for expanding the human knowledge base (could not be used for paper publish). If so, you better rethink your work. You are a researcher, but not senior

engineer. The degree is called XX of Philosophy, but not XX of Engineering or XX of Projects. (No offence to those researchers with a degree of XX of engineering) You should learn to separate your work into the research part and the engineering part. The engineering part is like the soil and the research part is the flower based on your soil. Well, we should admit that sometimes nurturing the soil is very important, but who can deny the beauty of the flower?

You better make a plan at the beginning. Even it is just a draft, this will save you a lot of time. Try to build a feedback loop in your planning system, and ask questions from your professors, colleagues, and friends, and think about their feedback to get a better output. And you should make your planning system dynamic but not static. Add some nodes or delete some if you could receive the output better or quicker. And then keep this system running. This is all about how to do research.

The first step and the best way to find your research topic is to start small. If your first job is to build a system with 20k lines code, or to read all four original 200-year-old math books in France but not in English, or to understand a 60 pages journal paper including 45 pages of proof, you are just defining stupidity at the most of time. Do not do that!

Finding what did those big professors do at the beginning of their research career as your first project, reading a 10-page paper with more than 1000 citations, writing 400 lines not-steal-from-GitHub-or-a-Third-Library code for an easy general problem in your area as your first step could be more helpful.

Learn to question yourself!
Some concrete questions about what I said above are:
Have you read David Silver' s first paper?
How many notes do you take by hand when you are reading a paper?
Do you know a lot of machine learning legends started their research on planning but not on learning at the beginning as similar to those computer vision legends started doing research on signal processing first?
Have you read Prof. Ren Wei' s most cited paper if you are from a control background? It is all about beautiful math proof!
If you are working on like, reinforcement learning, have you read the original Actor-Critic algorithm paper and Richard Sutton's papers which are related to his reinforcement learning book?

The last thing which may be helpful is to learn to be an independent researcher first and then to cooperate if you need. Learn to be strategic like a fox at first, learn to be strong (academically, mentally, and physically) as a bear then, and learn to cooperate like wolves if you are facing a bigger target!

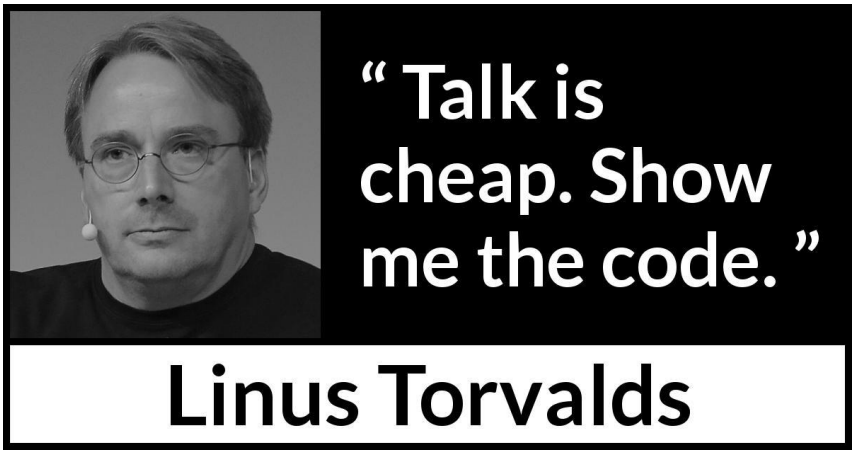

Fig3. “Talk is Cheap. Show me the code.” By Linus Torvalds

I hope this note could help you to do research in Multi-Agent Systems somehow, but talk is so cheap. The research itself is much harder!

You better:

ACT NOW!

ACT NOW!!

ACT NOW!!!

Acknowledgment

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