Deep learning and transit crew-schedule optimization

David Fabi

GIRO, General Manager,
Development and technologies

Montréal, Qc

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GIRO at a glance

Founded in 1979

Based in Montréal

400+ skilled employees

Integrated software solutions for planning & managing transport-related operations

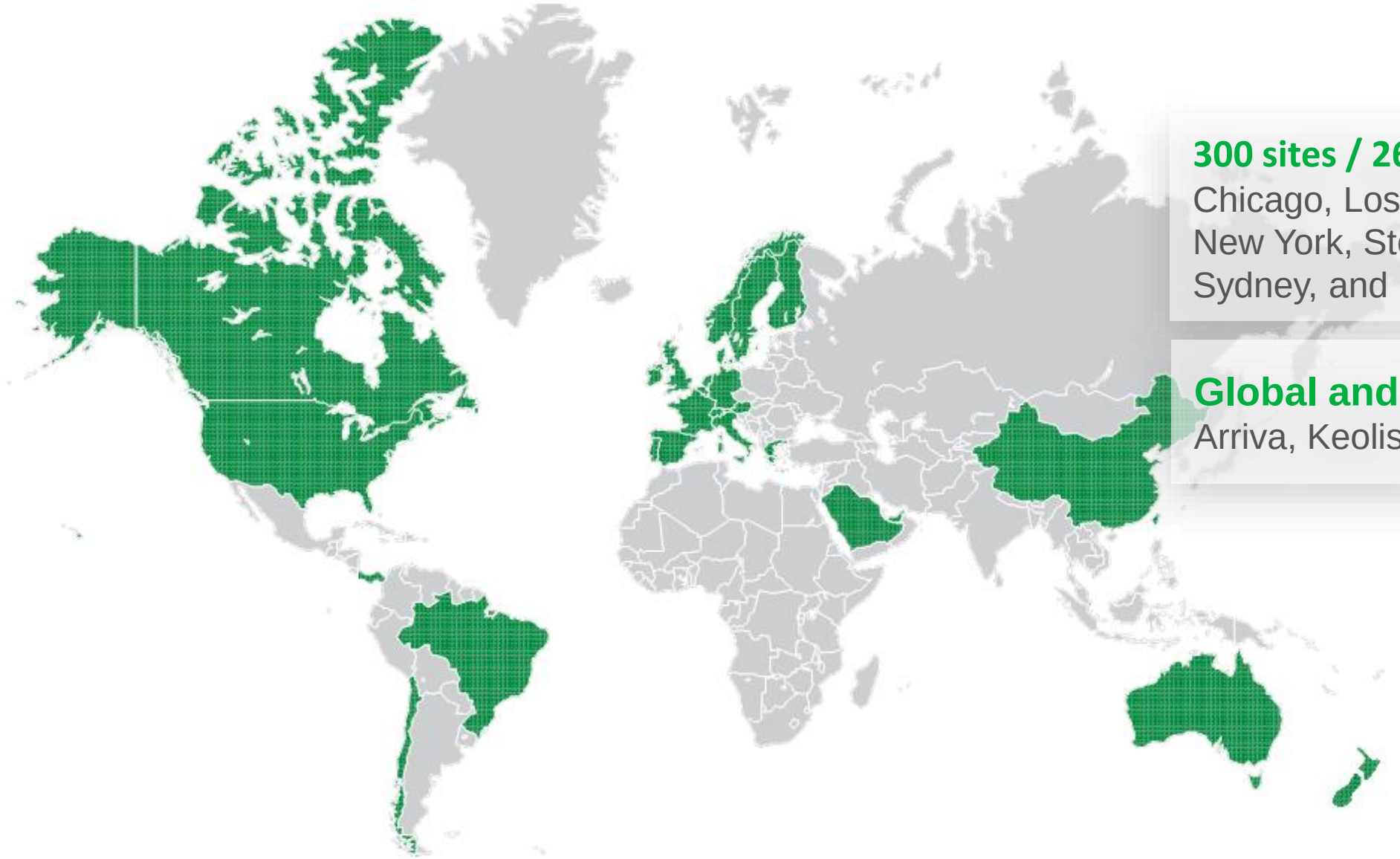
Public transport (*HASTUS™* & *HASTUS-Rail™*)

On-demand transport (*HASTUS-OnDemand™*)

Operations research and optimization

- At the root of our company
- Still at the core of our products

Our global market presence



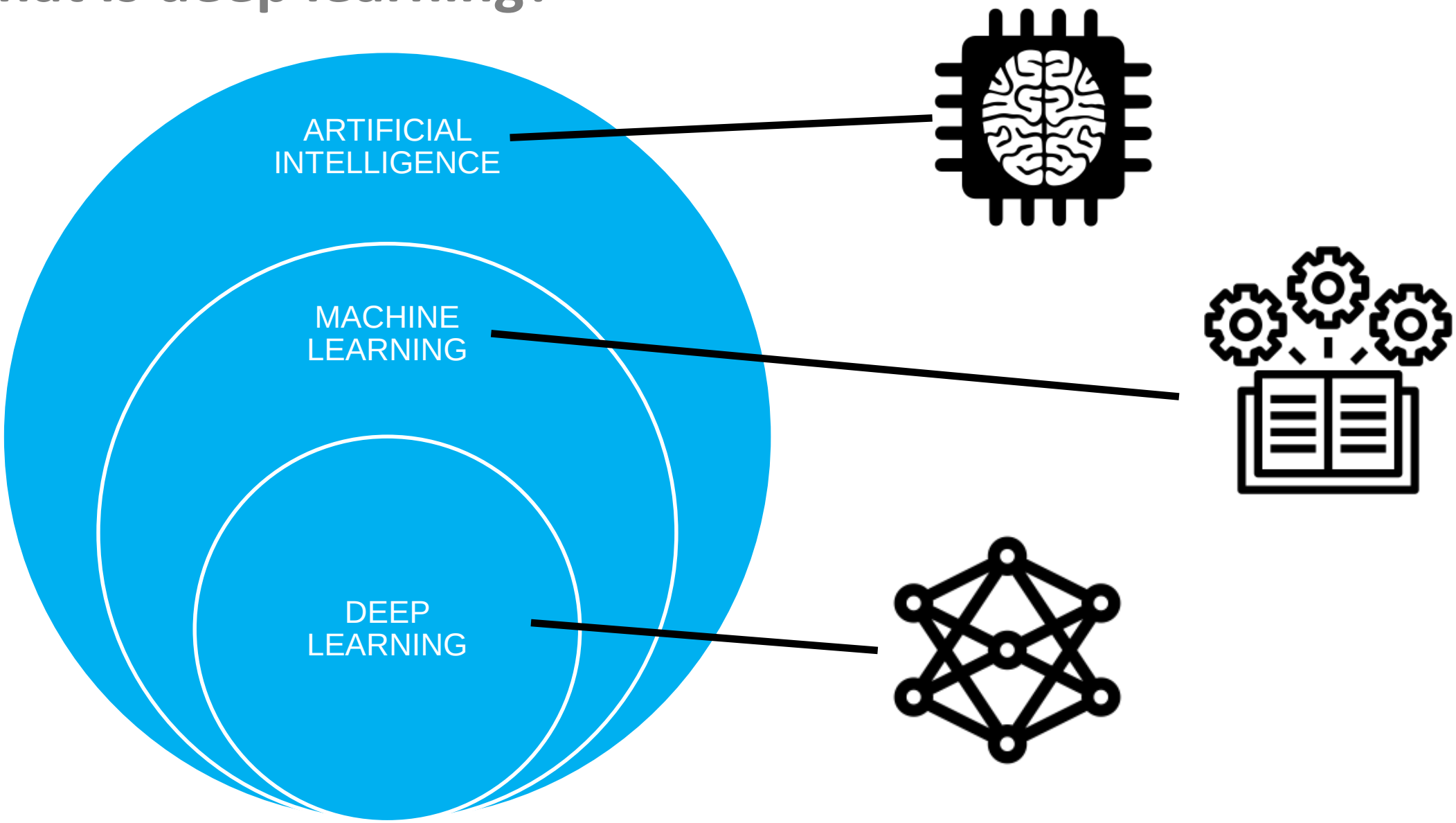
300 sites / 26 countries

Chicago, Los Angeles, Montréal, New York, Stockholm, Singapore, Sydney, and more

Global and local organizations

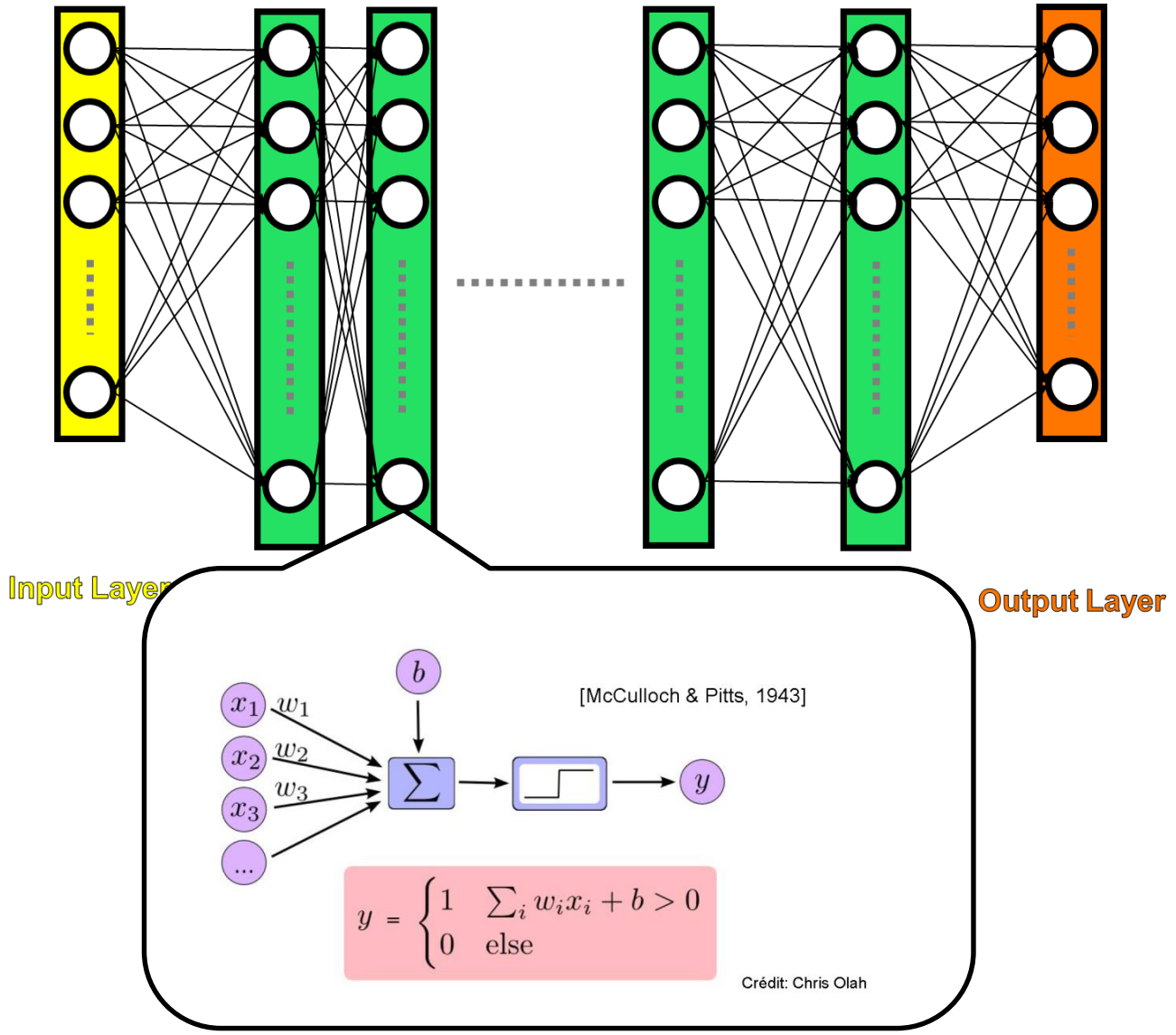
Arriva, Keolis, Transdev, and more

What is deep learning?



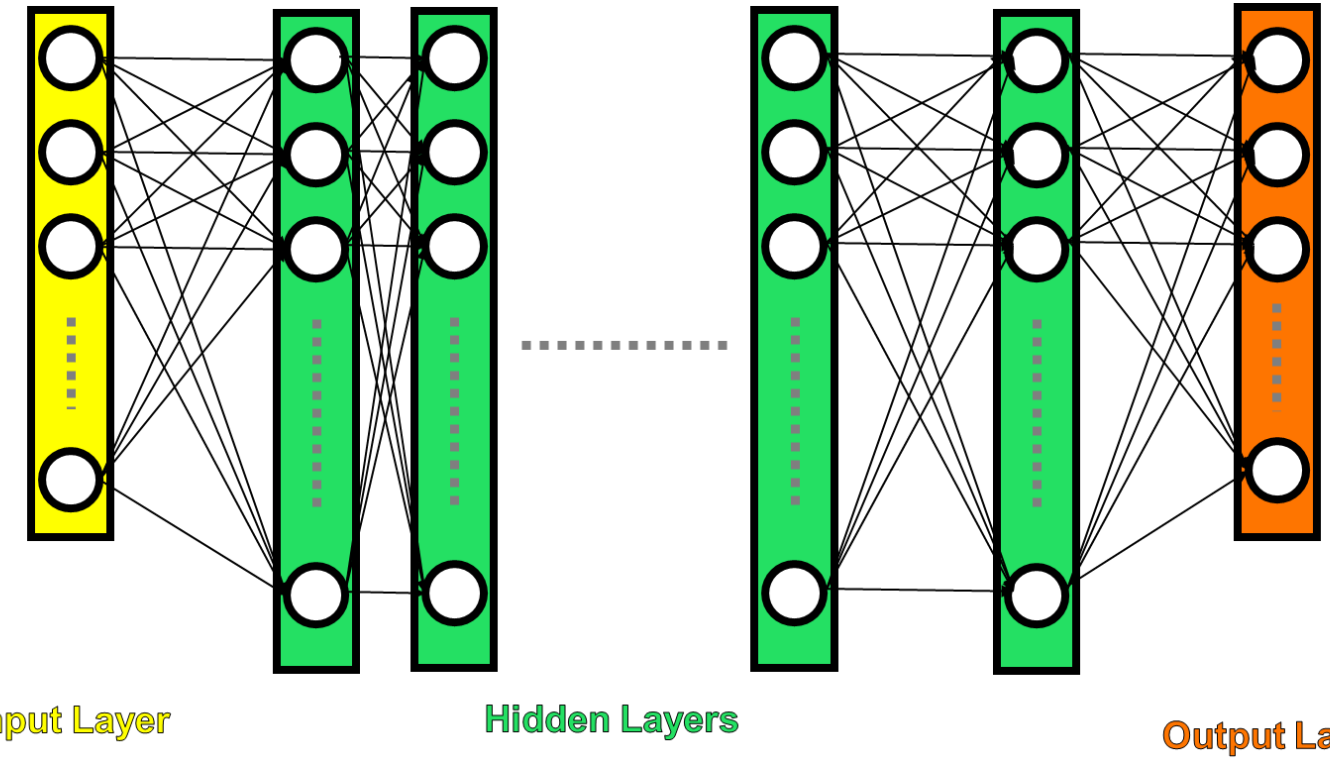
What is deep learning?

- Inspired by the human brain!
- A type of machine learning that uses deep levels of artificial neural network layers

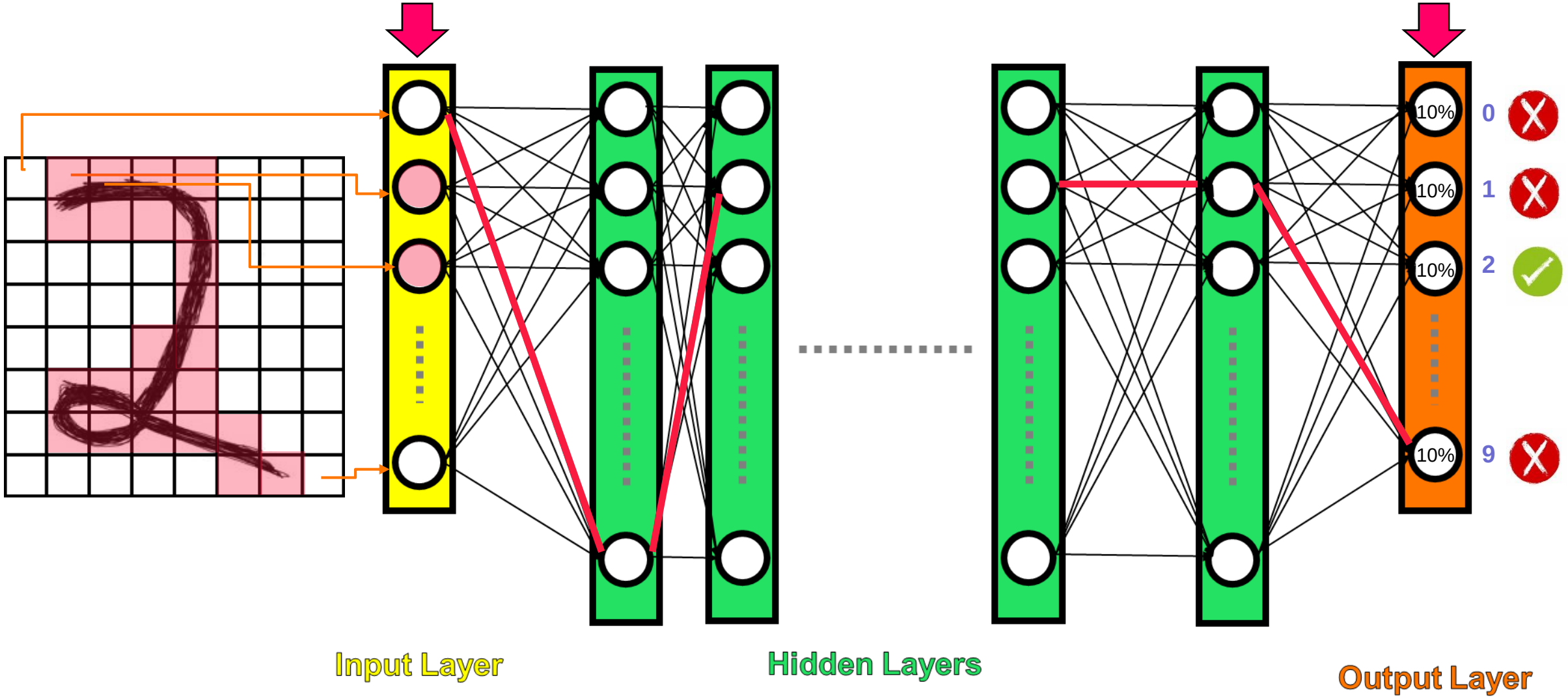


Two phases

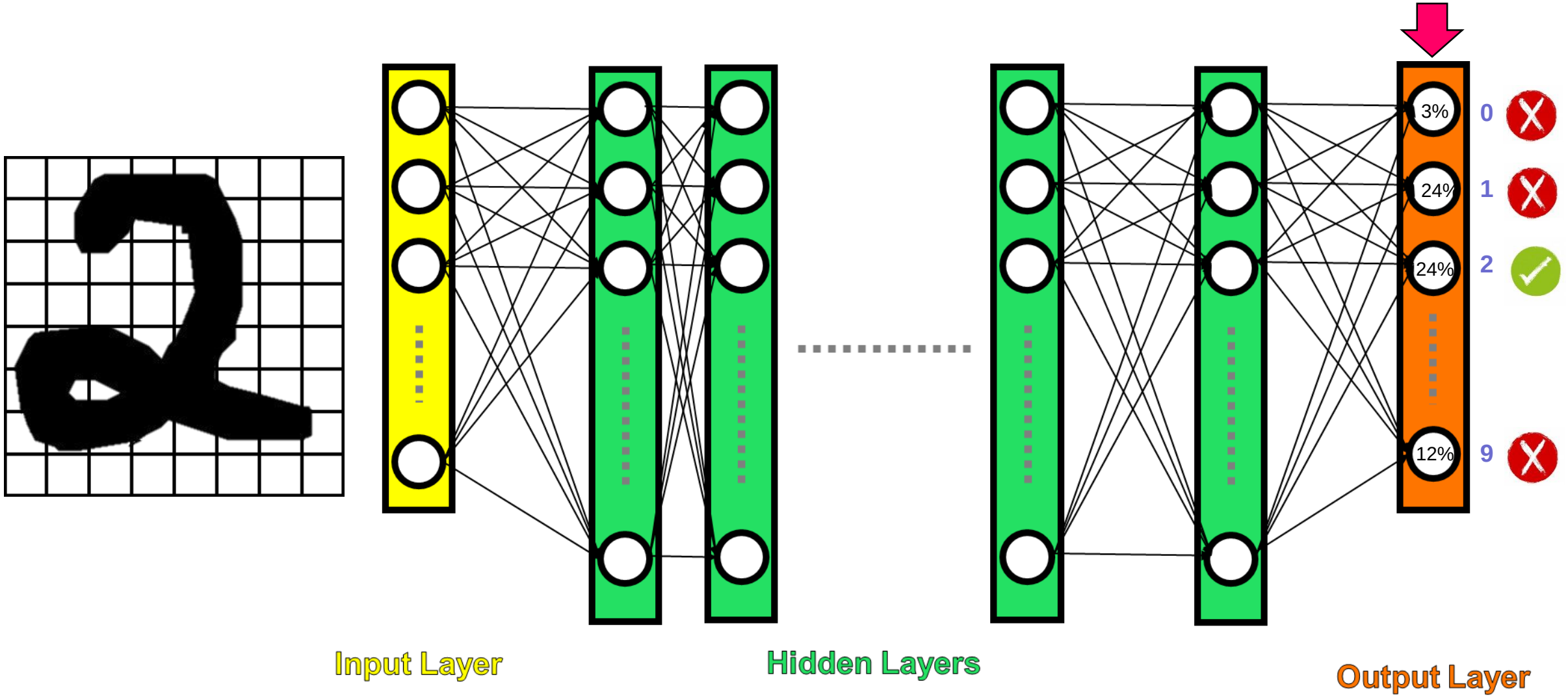
- Training (supervised)
  - A lot of data
  - A lot of computer power (GPU and now TPU processors), allowing for deep networks
  - The longer of the two phases
- Prediction
  - Fast



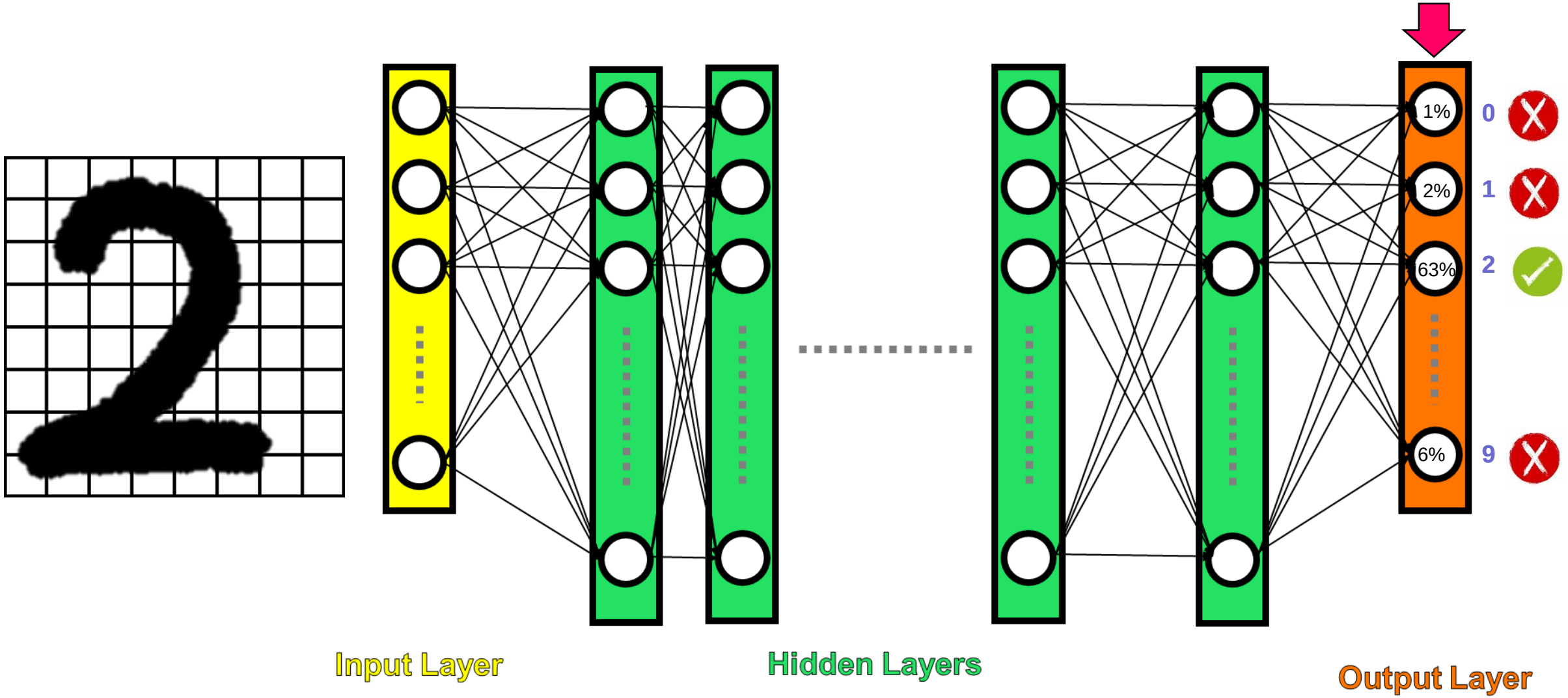
Two phases



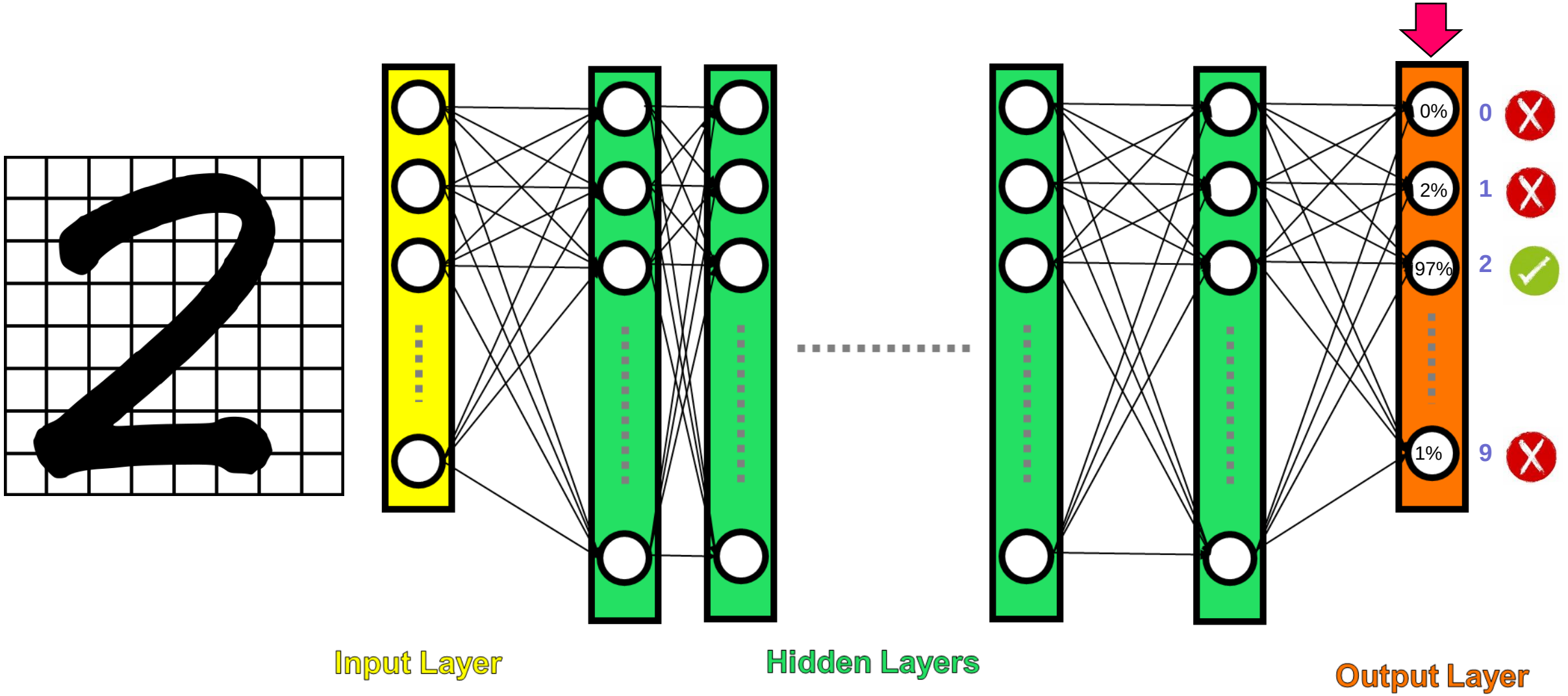
Two phases



Two phases



Two phases



Deep learning challenges

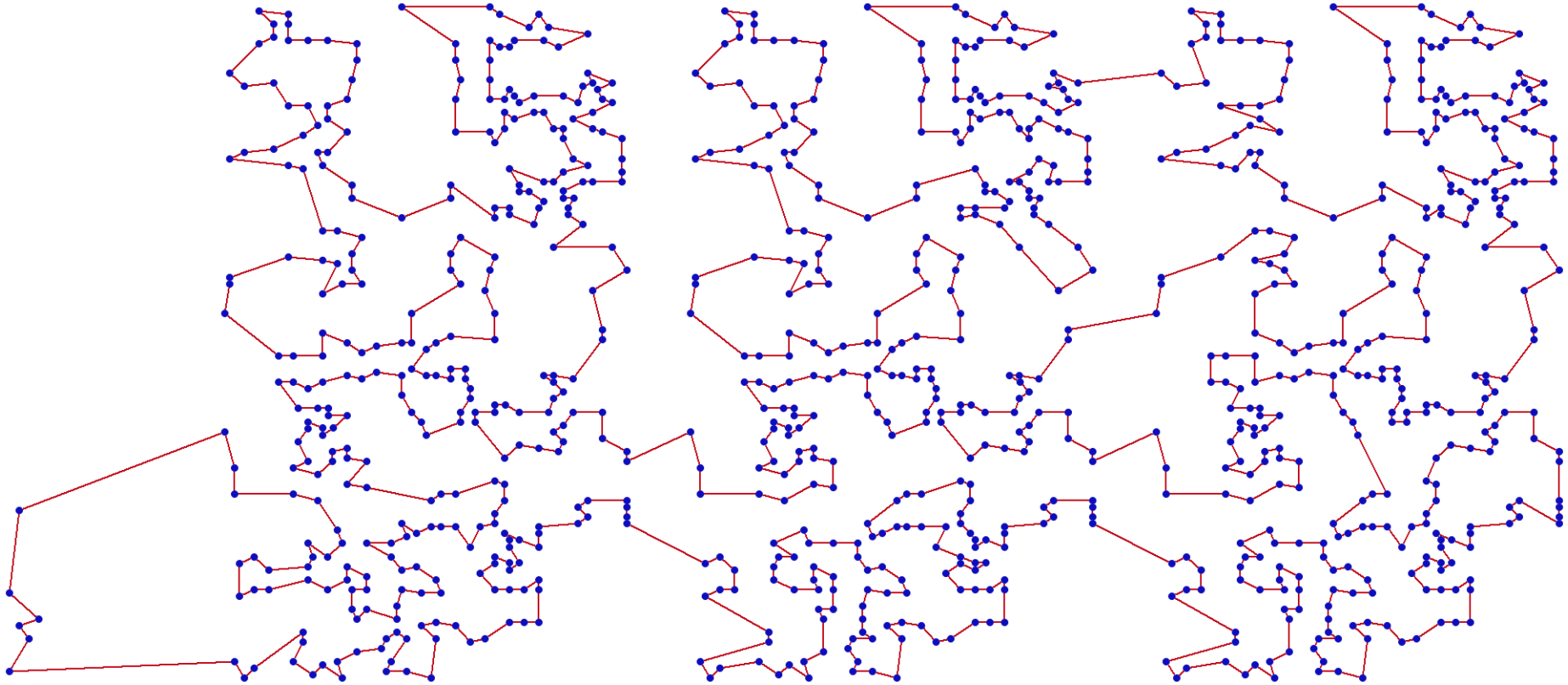
- Implementation challenges
  - What is the input layer?
  - What is the output layer?
  - How many hidden layers?
  - How many neurons per layer?
  - What are the weights on the arcs?
- Several open source platforms available
  - theano — University of Montreal (MILA/Yoshua Bengio)
  - torch — Facebook
  - TensorFlow — Google

Deep learning: does it work?

- Yes for
  - Spam detection
  - Speech recognition
  - Translation
  - Facial recognition
  - Driving
  - Chess playing
  - Credit card fraud detection
  - Image caption generation
  - …

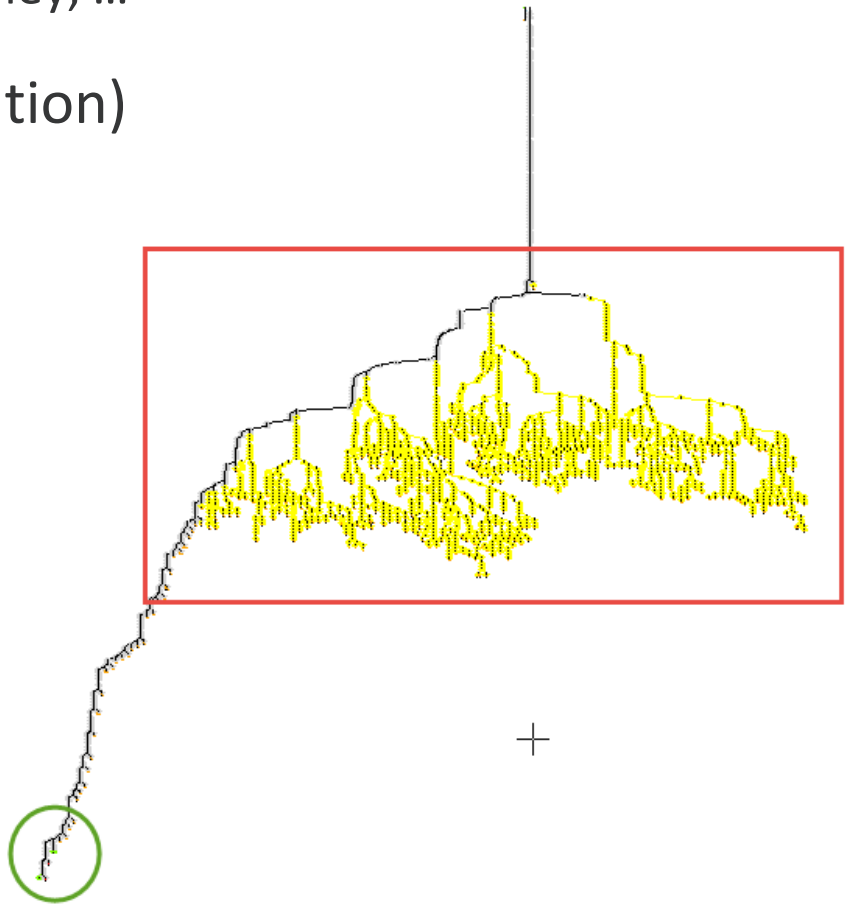
Deep learning and combinatorial optimization

- Not very efficient when **directly** applied
- For example TSP (Traveling Salesman Problem)

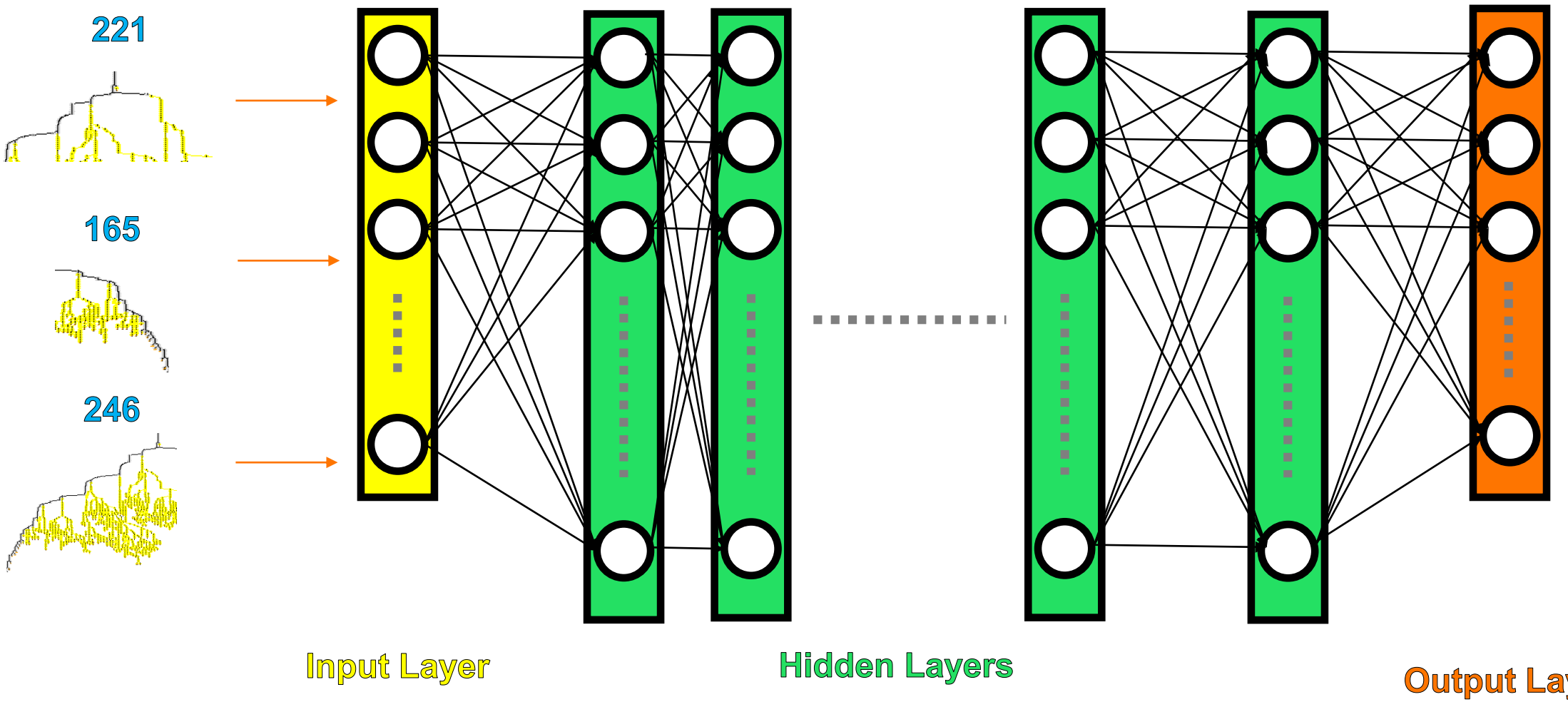


The *HASTUS/CrewOpt* case

- Optimization algorithm for transit crew scheduling
  - Installed at 186 sites worldwide
    - NYC, Chicago, LA, Barcelona, Oslo, Stockholm, Hong Kong, Sydney, …
- Based on operations research techniques (column generation)
- **Involves several heuristic decisions**
  - Branching
  - Arc sampling
  - Resources and dominance
  - …
- Semi-supervised deep learning can help
  - Learn to make better heuristic decisions
  - Learn features of good solutions

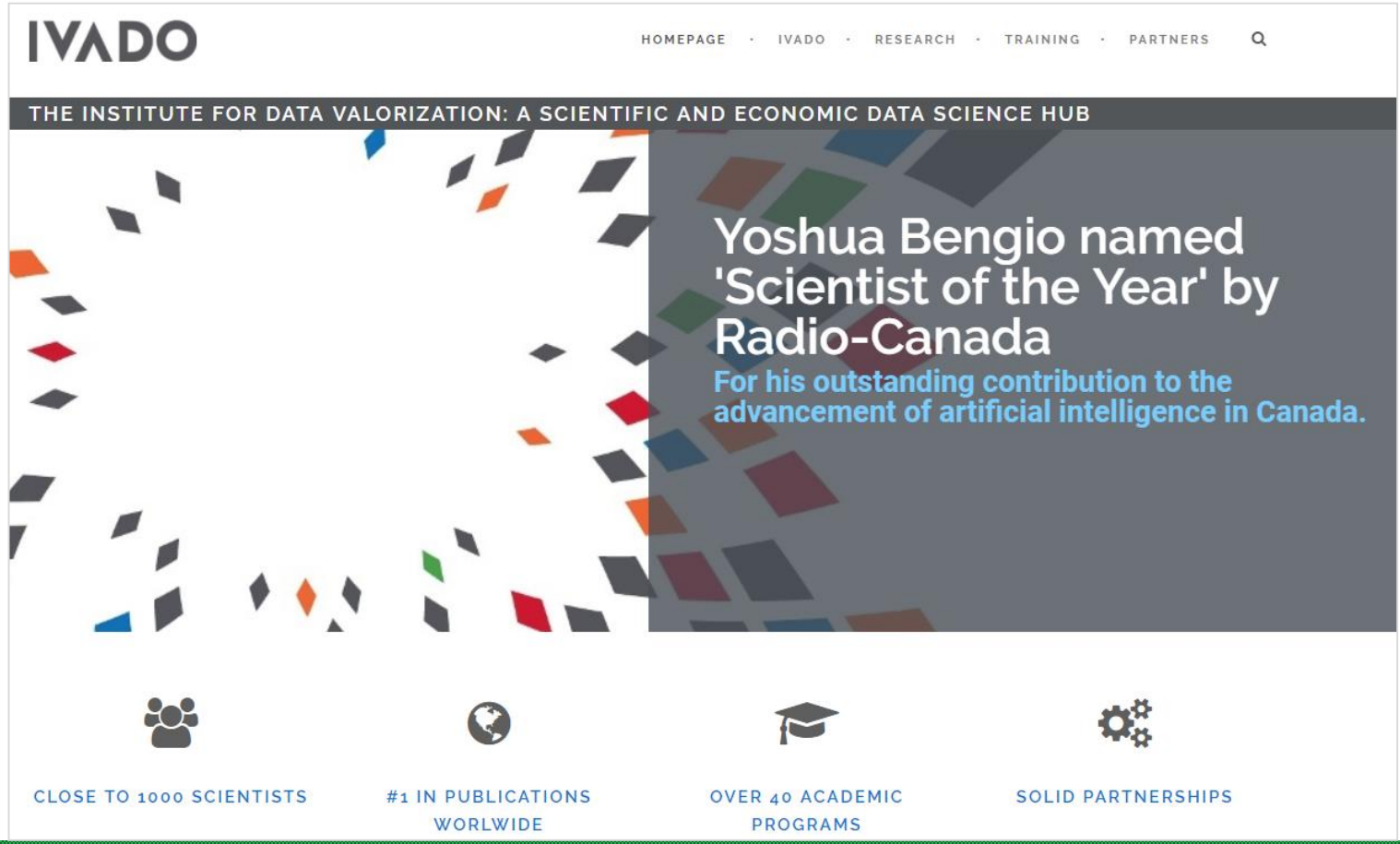


Deep learning and combinatorial optimization



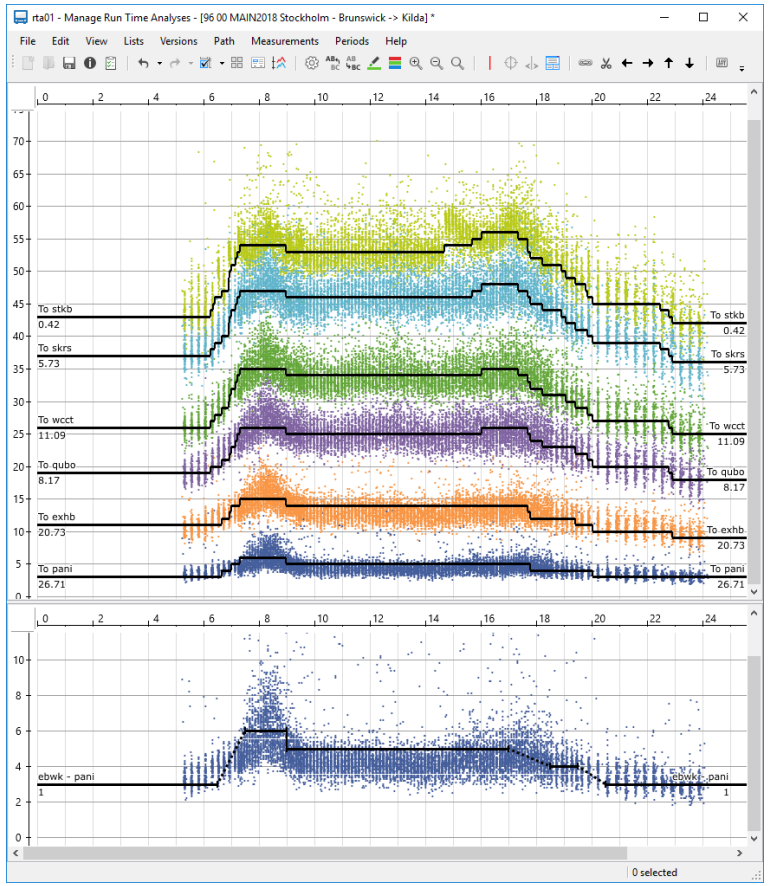
The *HASTUS/CrewOpt* case

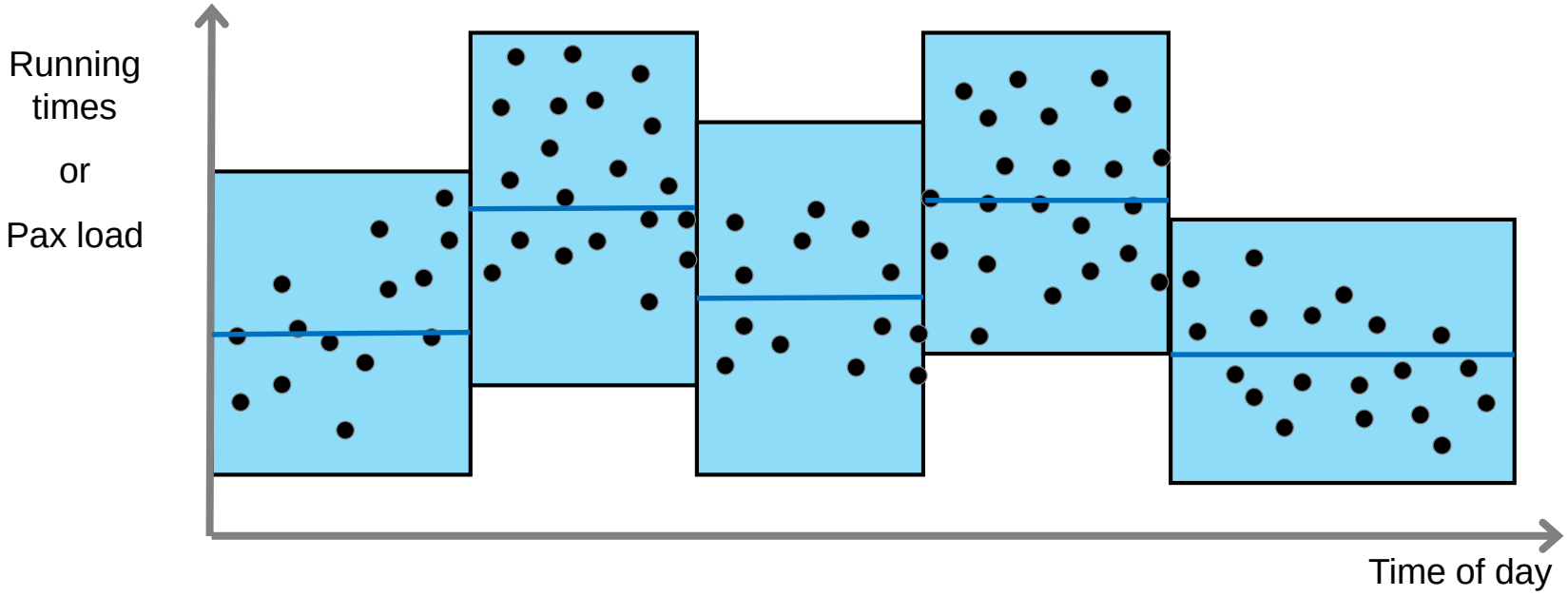
- Ongoing research project
  - IVADO partnership (ivado.ca)
- Expected improvements
  - Solution cost ($$$)
  - Running times (once trained)



Other deep learning applications

- Unsupervised learning
  - Useful to identify data clusters
  - Example
    - *Clustering* to identify higher values for [April 20, May 17]
    - Measures should be removed from analyses

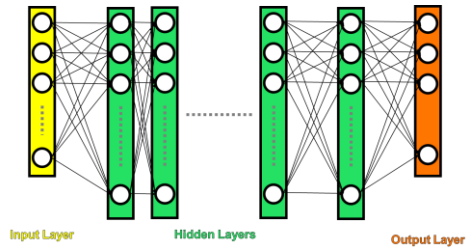




Other deep learning applications

- Forecasting (e.g. absenteeism)
  - Training

Input								Output
Date	Day	ºF	Start time	End time	Spread	Route	Gender	Absent
6/2/2017	Monday	28	6:47	15:08	8h21	168	Male	1
6/2/2017	Monday	28	7:39	16:02	8h23	51	Female	0
7/2/2017	Tuesday	33	9:20	19:08	9h48	12	Male	0
7/2/2017	Tuesday	33	6:47	15:08	8h21	168	Male	0
8/2/2017	Wednesday	26	14:00	23:58	9h58	121	Female	1
8/2/2017	Wednesday	26	5:30	13:12	7h42	51	Male	0
9/2/2017	Thursday	32	9:00	17:00	8h00	129	Male	0
9/2/2017	Thursday	32	8:37	16:08	7h31	168	Male	0
10/2/2017	Friday	35	6:47	20:08	13h21	51	Male	0



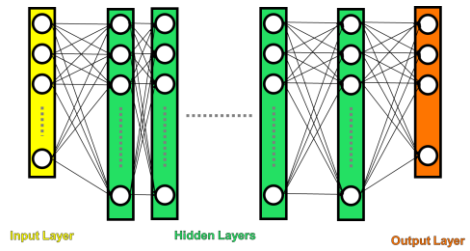
  - Prediction

5/2/2018	Monday	27	6:52	15:18	8h26	168	Male	0.21
6/2/2018	Tuesday	38	8:17	14:54	6h37	51	Female	0.03
22/6/2018	Friday	22	6:08	20:02	13h54	168	Male	0.46

Other deep learning applications

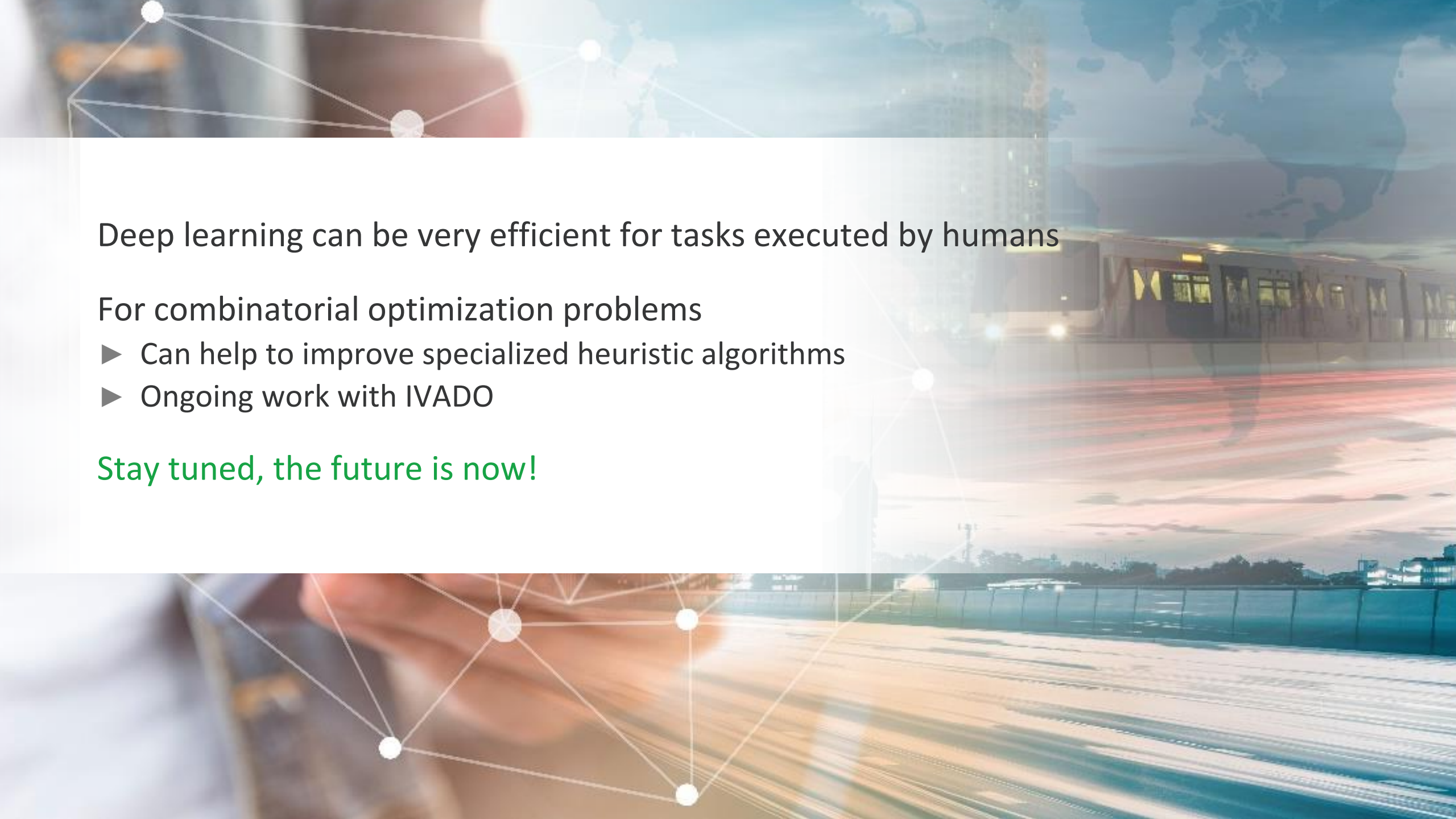
- Forecasting (e.g. demand prediction)
  - Training

Input									Output
Date	Day	ºF	Route	Stop	Rain	Football	Snow (in)	Time	Demand
6/2/2017	Monday	36	51	1012	Yes	No	0	7:12	8
6/2/2017	Monday	36	51	1015	Yes	No	0	8:15	12
7/2/2017	Tuesday	29	121	2103	No	No	5	13:13	10
7/2/2017	Tuesday	29	129	1050	No	No	5	12:14	6
8/2/2017	Wednesday	34	168	1234	No	No	0	20:15	1
8/2/2017	Wednesday	34	12		No	No	0	6:54	9
9/2/2017	Thursday	38	121	0113	No	Yes	0	9:14	3
9/2/2017	Thursday	38	129		No	Yes	0	11:13	2
10/2/2017	Friday	41	51	1124	Yes	No	0	8:00	15



  - Prediction

5/2/2018	Monday	27	51	1012		No	8	7:14	7
6/2/2018	Tuesday	31	129	1050		No	0	9:17	4
22/6/2018	Thursday	39	168	1234		Yes	0	16:43	15



Deep learning can be very efficient for tasks executed by humans

For combinatorial optimization problems

- Can help to improve specialized heuristic algorithms
- Ongoing work with IVADO

Stay tuned, the future is now!

Thank you!
Any questions?

David Fabi
General Manager,
Development & technologies
GIRO Inc.

info@giro.ca
+1 514.383.0404
/company/GIRO

Improving efficiency at every turn