Automated Negotiation in Supply Chain Management

Enrique Areyan Viqueira
eareyan@brown.edu

December 17, 2020

Presentation at Rollins EST. 1885

BROWN

Who am I?

- Ph.D. candidate, Computer Science, Brown University.
- Research Area: Artificial Intelligence (AI) / Multi-Agent Systems.
  Game Theory / Mechanism Design / Automated Negotiation.
- Originally from Caracas, Venezuela; in the U.S. since 2011.
- Prior to Brown, CS M.Sc. & MAT Mathematics at Indiana University.

Who am I?

- Ph.D. candidate, Computer Science, Brown University.
- Research Area: Artificial Intelligence (AI) / M
  Game Theory / Mechanism Design / Automated Negotiation.

Today's Focus!
Worked with undergrads!

- Originally from Caracas, Venezuela; in the U.S. since 2011.
- Prior to Brown, CS M.Sc. & MAT Mathematics at Indiana University.

Please feel free to interrupt me!
Let’s make this talk a conversation!

Outline

- **Part 1:** Supply Chains
- **Part 2:** Artificial Negotiation Agents for Supply Chains
- **Part 3:** Future Research Plans

Image credit

Part 1: Supply Chains

Why are supply chains important?
How do they function?
How could they function better?

Supply Chains

A supply chain is a sequence of **processes** by which **raw materials** are converted into **finished goods**.

Supply Chains

A supply chain is a sequence of **processes** by which **raw materials** are converted into **finished goods**.

Virtually ***all*** goods and services we consume were produced in some supply chain.

Supply Chains

A supply **s** are converte

Virtually **a** me supply ch

Milton Friedman, Nobel laureate
https://youtu.be/67tHtpac5ws

Supply Chains

A supply chain is a sequence of **processes** by which **raw materials** are converted into **finished goods**.

Virtually ***all*** goods and services we consume were produced in some supply chain.

Supply Chains

A supply chain is a sequence of **processes** by which **raw materials** are converted into **finished goods**.

Virtually ***all*** goods and services we consume were produced in some supply chain.

Participation in supply chains has contributed to **industrialisation** and high rates of **economic growth** in several developing economies (WTO).

Supply Chains (cont.)

Supply chains are **decentralized**, i.e., no central coordinator.

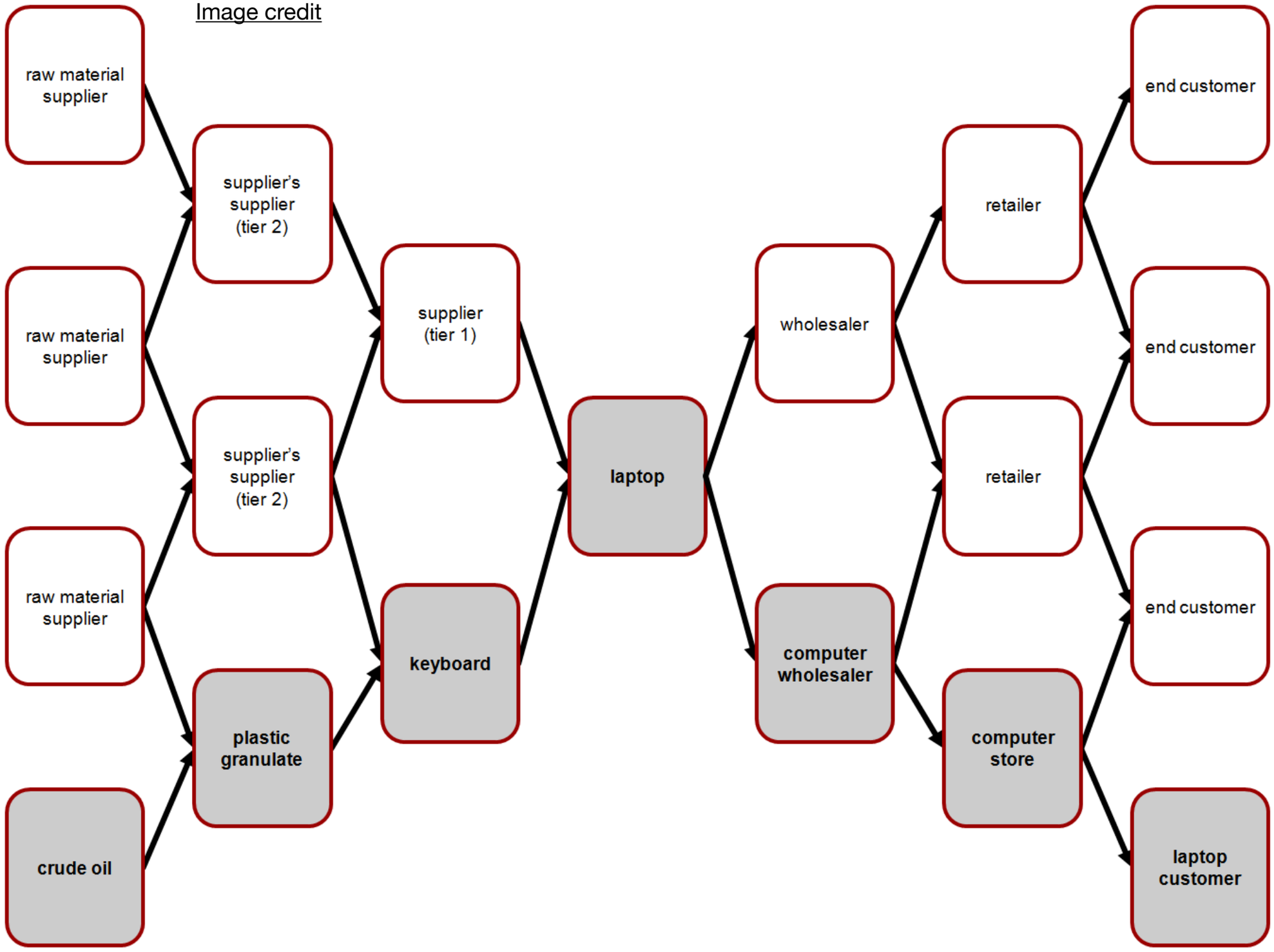
Supply Chains (cont.)

Supply chains are **decentralized**, i.e., no central coordinator.

Instead, managers **negotiate** contracts to procure products.

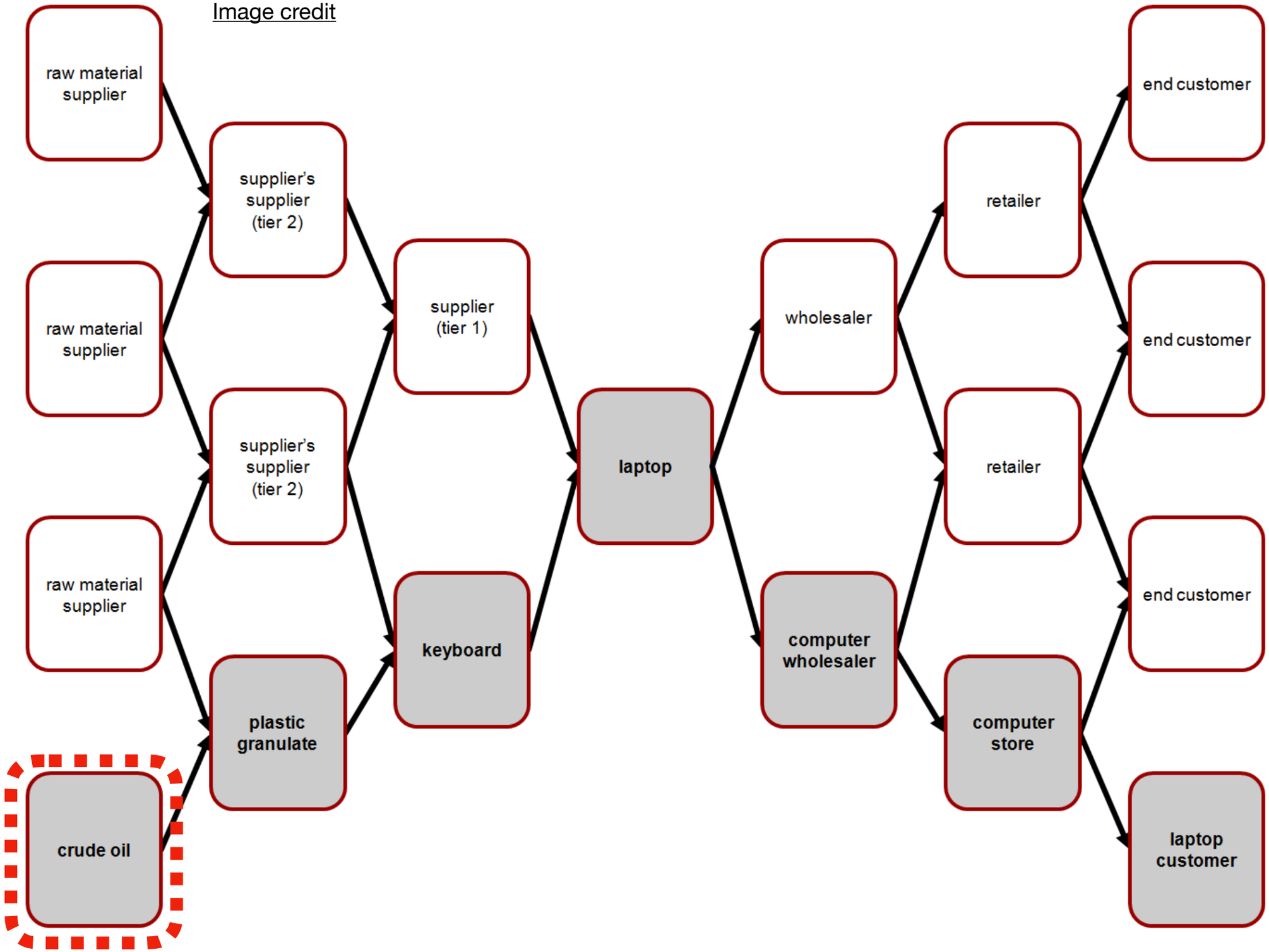
Supply Chains (cont.)

Image credit



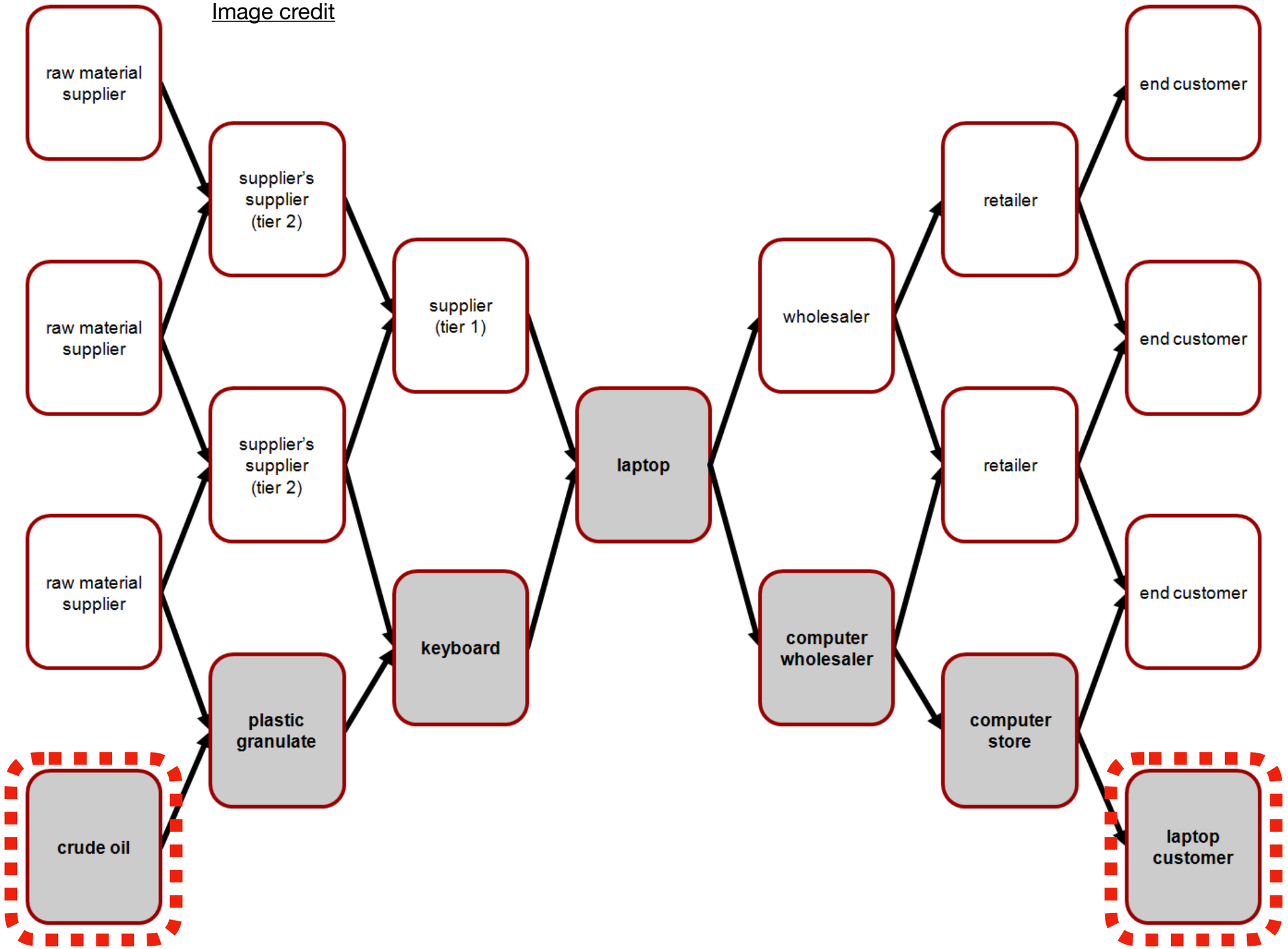
Supply Chains (cont.)

Image credit



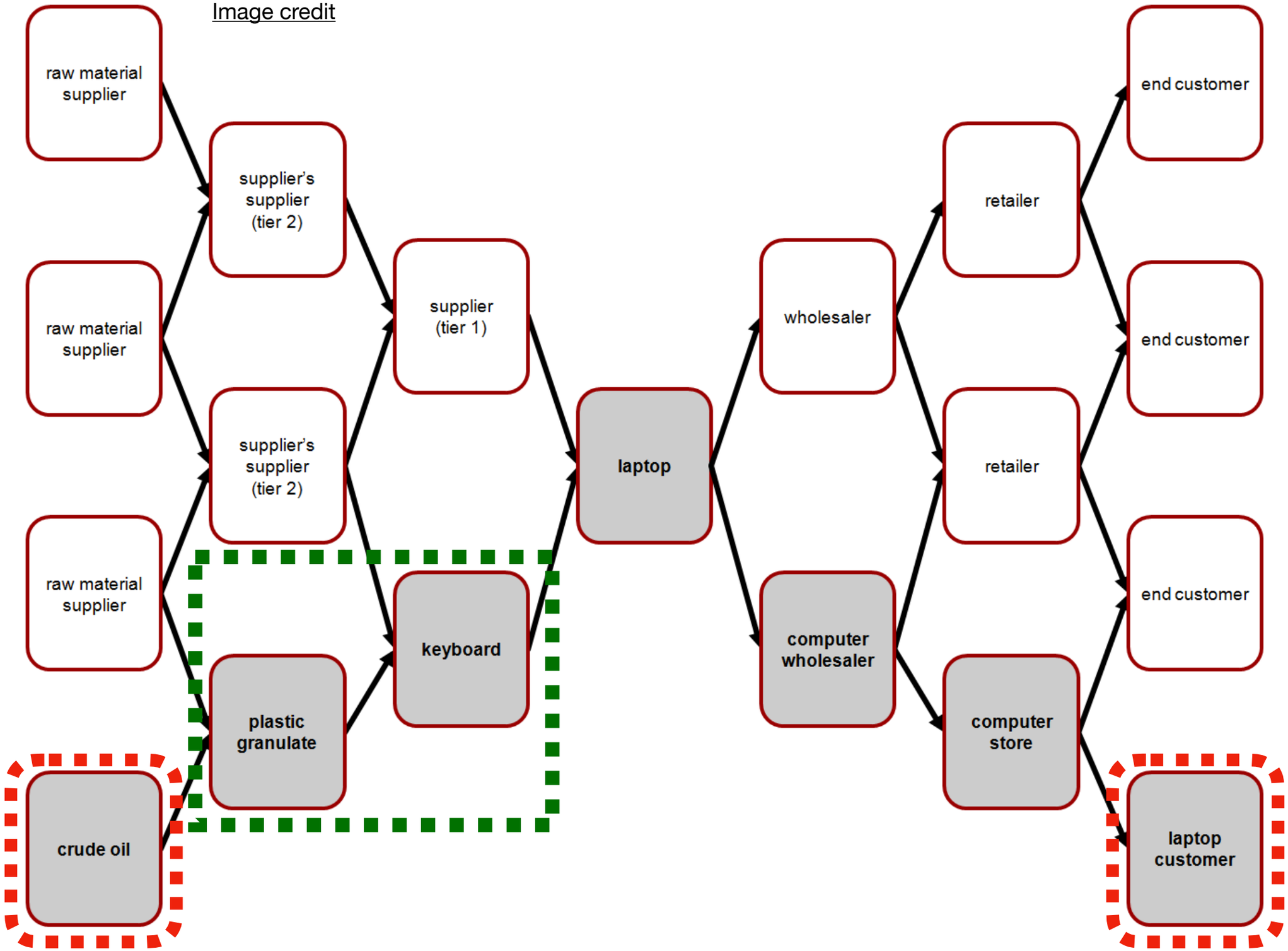
Supply Chains (cont.)

Image credit

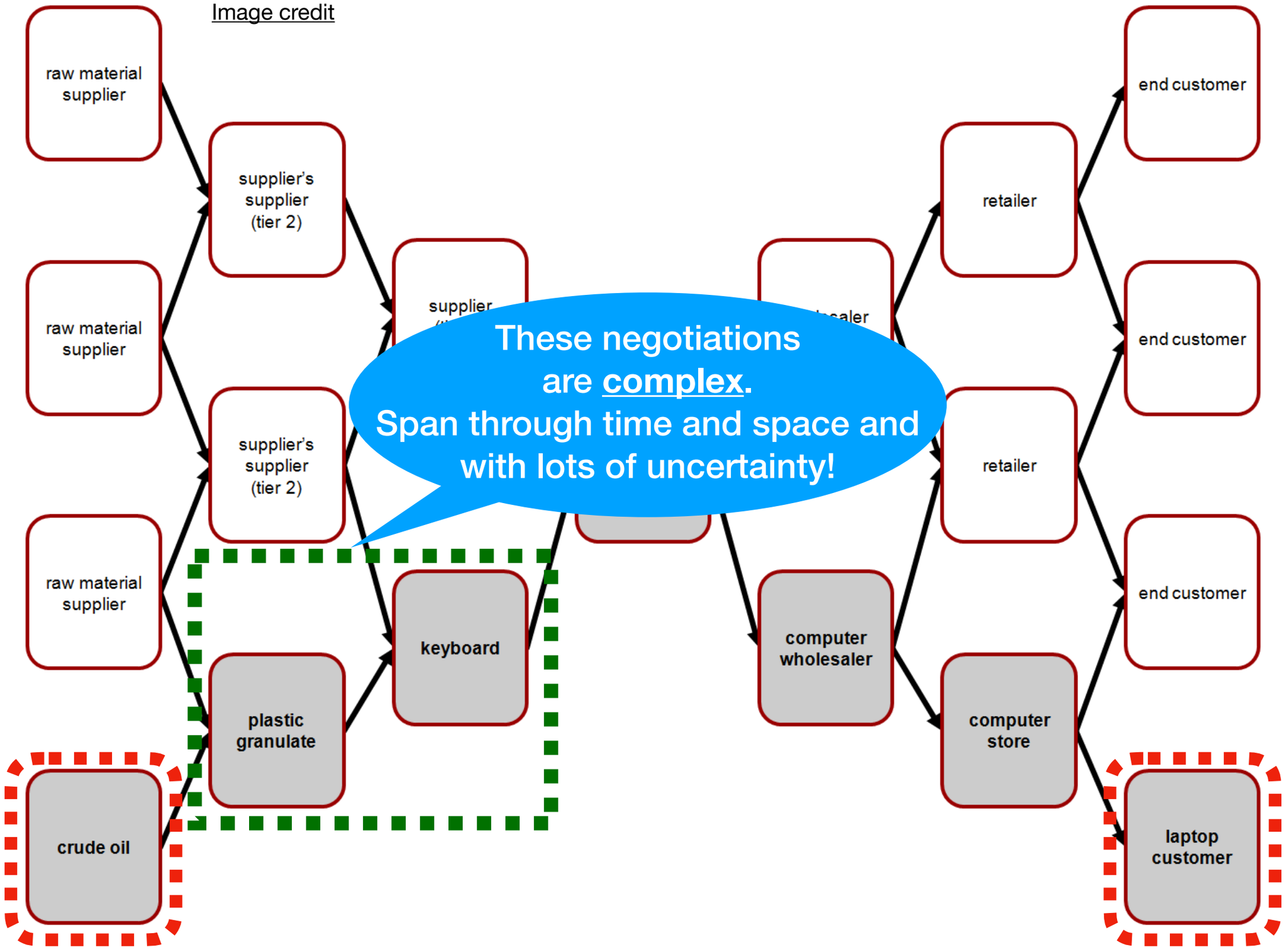


Supply Chains (cont.)

Image credit



Supply Chains (cont.)



Negotiation

A method to achieve **agreements** among **self-interested** actors.

Negotiation

A method to achieve **agreements** among **self-interested** actors.

Ideally, negotiations achieve **win-win** agreements, i.e., actors should be better off after negotiating.

Negotiation

A method to achieve **agreements** among **self-interested** actors.

Ideally, negotiations achieve **win-win** agreements, i.e., actors should be better off after negotiating.

Negotiation Protocol

Negotiation Strategy

Negotiation

A method to achieve **agreements** among **self-interested** actors.

Ideally, negotiations achieve **win-win** agreements, i.e., actors should be better off after negotiating.

Negotiation Protocol

Defines how a negotiation is conducted
e.g., alternate offers and counteroffers, one at a time

Negotiation Strategy

Negotiation

A method to achieve **agreements** among **self-interested** actors.

Ideally, negotiations achieve **win-win** agreements, i.e., actors should be better off after negotiating.

Negotiation Protocol — Defines how a negotiation is conducted
e.g., alternate offers and counteroffers, one at a time

Negotiation Strategy — Defines how an actor behaves during negotiation
e.g., be willing to accept "worst" deals as time passes

Automated Negotiation

Image credits: 1, 2, 3

Automated Negotiation

Actor (Institution or Individual) “has” a utility function, i.e., values for outcomes

Image credits: 1, 2, 3

Automated Negotiation

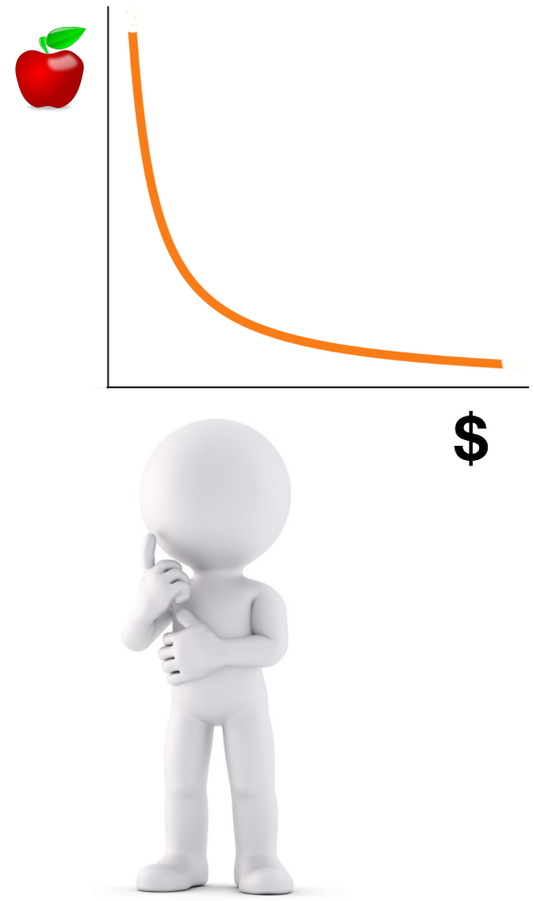


Image credits: 1, 2, 3

Automated Negotiation

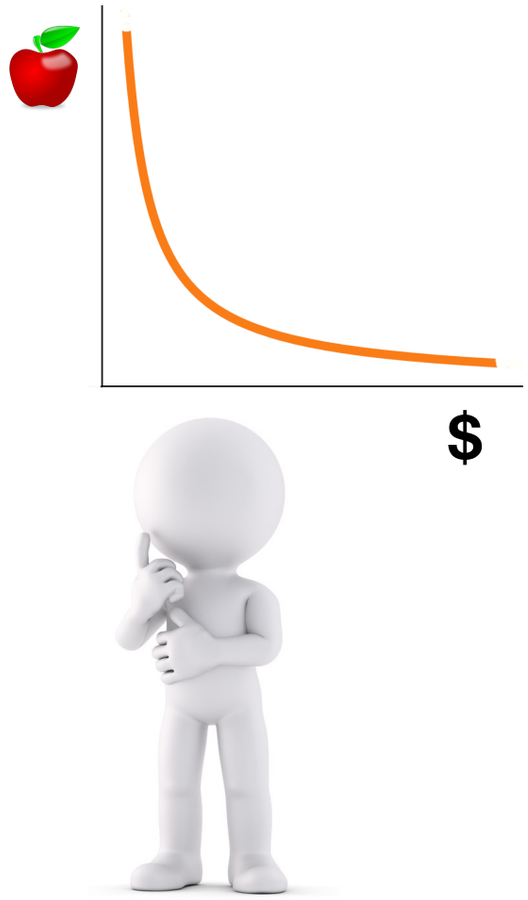
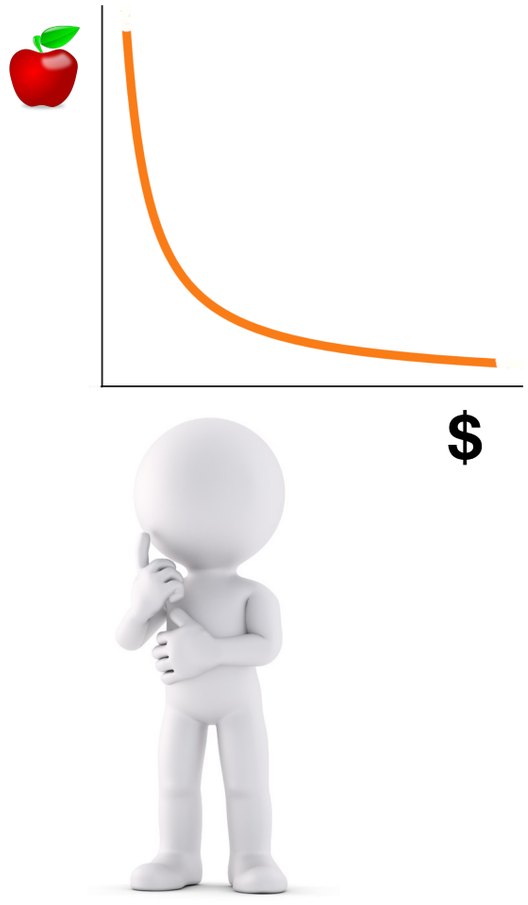


Image credits: 1, 2, 3

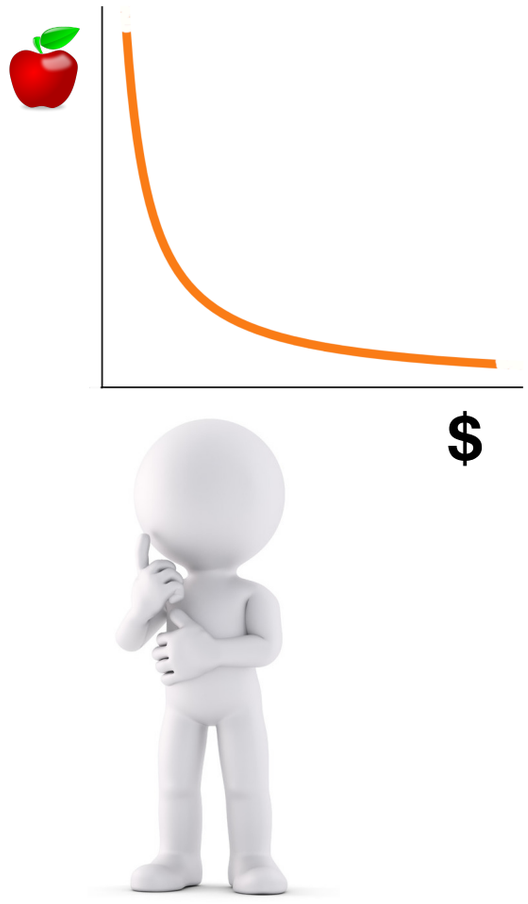
Automated Negotiation



Artificial Agent
Negotiates on behalf of an actor.

Image credits: 1, 2, 3

Automated Negotiation

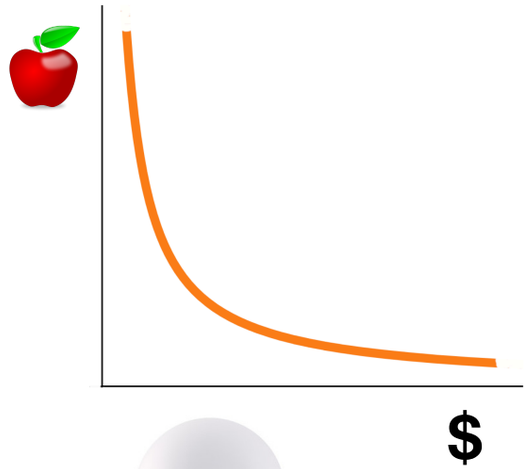


Protocol

Artificial Agent
Negotiates on behalf of an actor.

Image credits: 1, 2, 3

Automated Negotiation

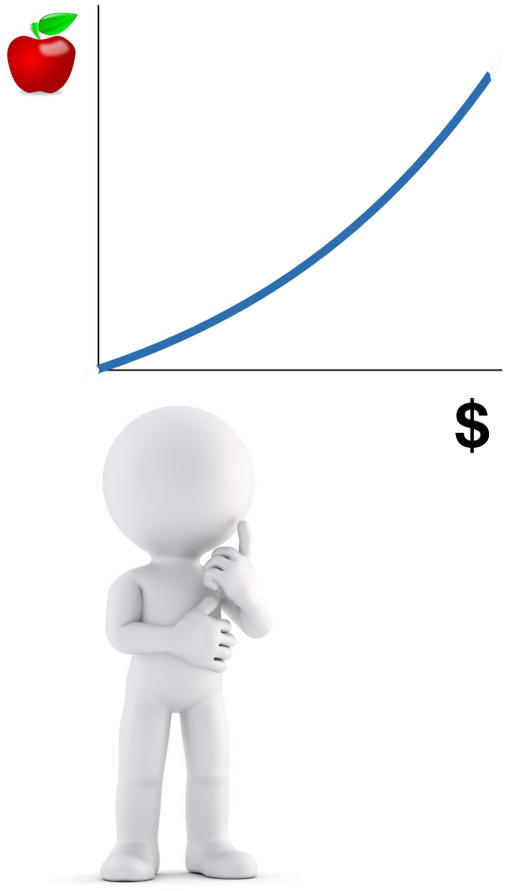


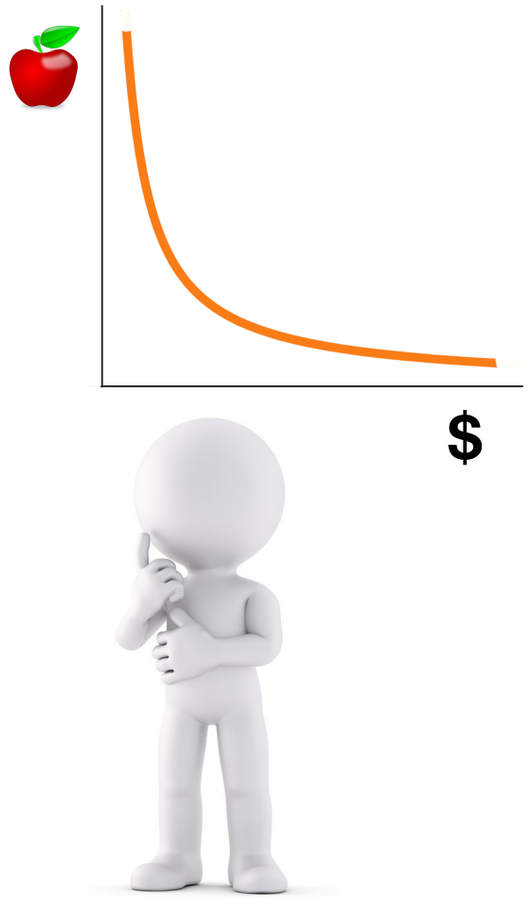
Protocol

Artificial Agent
Negotiates on behalf of an actor.

Image credits: 1, 2, 3

Automated Negotiation



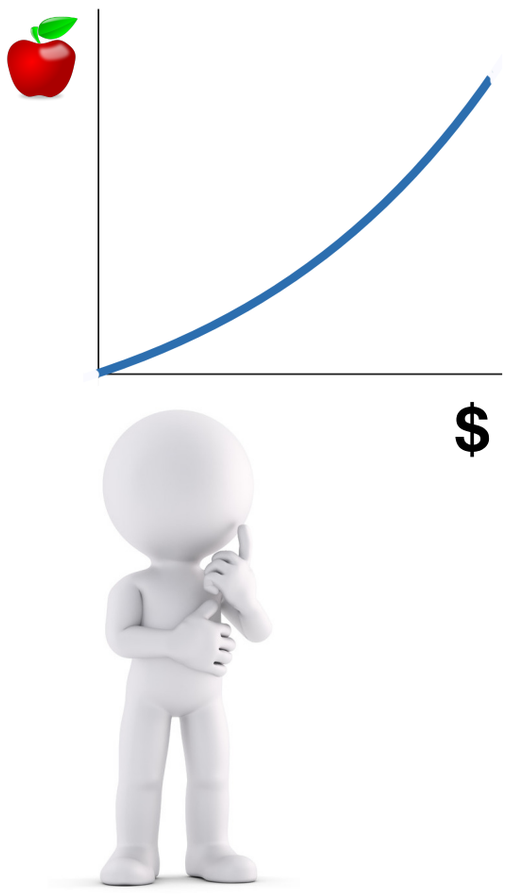


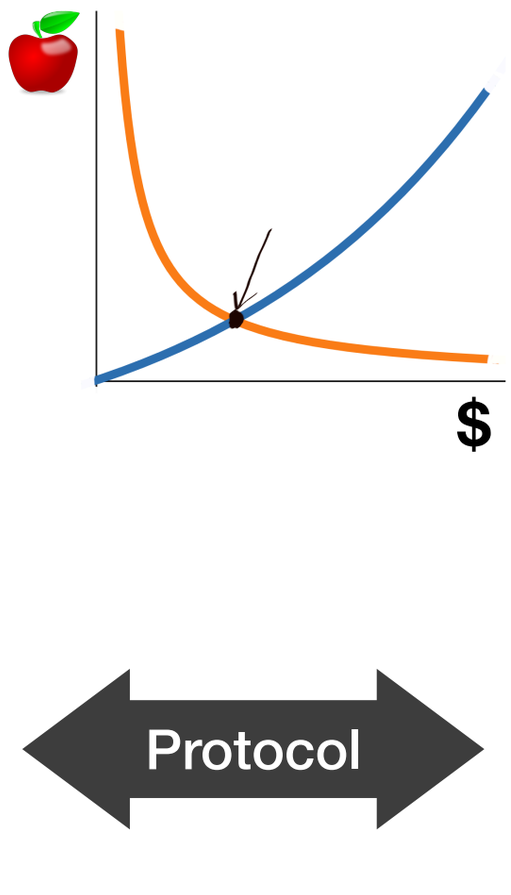
Protocol

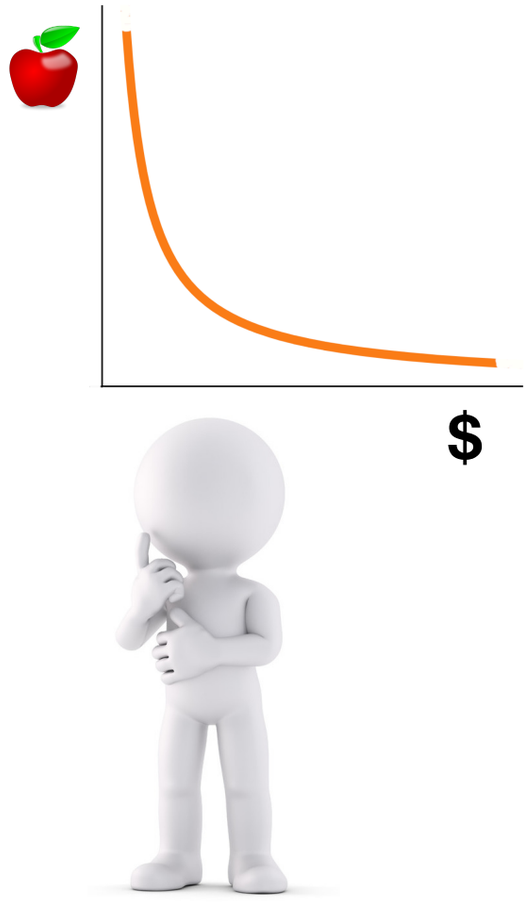
Artificial Agent
Negotiates on behalf of an actor.

Image credits: 1, 2, 3

Automated Negotiation





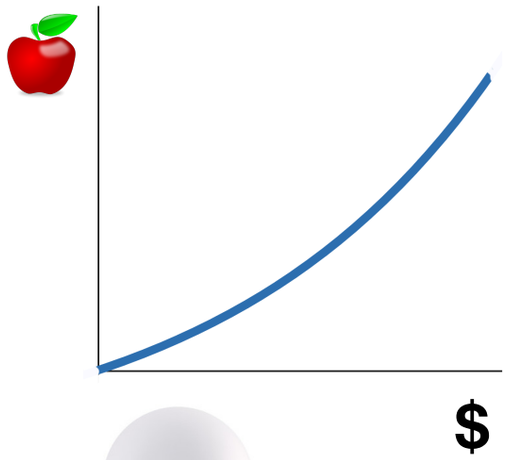


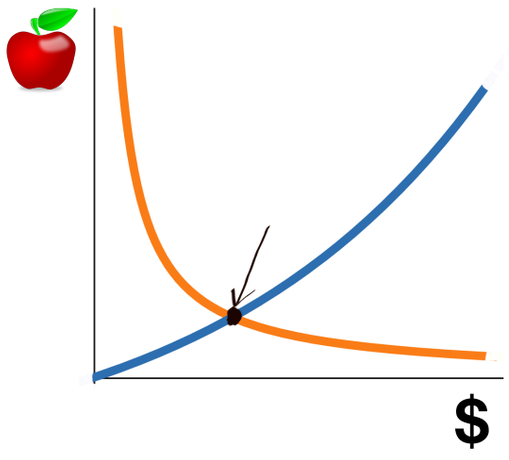
Protocol

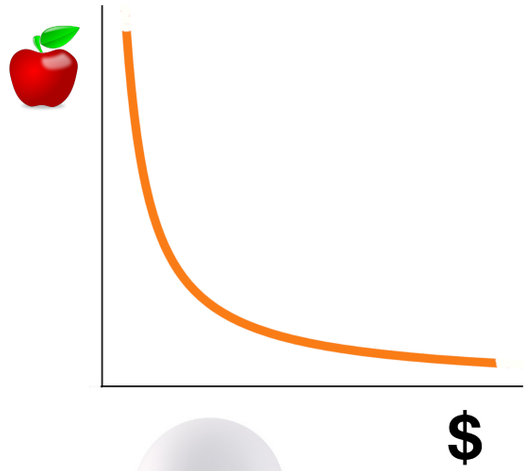
Artificial Agent
Negotiates on behalf of an actor.

Image credits: 1, 2, 3

Automated Negotiation







Protocol

Agent must understand actor and opponent!

Agent must understand actor and opponent!

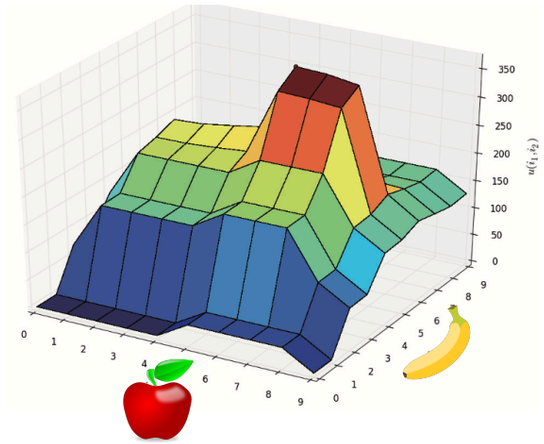
Image credits: 1, 2, 3

Automated Negotiation

Protocol

Image credits: 1, 2, 3

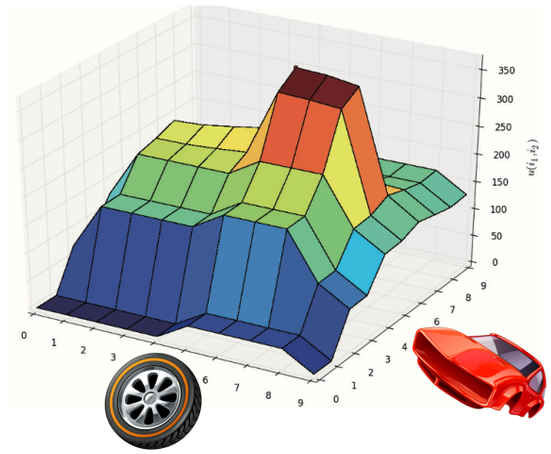
Automated Negotiation



Protocol

Image credits: 1, 2, 3

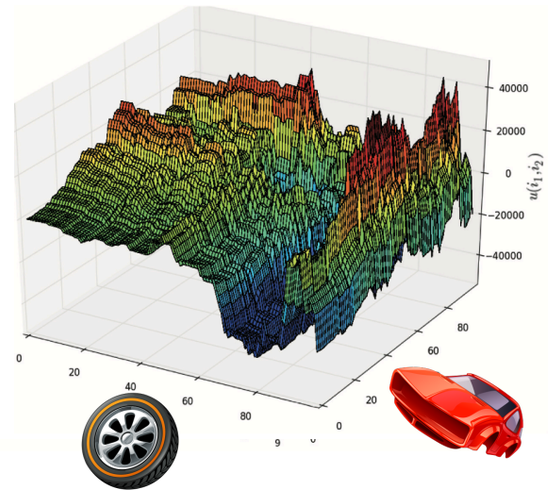
Automated Negotiation



Protocol

Image credits: 1, 2, 3

Automated Negotiation

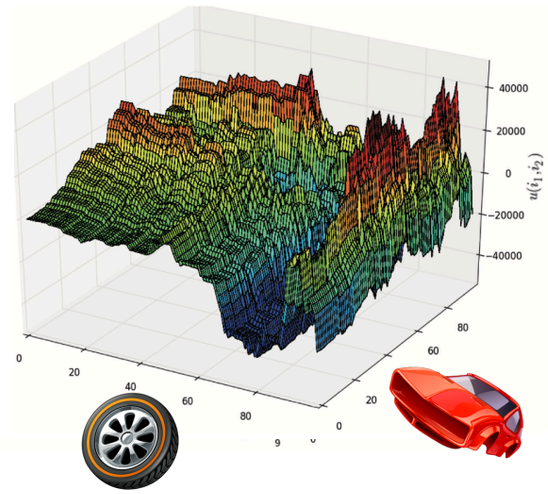


Protocol

Image credits: 1, 2, 3

Automated Negotiation

...



Protocol

Image credits: 1, 2, 3

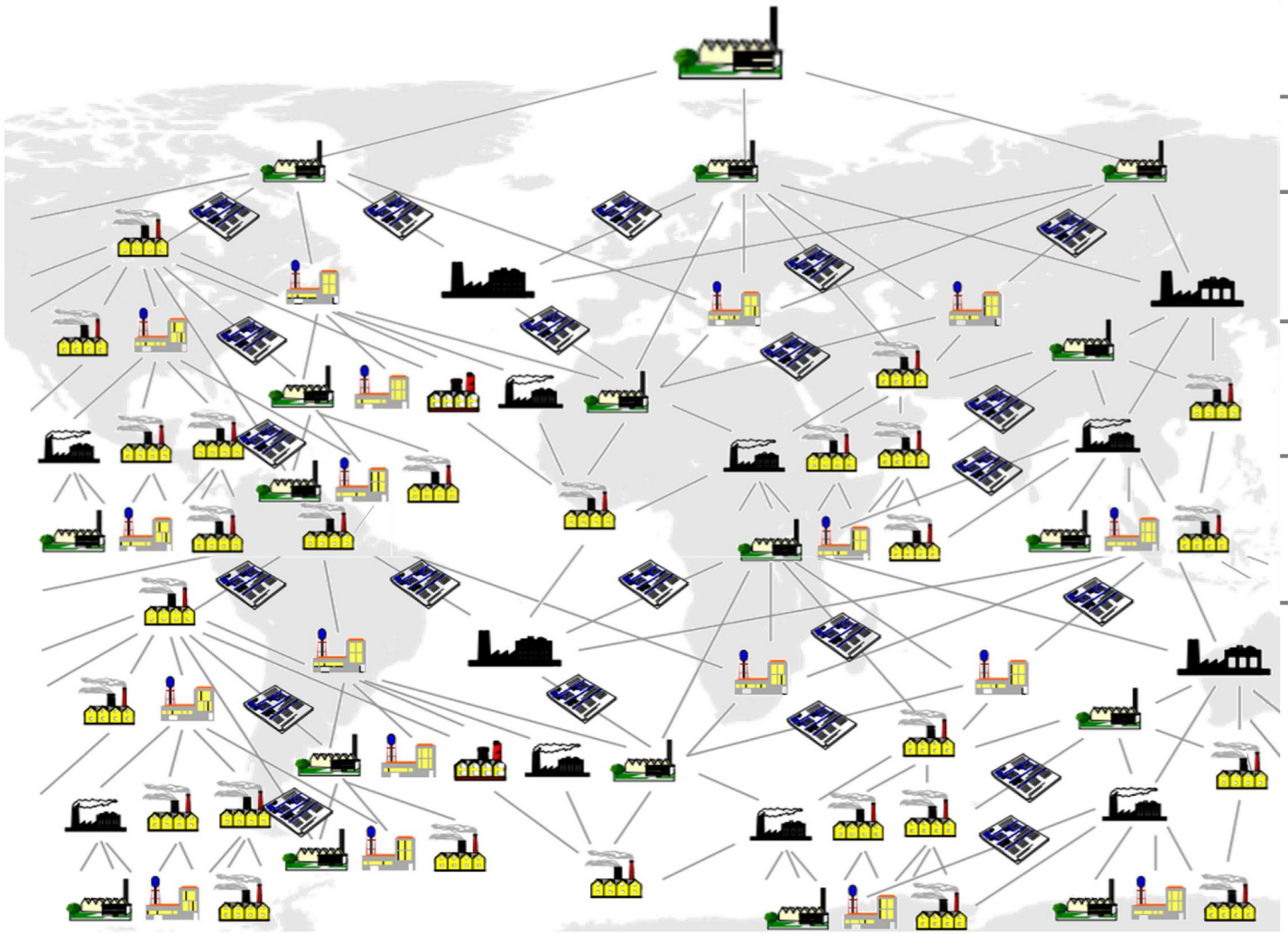
Automated Negotiation in Supply Chains

Why automate negotiations in supply chains?

Automated Negotiation in Supply Chains

Why automate negotiations in supply chains?

A complex supply chain



OEM: 1

Tier 1: 3500

X 500

Tier 2: 1,75 Mio.

X 100

Tier 3: 175 Mio.

X 50

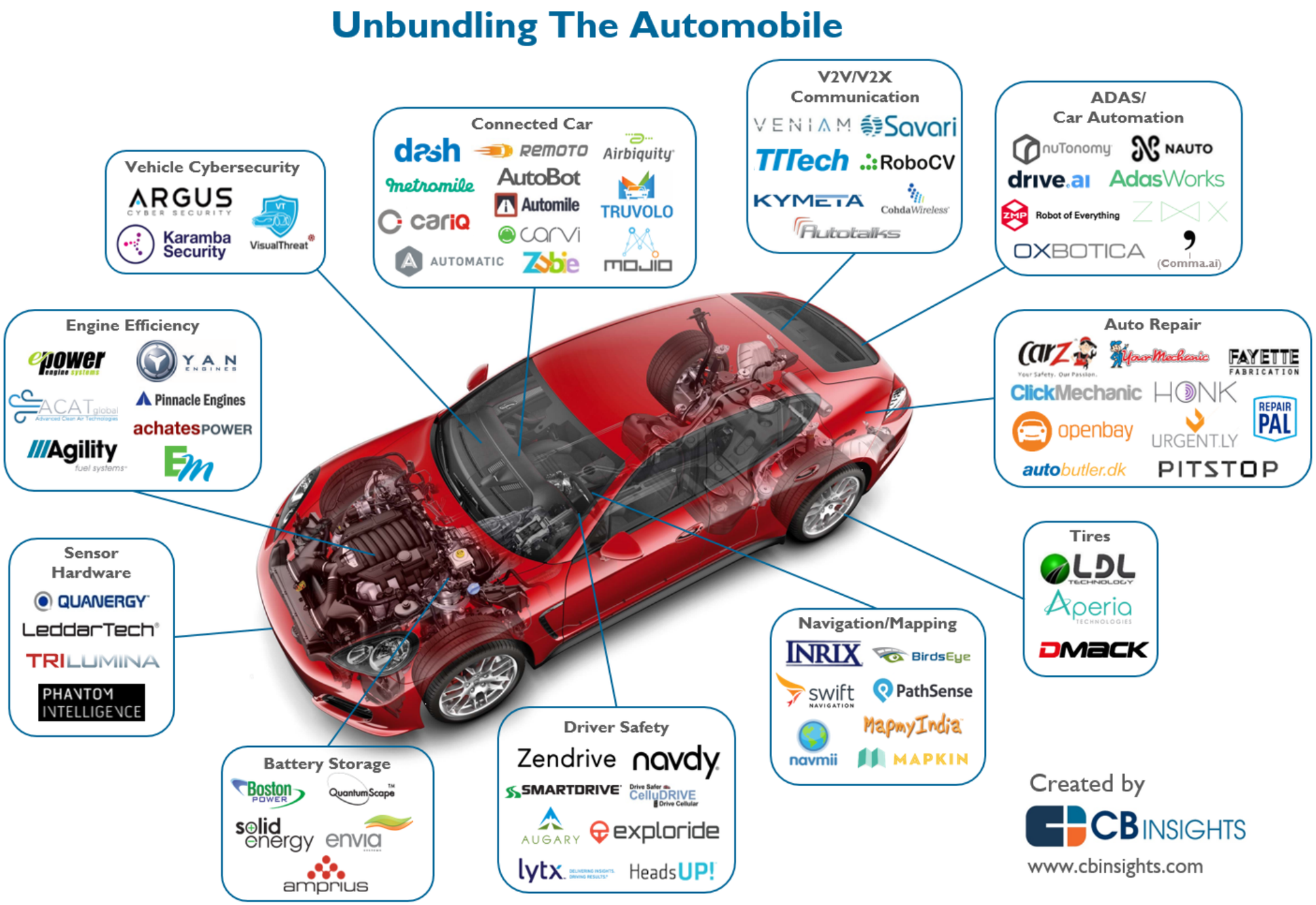
Tier 4: 8,75 Bn.

50 to 80% suppliers are coming from outside Europe

3-8 levels in the Automotive supply chain

Automated Negotiation in Supply Chains

Why automate negotiations in supply chains?



Automated Negotiation in Supply Chains (cont.)

- Human negotiations lead to an estimated 17-40% *value leakage* (lots of lost $$) in some estimates (KPMG report: https://bit.ly/3kDRy6l)

Automated Negotiation in Supply Chains (cont.)

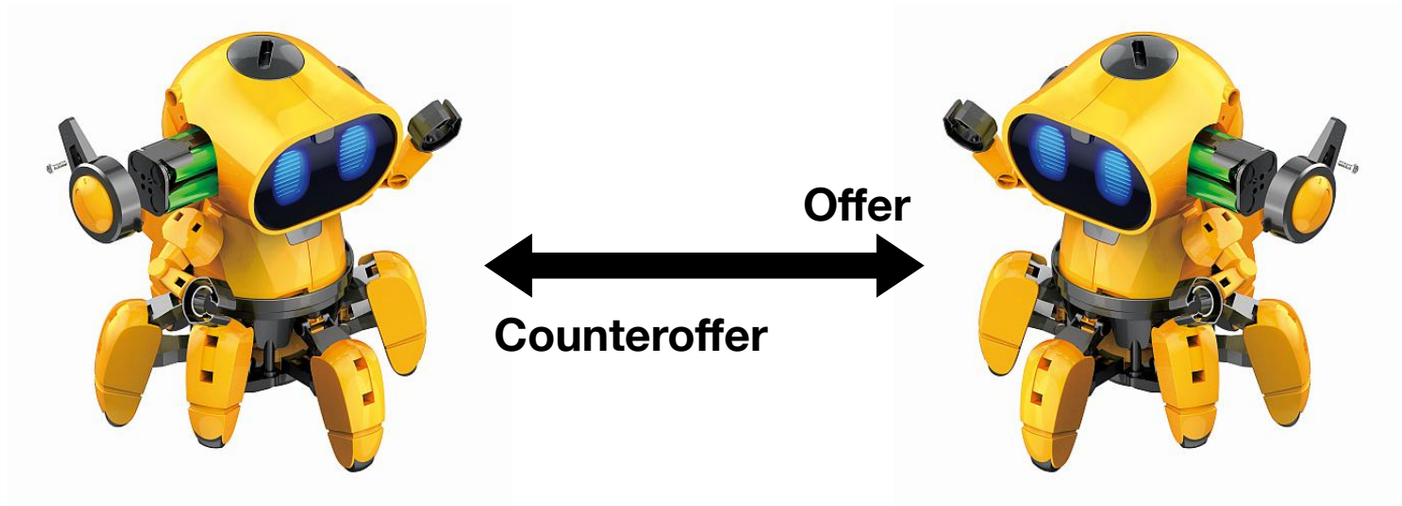
- Human negotiations lead to an estimated 17-40% *value leakage* (lots of lost $$) in some estimates (KPMG report: https://bit.ly/3kDRy6I)

- Studies suggests that at least 15 companies are working to contract *support systems* (Forrester report: https://bit.ly/3nwXEaY)

Automated Negotiation in Supply Chains (cont.)

- Human negotiations lead to an estimated 17-40% *value leakage* (lots of lost $$) in some estimates (KPMG report: https://bit.ly/3kDRy6I)
- Studies suggests that at least 15 companies are working to contract *support systems* (Forrester report: https://bit.ly/3nwXEaY)
- A recent proposal to *standardize negotiation protocols* for SCM and other applications (UN/CEFACT Project website: https://bit.ly/38LOsLX)

Image credit



Part 2: Artificial Negotiation Agents for Supply Chains

How can we develop agents for supply chains?

How can we measure our progress?

Why (or why not) are games a good idea?

Advancing Research via Games

Long-standing tradition of using **games** to advance Artificial Intelligence (AI) research.

Image credits: 1, 2, 3

Advancing Research via

Not to be confused with video games!

Long-standing tradition of using **games** to advance Artificial Intelligence (AI) research.

Image credits: 1, 2, 3

Advancing Research via Games

Long-standing tradition of using **games** to advance Artificial Intelligence (AI) research.

Image credits: 1, 2, 3

Advancing Research via Games

Long-standing tradition of using **games** to advance Artificial Intelligence (AI) research.

Image credits: 1, 2, 3

Advancing Research via Games

Long-standing tradition of using **games** to advance Artificial Intelligence (AI) research.

Image credits: 1, 2, 3

Advancing Research via Games

Long-standing tradition of using **games** to advance Artificial Intelligence (AI) research.

Image credits: 1, 2, 3

Advancing Research via Games

Long-standing tradit igence (AI) research.

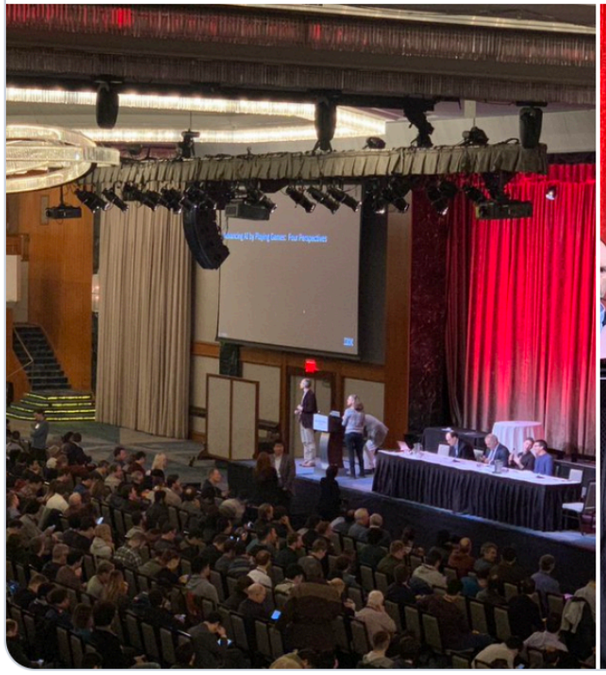
https://vimeo.com/389556398

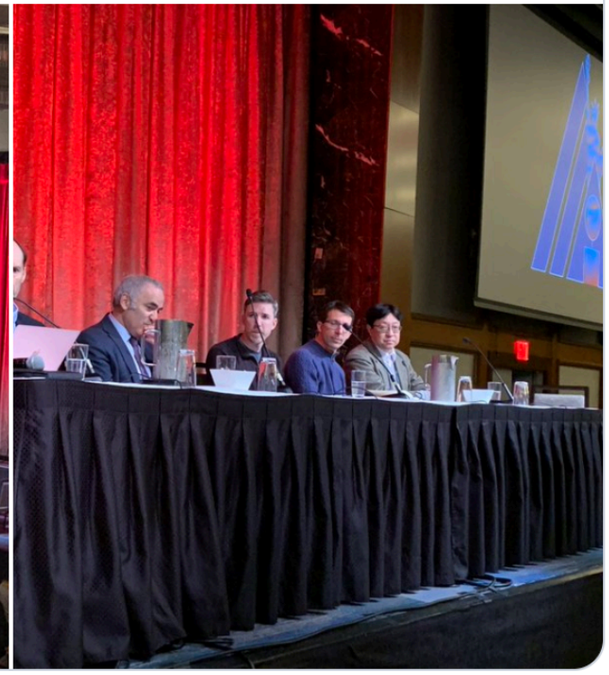
Tweet

Garry Kasparov
@Kasparov63

Many thanks to @RealAAAI, Amy Greenwald, and my illustrious co-panelists today. I'm happy to share by experiences and thought, but they are moving the world forward with their research and innovations. Fascinating conversation!

> **AAAI** @RealAAAI · Feb 11
> The AI History panel is beginning! With @Kasparov63, Michael Bowling, @murraycampbell, Hiroaki Kitano, David Silver, and Amy Greenwald.





7:39 PM · Feb 11, 2020 · TweetDeck

Image credits: 1, 2, 3

International Automated Negotiating Agents Competition (ANAC)

From their website, http://web.tuat.ac.jp/~katfuji/ANAC2020:

“ANAC provides a unique benchmark for evaluating practical negotiation strategies in multi-issue **domains**”.

<u>Leagues</u>

- Automated Negotiation
- Human-Agent
- LeagueWerewolf Game
- HUMAIN League
- **Supply Chain Management (new, since 2019)**

International Automated Negotiating Agents Competition (ANAC)

From their website, http://web.tuat.ac.jp/~katfuji/ANAC2020:

"ANAC provides a unique benchmark for evaluating practical negotiation strategies in multi-issue **domains**".

A league models some of the challenges that automated negotiation agents face in some domain

<u>Leagues</u>

* Automated Negotiation
* Human-Agent
* LeagueWerewolf Game
* HUMAIN League
* **Supply Chain Management (new, since 2019)**

Supply Chain Management League (SCML) - Very Briefly!

Design and build an **autonomous agent** that **negotiates** on behalf of a **factory manager** situated in a **supply chain** management simulation.

Image credits: (2)

Supply Chain Mana L) - Very Briefly!

Once deployed in the game, no further changes to the agent can be made.

Design and build an **autonomous agent** that **negotiates** on behalf of a **factory manager** situated in a **supply chain** management simulation.

Image credits: (2)

Supply Chain Management League (SCML) - Very Briefly!

Design and build an **autonomous agent** that **negotiates** on behalf of a **factory manager** situated in a **supply chain** management simulation.

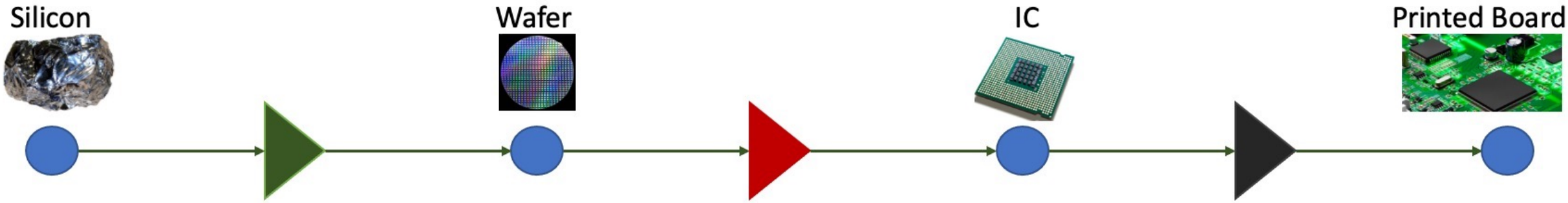


Image credits: (2)

Supply Chain Management League (SCML) - Very Briefly!

Design and build an **autonomous agent** that **negotiates** on behalf of a **factory manager** situated in a **supply chain** management simulation.

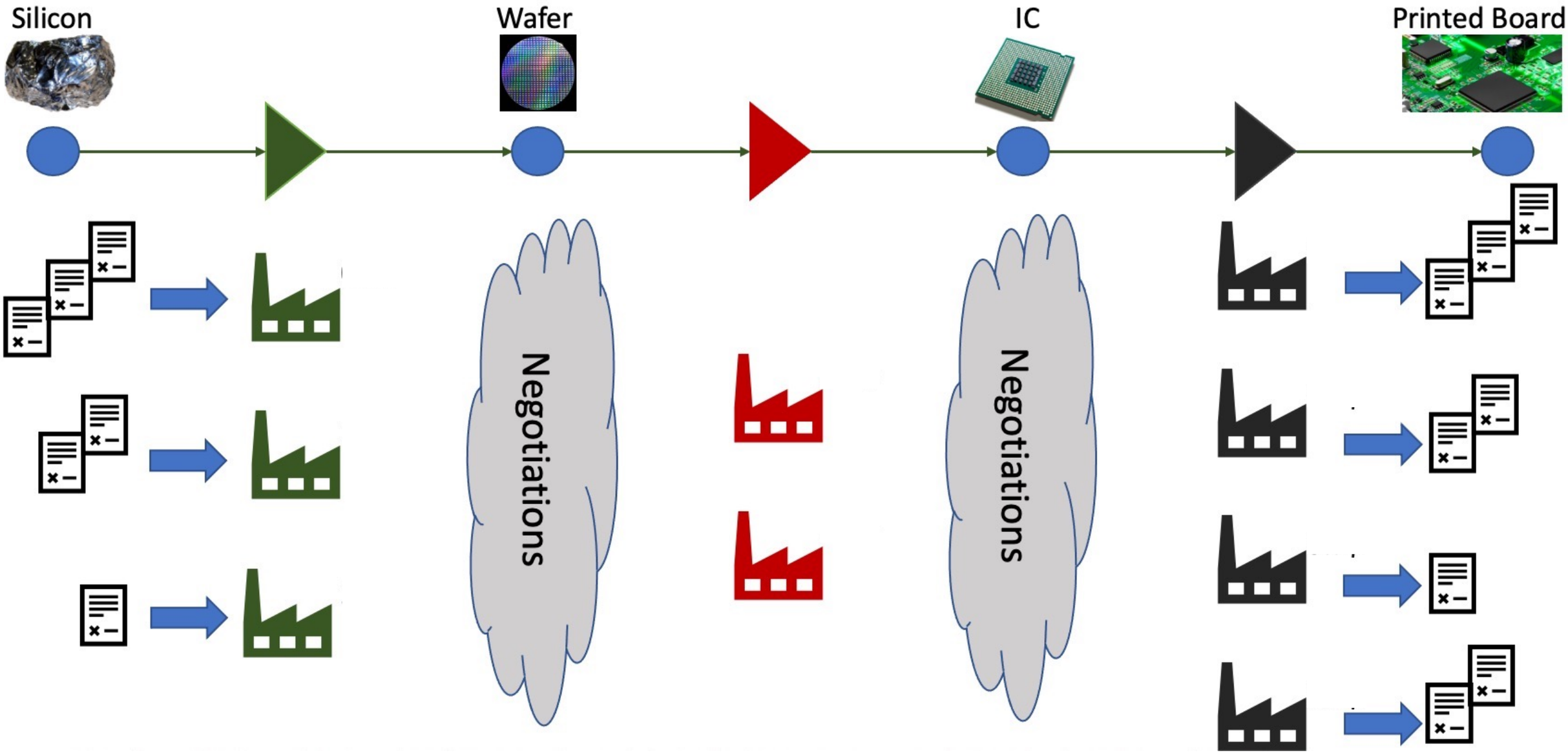


Image credits: (2)

Supply Chain Management League (SCML) - Very Briefly!

Design and build an **autonomous agent** that **negotiates** on behalf of a **factory manager** situated in a **supply chain** management simulation.

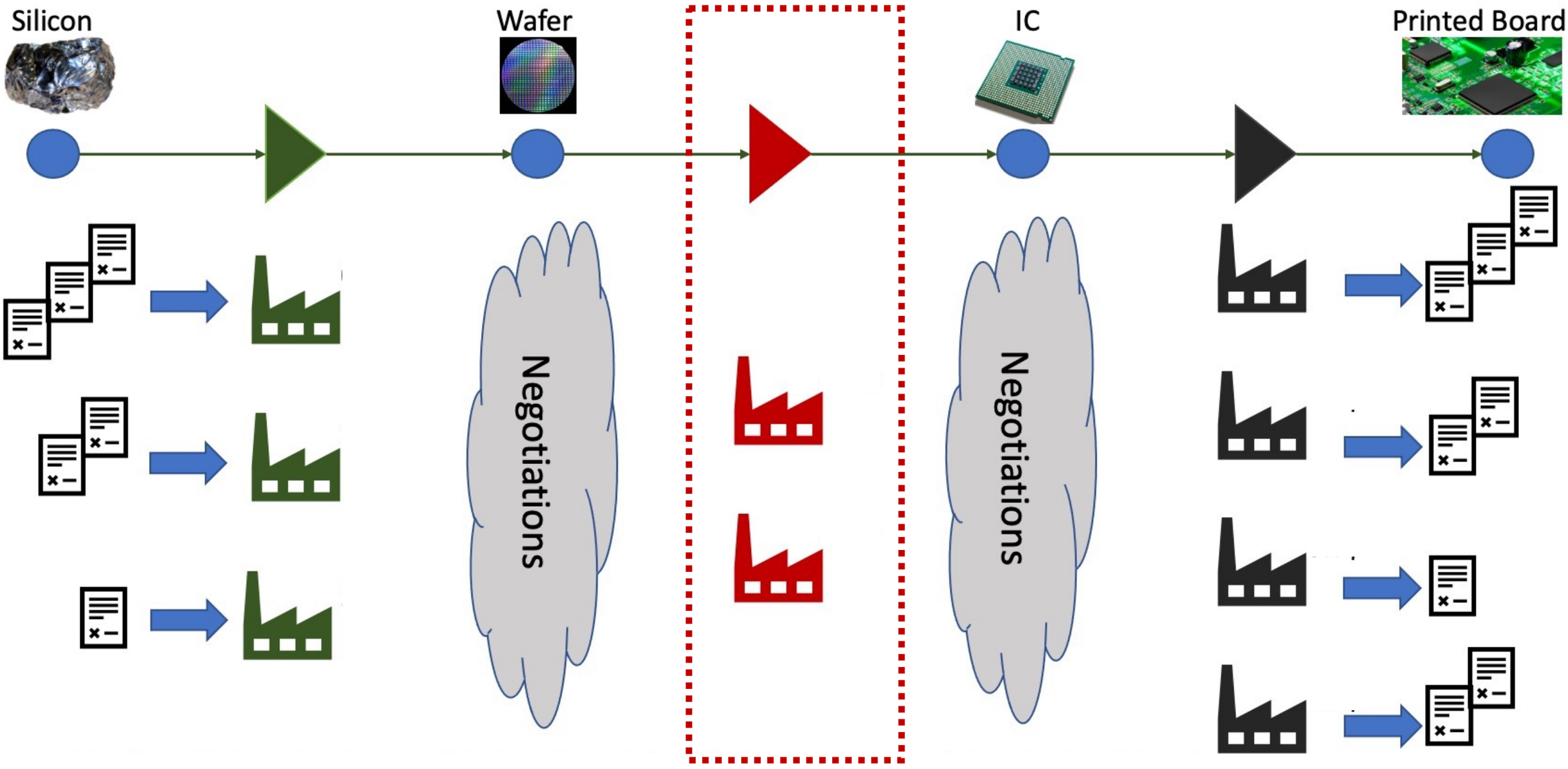


Image credits: (2)

Supply Chain Management League (SCML) - Very Briefly!

Design and build an **autonomous agent** that **negotiates** on behalf of a **factory manager** situated in a **supply chain** management simulation.

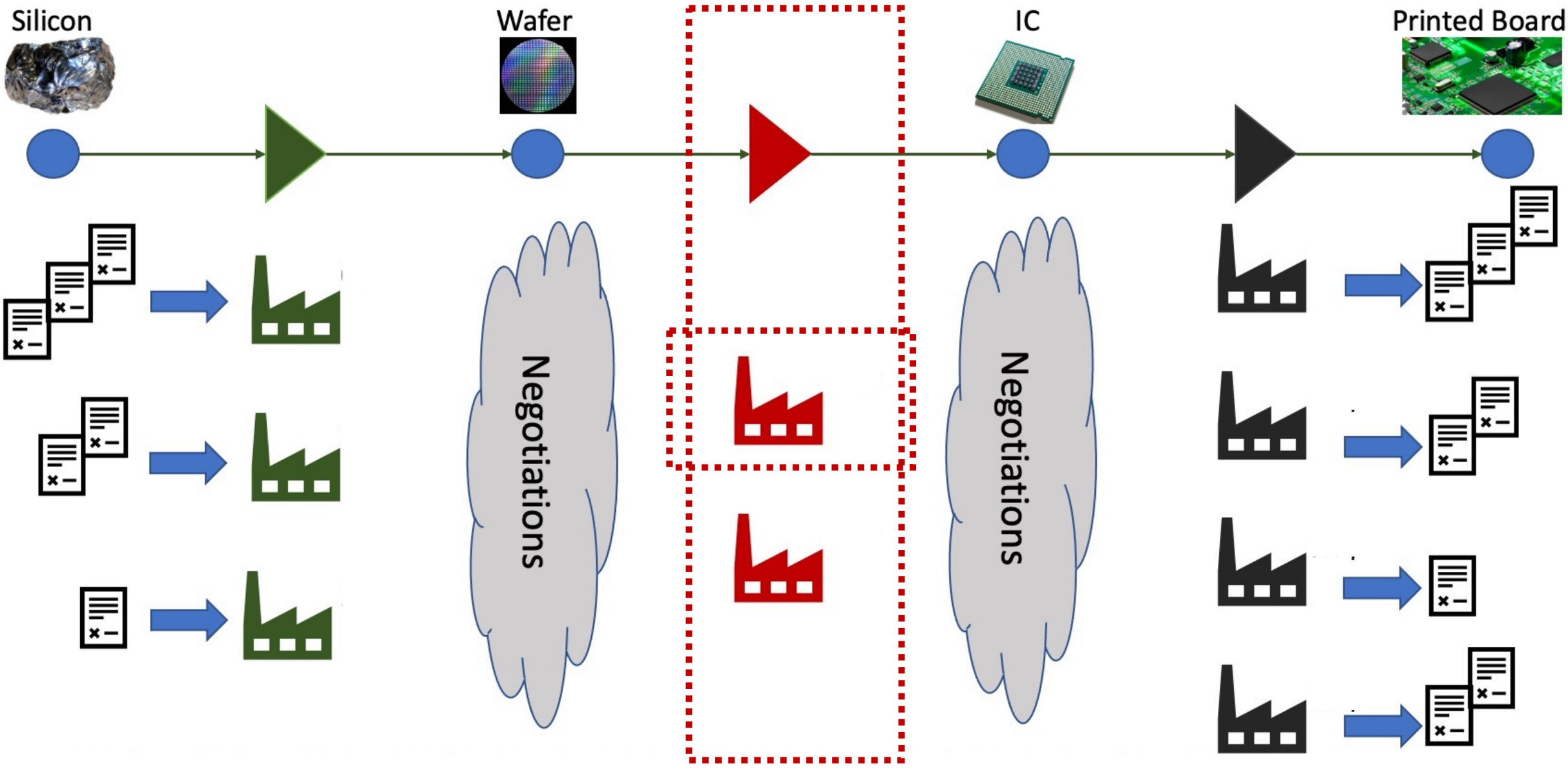


Image credits: (2)

Supply Chain Management League (SCML) - Very Briefly!

Design and build an **autonomous agent** that **negotiates** on behalf of a **factory manager** situated in a **supply chain** management simulation.

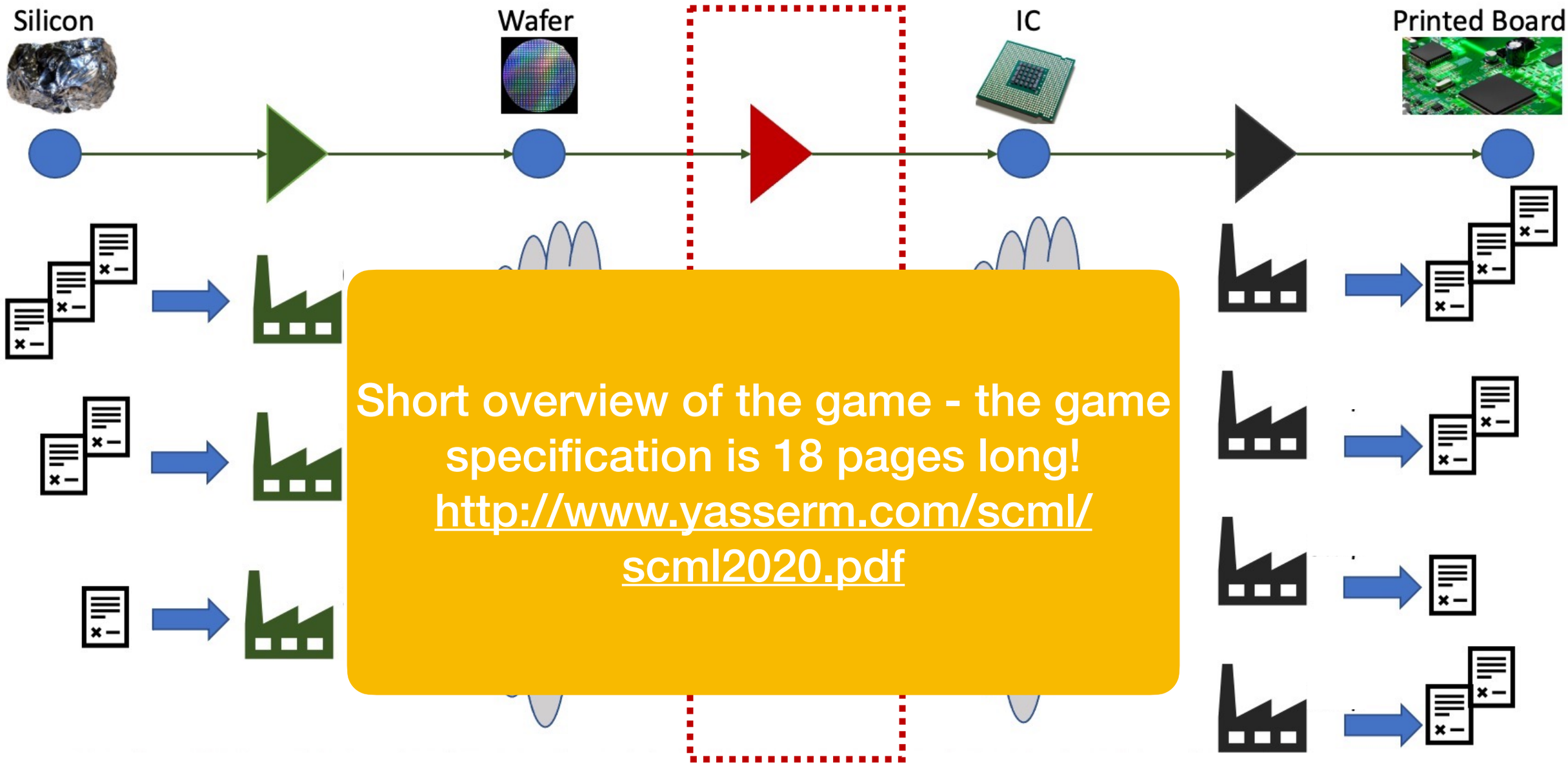


Image credits: (2)

Supply Chain Management League (SCML) (cont.)

Challenge: **maximize** factory's **profit** at the end of the game.

Supply Chain Management League (SCML) (cont.)

Challenge: **maximize** factory's **profit** at the end of the game.

[**Start**, Day 1, Day 2, Day 3, … , **End of game**]

Supply Chain Management League (SCML) (cont.)

Challenge: **maximize** factory's **profit** at the end of the game.

[**Start**, Day 1, Day 2, Day 3, … , **End of game**]

This is an ***intricate*** challenge because your agent must (at least):

Supply Chain Management League (SCML) (cont.)

Challenge: **maximize** factory's **profit** at the end of the game.

[**Start**, Day 1, Day 2, Day 3, … , **End of game**]

This is an ***intricate*** challenge because your agent must (at least):

- **Devise** some utility function

Supply Chain Management League (SCML) (cont.)

Challenge: **maximize** factory's **profit** at the end of the game.

[**Start**, Day 1, Day 2, Day 3, … , **End of game**]

This is an ***intricate*** challenge because your agent must (at least):

- **Devise** some utility function
- Negotiate with **multiple** other agents under **uncertainty**

Supply Chain Management League (SCML) (cont.)

Challenge: **maximize** factory's **profit** at the end of the game.

[**Start**, Day 1, Day 2, Day 3, … , **End of game**]

This is an ***intricate*** challenge because your agent must (at least):

- **Devise** some utility function
- Negotiate with **multiple** other agents under **uncertainty**
- Manage or quantify t**rust** (can your agent trust other agents?)

Supply Chain Management League (SCML) (cont.)

Challenge: **maximize** factory's **profit** at the end of the game.

[**Start**, Day 1, Day 2, Day 3, … , **End of game**]

This is an ***intricate*** challenge because your agent must (at least):

- **Devise** some utility function
- Negotiate with **multiple** other agents under **uncertainty**
- Manage or quantify t**rust** (can your agent trust other agents?)
- etc.

Supply Chain Management League (SCML) (cont.)

Challenge: **maximize** factory's **profit** at the end of the game.

[**Start**, Day 1, Day 2, Day 3, … , **End of game**]

This is an ***intricate*** challenge because your agent must (at least):

- **Devise** some utility function
- Negotiate with **multiple** other agents under **uncertainty**
- Manage or quantify t**rust** (can your agent trust other agents?)
- etc.

Resources	
Website	https://scml.cs.brown.edu/
Code	https://www.github.com/yasserfarouk/scml
YouTube Tutorials	https://tinyurl.com/y5koqxfu
Online Competition	https://scml.cs.brown.edu

Our Agents for SCML

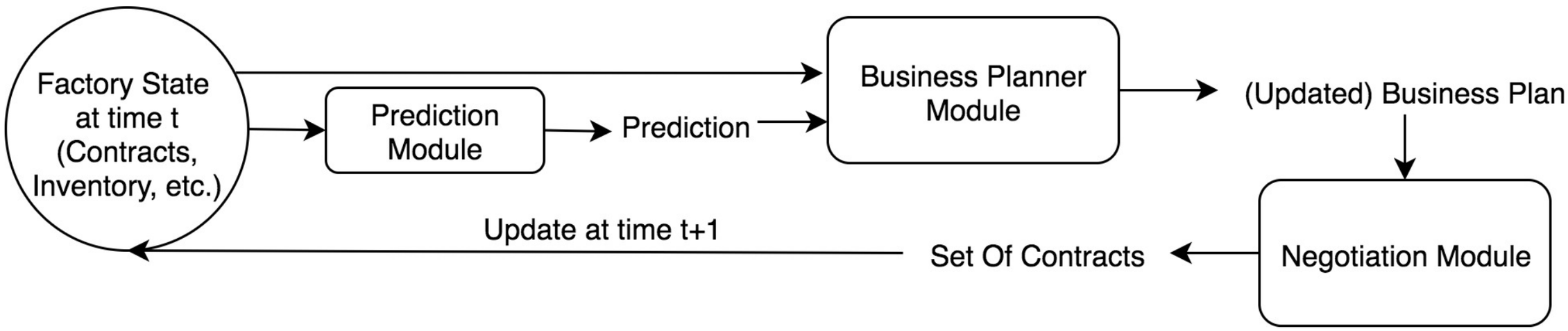
An agent's architecture in 3 modules:

- Prediction
- Business Planner
- Negotiation

Our Agents for SCML

An agent's architecture in 3 modules:

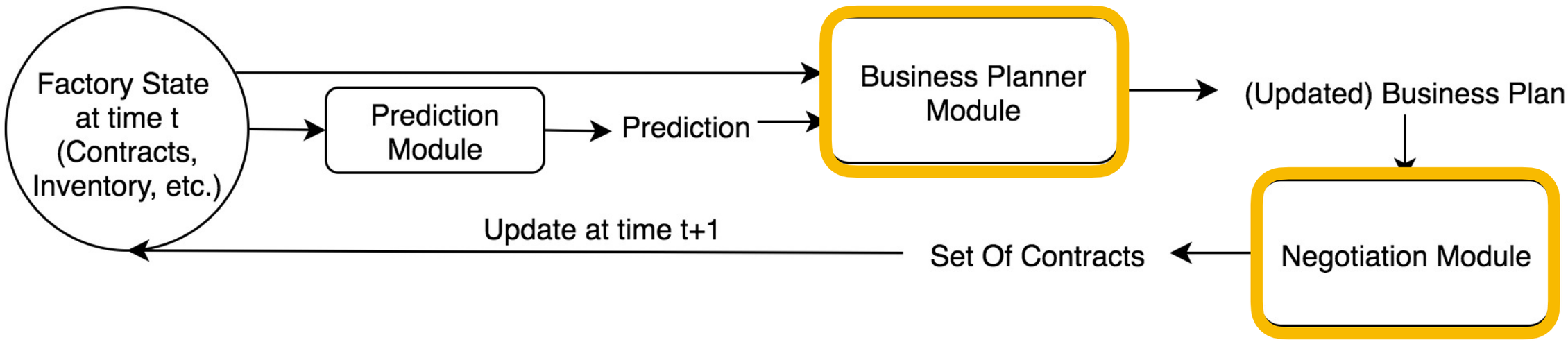
- Prediction
- Business Planner
- Negotiation



Our Agents for SCML

An agent's architecture in 3 modules:

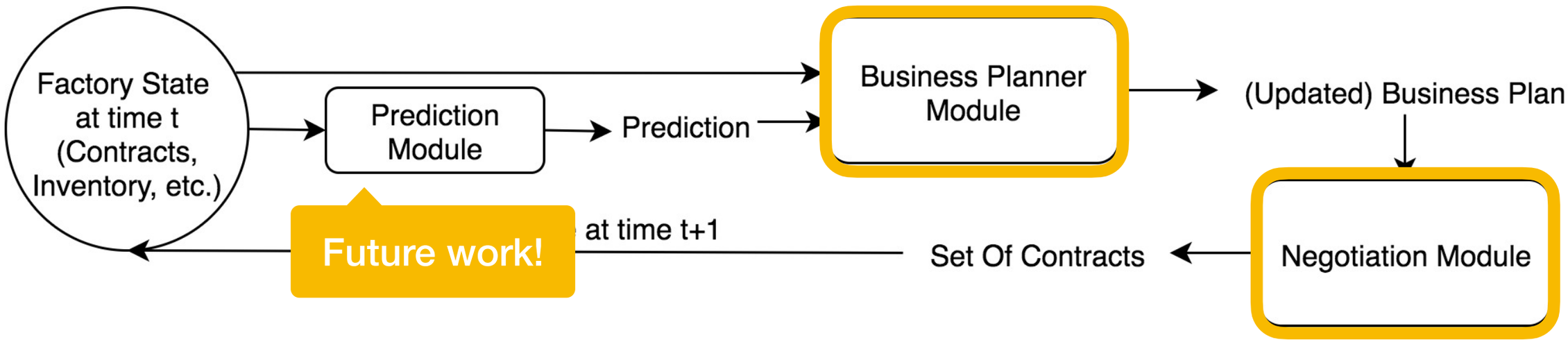
- Prediction
- Business Planner
- Negotiation



Our Agents for SCML

An agent's architecture in 3 modules:

- Prediction
- Business Planner
- Negotiation



Our Agents for SCML - Business Plan

Uncertain **supply** (of raw materials) and **demand** (of finished products).

Still, agent needs to **buy** (raw materias) and **sell** (finished products) to earn profit.

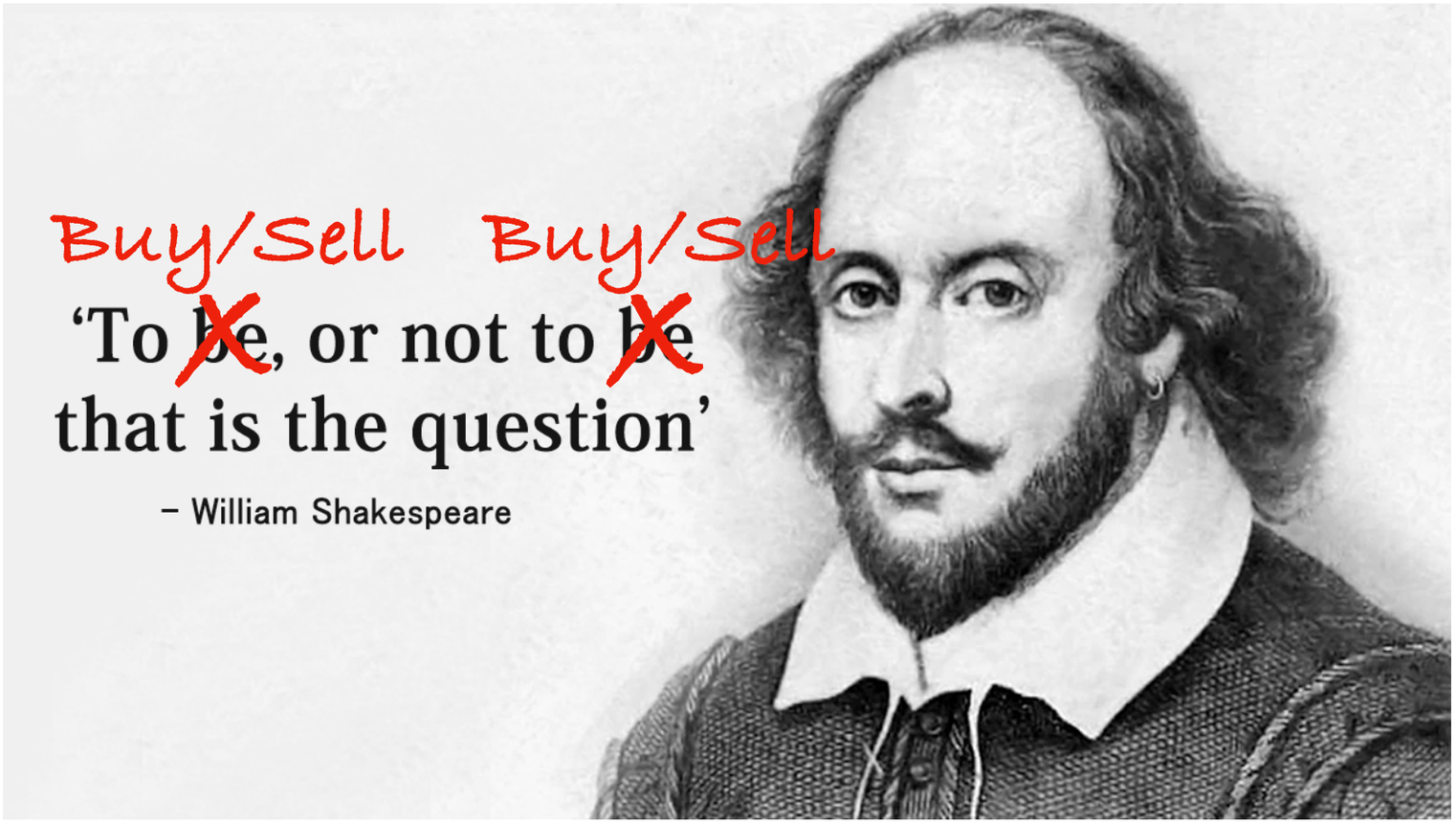
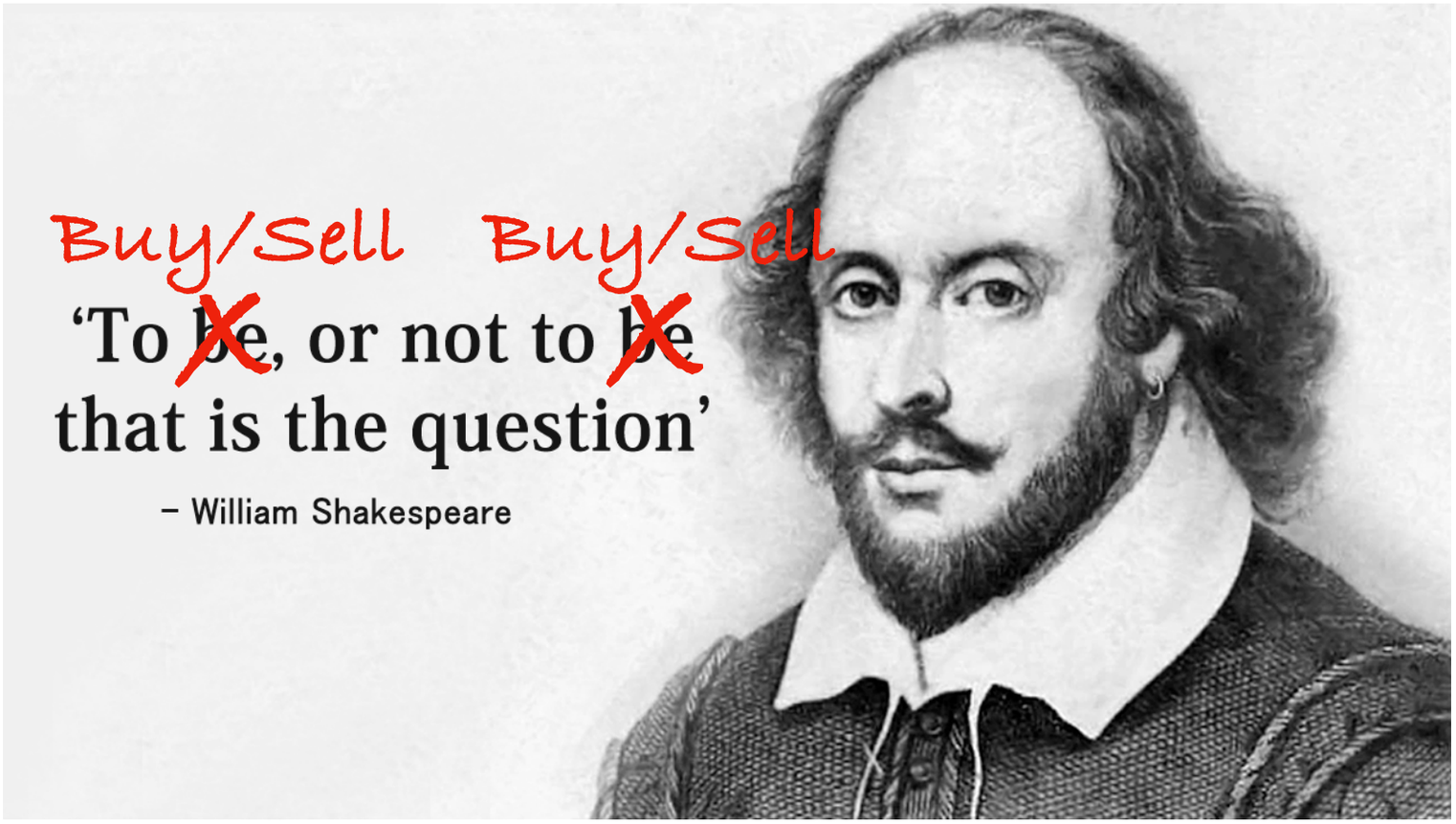


Image credits

Our Agents for SCML - Business Plan

Uncertain **supply** (of raw materials) and **demand** (of finished products).

Still, agent needs to **buy** (raw materias) and **sell** (finished products) to earn profit.



Let's start *simple*. Suppose there was no uncertainty. What to do then?

Image credits

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and finished product, $p_{product}$

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and finished product, $p_{product}$

Then, we can formulate the **profit maximizing plan** as

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and finished product, $p_{product}$

Then, we can formulate the **profit maximizing plan** as

$$\max_{q_{raw}, q_{product}} \{q_{product}\, p_{product} - q_{raw}\, p_{raw}\}$$

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and fi product, p

Then, we can formulate the **maximizir** as

The agent decides!

The agent decides!

$$\max_{q_{raw}, q_{product}} \{q_{product}\, p_{product} - q_{raw}\, p_{raw}\}$$

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and fi product, p

Then, we can formulate the **maximizir** as

The agent decides!

The agent decides!

$$\max_{q_{raw}, q_{product}} \{q_{product}\, p_{product} - q_{raw}\, p_{raw}\}$$

In reality, the agent is subject to **supply and demand constraints**!

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and fi product, p

The agent decides!

The agent decides!

Then, we can formulate the **maximizir** as

$$\max_{q_{raw}, q_{product}} \{q_{product}\, p_{product} - q_{raw}\, p_{raw}\}$$

In reality, the agent is subject to **supply and demand constraints**!

Suppose the agent **knows quantities:**

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and fi product, p

The agent decides!

The agent decides!

Then, we can formulate the **maximizir** as

$$\max_{q_{raw}, q_{product}} \{q_{product}\, p_{product} - q_{raw}\, p_{raw}\}$$

In reality, the agent is subject to **supply and demand constraints**!

Suppose the agent **knows quantities:**

supply of raw material, Q_{raw} and demand of finished product, $Q_{product}$

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and fi product, p

The agent decides!

The agent decides!

Then, we can formulate the **maximizir** as

$$\max_{q_{raw}, q_{product}} \{q_{product}\, p_{product} - q_{raw}\, p_{raw}\}$$

In reality, the agent is subject to **supply and demand constraints**!

Suppose the agent **knows quantities:**

supply of raw material, Q_{raw} and demand of finished product, $Q_{product}$

Then, we can **reformulate the profit maximizing plan** as

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and fi product, p

The agent decides!

The agent decides!

Then, we can formulate the **maximizir** as

$$\max_{q_{raw}, q_{product}} \{q_{product}\, p_{product} - q_{raw}\, p_{raw}\}$$

In reality, the agent is subject to **supply and demand constraints**!

Suppose the agent **knows quantities:**

supply of raw material, Q_{raw} and demand of finished product, $Q_{product}$

Then, we can **reformulate the profit maximizing plan** as

$$\max_{q_{raw}, q_{product}} \{\min(q_{product}, Q_{product})\, p_{product} - \min(q_{raw}, Q_{raw})\, p_{raw}\}$$

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and fi product, p

The agent decides!

The agent decides!

Then, we can formulate the **maximizir** as

$$\max_{q_{raw}, q_{product}} \{q_{product}\, p_{product} - q_{raw}\, p_{raw}\}$$

In reality, the agent is subject to **supply and demand constraints**!

Suppose the agent **knows quantities:**

supply of raw material, Q_{raw} and demand of finished product, $Q_{product}$

Then, we can **reformulate the profit maximizing plan** as

$$\max_{q_{raw}, q_{product}} \{\min(q_{product}, Q_{product})\, p_{product} - \min(q_{raw}, Q_{raw})\, p_{raw}\}$$

The agent decides!

The agent decides!

Our Agents for SCML - Business Plan (cont. 1.)

Suppose the agent **knows prices:**

raw material, p_{raw} and fi product, p

The agent decides!

The agent decides!

Then, we can formulate the **maximizir** as

$$\max_{q_{raw}, q_{product}} \{q_{product}\, p_{product} - q_{raw}\, p_{raw}\}$$

In reality, the agent is subject to **supply and demand constraints**!

Suppose the agent **knows quantities:**

supply of raw material, Q_{raw} and demand of finished product, $Q_{product}$

Then, we can **reformulate the profit maximizing plan** as

$$\max_{q_{raw}, q_{product}} \{\min(q_{product}, Q_{product})\, p_{product} - \min(q_{raw}, Q_{raw})\, p_{raw}\}$$

The agent decides!

But subject to constraints!

The agent decides!

But subject to constraints!

Our Agents for SCML - Business Plan (cont. 2.)

But, the agent **does not know** supplied or demanded quantities!

Our Agents for SCML - Business Plan (cont. 2.)

But, the agent **does not know** supplied or demanded quantities!

We build **uncertainty models** of these quantities!

Our Agents for SCML - Business Plan (cont. 2.)

But, the agent **does not know** supplied or demanded quantities!

We build **uncertainty models** of these quantities!

And learn them from gameplay data (e.g., self-play).

Our Agents for SCML - Business Plan (cont. 2.)

But, the agent **does not know** supplied or demanded quantities!

We build **uncertainty models** of these quantities!

And learn them from gameplay data (e.g., self-play).

$$\max_{q_{raw}, q_{product}} \mathbb{E}\left[\min(q_{product}, Q_{product})\, p_{product} - \min(q_{raw}, Q_{raw})\, p_{raw}\right]$$

Our Agents for SCML - Business Plan (cont. 2.)

But, the agent **does not know** supplied or demanded quantities!

We build **uncertainty models** of these quantities!

And learn them from gameplay data (e.g., self-play).

$$\max_{q_{raw}, q_{product}} \mathbb{E}\left[\min(q_{product}, Q_{product})\, p_{product} - \min(q_{raw}, Q_{raw})\, p_{raw}\right]$$

Expectation!

Our Agents for SCML - Business Plan (cont. 2.)

But, the agent **does not know** supplied or demanded quantities!

We build **uncertainty models** of these quantities!

And learn them from gameplay data (e.g., self-play).

$$\max_{q_{raw}, q_{product}} \mathbb{E}\left[\min(q_{product}, Q_{product})\, p_{product} - \min(q_{raw}, Q_{raw})\, p_{raw}\right]$$

Expectation!

The agent decides!

The agent decides!

Our Agents for SCML - Business Plan (cont. 2.)

But, the agent **does not know** supplied or demanded quantities!

We build **uncertainty models** of these quantities!

And learn them from gameplay data (e.g., self-play).

$$\max_{q_{raw}, q_{product}} \mathbb{E}\left[\min(q_{product}, Q_{product})\, p_{product} - \min(q_{raw}, Q_{raw})\, p_{raw}\right]$$

Expectation!

The agent decides!

Random Variable

The agent decides!

Random Variable

Our Agents for SCML - Business Plan (cont. 3.)

Ignoring *some* (ok, *a lot*! :-)) of details, our final agents for 2019/2020 solve this equation

Our Agents for SCML - Business Plan (cont. 3.)

Ignoring *some* (ok, *a lot*! :-)) of details, our final agents for 2019/2020 solve this equation

$$\max_{q^t_{raw}, q^t_{product}} \mathbb{E}\left[\sum_{t=1}^{T} \min(q^t_{product}, Q^t_{product})\, p^t_{product} - \min(q^t_{raw}, Q^t_{raw})\, p^t_{raw}\right]$$

Subject to **inventory control** (cannot sell finished product before procuring raw materials!), and **acts accordingly**.

Our Agents for SCML - Business Plan (cont. 3.)

Ignoring *some* (ok, *a lot*! :-)) of details, our final agents for 2019/2020 solve this equation

$$\max_{q^t_{raw}, q^t_{product}} \mathbb{E}\left[\sum_{t=1}^{T} \min(q^t_{product}, Q^t_{product})\, p^t_{product} - \min(q^t_{raw}, Q^t_{raw})\, p^t_{raw}\right]$$

The problem is actually multi-period!

- **ntory control** (cannot sell finished product before procuring raw materials!), and **acts accordingly**.

Our Agents for SCML - Business Plan (cont. 3.)

Ignoring *some* (ok, *a lot*! :-)) of details, our final agents for 2019/2020 solve this equation

$$\max_{q^t_{raw}, q^t_{product}} \mathbb{E}\left[\sum_{t=1}^{T} \min(q^t_{product}, Q^t_{product})\, p^t_{product} - \min(q^t_{raw}, Q^t_{raw})\, p^t_{raw}\right]$$

The problem is actually multi-period!

ntory control (cannot sell finished product before procuring raw materials!), and **acts accordingly**.

A **plan** is a sequence $q^t_{raw}, q^t_{product}$, for $t = 1,2,\ldots,T$

Acts means to implement the plan.

Our Agents for SCML - Business Plan (cont. 3.)

Ignoring *some* (ok, *a l*

solve this equation

Solving this equation is computationally challenging!
We efficiently solved it using dynamic programming and other algorithmic/AI techniques!

$$\max_{q^t_{raw}, q^t_{product}} \mathbb{E}\left[\sum_{t=1}^{T} \min(q^t_{product}, Q^t_{product})\, p^t_{product} - \min(q^t_{raw}, Q^t_{raw})\, p^t_{raw}\right]$$

The problem is actually multi-period!

ntory control (cannot sell finished product before procuring raw materials!), and **acts accordingly**.

A **plan** is a sequence $q^t_{raw}, q^t_{product}$, for $t = 1,2,\ldots,T$

Acts means to implement the plan.

Our Agents for SCML - Aspiration Negotiation

Implementing the plan **via** negotiations.

Our Agents for SCML - Aspiration Negotiation

Implementing the plan **via** negotiations.

Actor (Institution or Individual) has! a utility function, i.e., values for outcomes

The plan can be used as a "**utility function**". How?

Our Agents for SCML - Aspiration Negotiation

Implementing the plan **via** negotiations.

Actor (Institution or Individual) has! a utility function, i.e., values for outcomes

The plan can be used as a "**utility function**". How?

High (low) utility for negotiations that drive the agent closer (farther) to **fulfilling** its plan.

Our Agents for SCML - Aspiration Negotiation

Implementing the plan **via** negotiations.

Actor (Institution or Individual) has! a utility function, i.e., values for outcomes

The plan can be used as a "**utility function**". How?

High (low) utility for negotiations that drive the agent closer (farther) to **fulfilling** its plan.

Aspiration Negotiator! (Time-based strategy, Faratin et.al. [4])

Our Agents for SCML - Aspiration Negotiation

Implementing the plan **via** negotiations.

Actor (Institution or Individual) has! a utility function, i.e., values for outcomes

The plan can be used as a "**utility function**". How?

High (low) utility for negotiations that drive the agent closer (farther) to **fulfilling** its plan.

Aspiration Negotiator! (Time-based strategy, Faratin et.al. [4])

Start with some **aspiration level** (minimum utility willing to accept).

Our Agents for SCML - Aspiration Negotiation

Implementing the plan **via** negotiations.

Actor (Institution or Individual) has! a utility function, i.e., values for outcomes

The plan can be used as a "**utility function**". How?

High (low) utility for negotiations that drive the agent closer (farther) to **fulfilling** its plan.

Aspiration Negotiator! (Time-based strategy, Faratin et.al. [4])

Start with some **aspiration level** (minimum utility willing to accept).

To start, do not accept offers below the aspiration level.

Our Agents for SCML - Aspiration Negotiation

Implementing the plan **via** negotiations.

Actor (Institution or Individual) has! a utility function, i.e., values for outcomes

The plan can be used as a "**utility function**". How?

High (low) utility for negotiations that drive the agent closer (farther) to **fulfilling** its plan.

Aspiration Negotiator! (Time-based strategy, Faratin et.al. [4])

Start with some **aspiration level** (minimum utility willing to accept).

To start, do not accept offers below the aspiration level.

As time passes, **concede** some utility hoping to reach an agreement!

Our Agents for SCML - Aspiration Negotiation

Implementing the plan **via** negotiations.

Actor (Institution or Individual) has! a utility function, i.e., values for outcomes

The plan can be used as a "**utility function**". How?

High (low) utility for negotiations that drive the agent closer (farther) to **fulfilling** its plan.

Aspiration Negotiator! (Time-based strategy, Faratin et.al. [4])

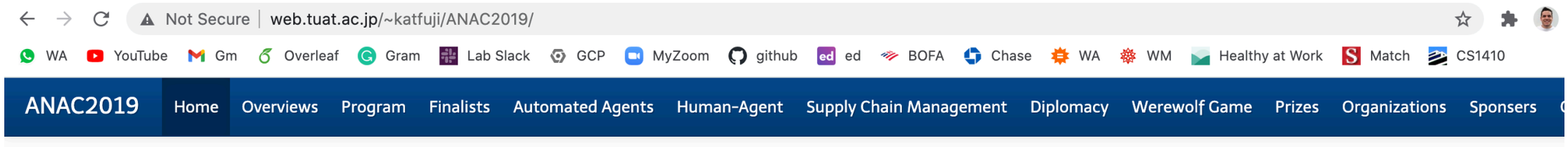
Start with som to accept).

To start, do n

As time passe n agreement!

Lots of unspecified parameters!
How to set initial aspiration level?
How fast to concede?
Lots of opportunities for further research!

Our Agents for SCML - Results So Far



Winners

Automated Agents League

Individual Utility

Winner	AgentGG	Shaobo Xu and Peihao Ren	University of Southampton	UK
2nd	KakeSoba	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan
3rd	SAGA	Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Joint Utility

Winner	winkyAgent	Siqi Chen and Jie Lin	Tianjin University	China
2nd	FSEGA2019	Stancu Anca	Bábes Bolyai University	România
3rd	AgentGP	Tomoya Fukui	Nagoya Institute of Technology	Japan

Human-Agent League

1st	Draft	Bohan Xu and Shadow Pritchard and James Hale and Sandip Sen	University of Tulsa	USA
2nd	Dona	Eden Shalom Erez, Inon Zuckerman, Galit Haim	Ariel University and The College of Management Academic Studies	Israel

Supply Chain Management League

Standard Category

1st	IFFM	Masanori Hirano, Taisei Mukai, Hiroyasu Matsushima, Kiyoshi Izumi	University of Tokyo	Japan
2nd	NVM	Enrique Areyan Viqueira, Amy Greenwald	AIST and Brown University	Japan and USA
3rd	SAHA	Nahum Alvarez	AIST	Japan

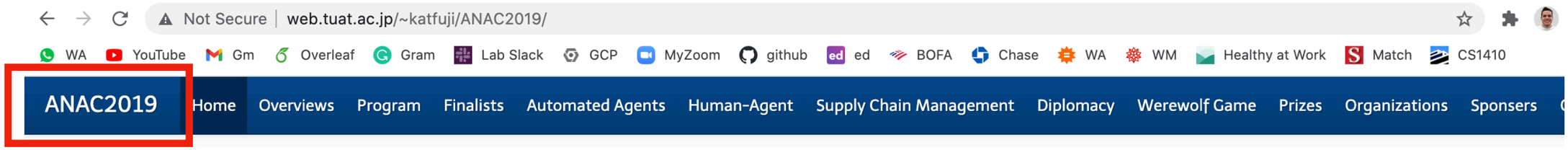
Collusion Category

1st	IFFM	Masanori Hirano, Taisei Mukai, Hiroyasu Matsushima, Kiyoshi Izumi	University of Tokyo	Japan
2nd	NVM	Enrique Areyan Viqueira, Amy Greenwald	AIST and Brown University	Japan and USA
3rd	FJ2	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan

Sabotage Category

Honorable Mention Award	Monopoly	Ryoto Ishikawa and Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Our Agents for SCML - Results So Far



Winners

Automated Agents League

Individual Utility

Winner	AgentGG	Shaobo Xu and Peihao Ren	University of Southampton	UK
2nd	KakeSoba	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan
3rd	SAGA	Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Joint Utility

Winner	winkyAgent	Siqi Chen and Jie Lin	Tianjin University	China
2nd	FSEGA2019	Stancu Anca	Bábes Bolyai University	România
3rd	AgentGP	Tomoya Fukui	Nagoya Institute of Technology	Japan

Human-Agent League

1st	Draft	Bohan Xu and Shadow Pritchard and James Hale and Sandip Sen	University of Tulsa	USA
2nd	Dona	Eden Shalom Erez, Inon Zuckerman, Galit Haim	Ariel University and The College of Management Academic Studies	Israel

Supply Chain Management League

Standard Category

1st	IFFM	Masanori Hirano, Taisei Mukai, Hiroyasu Matsushima, Kiyoshi Izumi	University of Tokyo	Japan
2nd	NVM	Enrique Areyan Viqueira, Amy Greenwald	AIST and Brown University	Japan and USA
3rd	SAHA	Nahum Alvarez	AIST	Japan

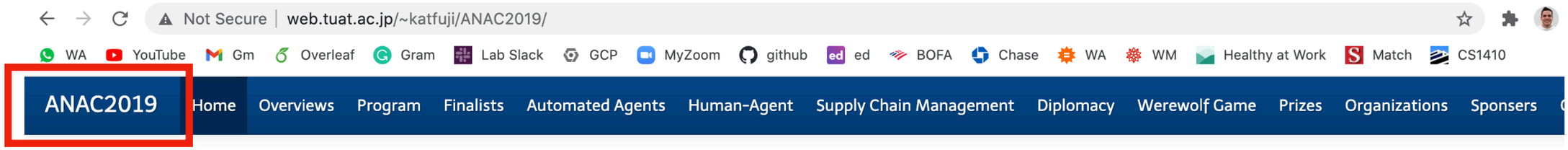
Collusion Category

1st	IFFM	Masanori Hirano, Taisei Mukai, Hiroyasu Matsushima, Kiyoshi Izumi	University of Tokyo	Japan
2nd	NVM	Enrique Areyan Viqueira, Amy Greenwald	AIST and Brown University	Japan and USA
3rd	FJ2	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan

Sabotage Category

Honorable Mention Award	Monopoly	Ryoto Ishikawa and Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Our Agents for SCML - Results So Far



Winners

Automated Agents League

Individual Utility

Winner	AgentGG	Shaobo Xu and Peihao Ren	University of Southampton	UK
2nd	KakeSoba	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan
3rd	SAGA	Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Joint Utility

Winner	winkyAgent	Siqi Chen and Jie Lin	Tianjin University	China
2nd	FSEGA2019	Stancu Anca	Bábes Bolyai University	România
3rd	AgentGP	Tomoya Fukui	Nagoya Institute of Technology	Japan

Human-Agent League

1st	Draft	Bohan Xu and Shadow Pritchard and James Hale and Sandip Sen	University of Tulsa	USA
2nd	Dona	Eden Shalom Erez, Inon Zuckerman, Galit Haim	Ariel University and The College of Management Academic Studies	Israel

Supply Chain Management League

Standard Category

1st	IFFM	Masanori Hirano, Taisei Mukai, Hiroyasu Matsushima, Kiyoshi Izumi	University of Tokyo	Japan
2nd	NVM	Enrique Areyan Viqueira, Amy Greenwald	AIST and Brown University	Japan and USA
3rd	SAHA	Nahum Alvarez	AIST	Japan

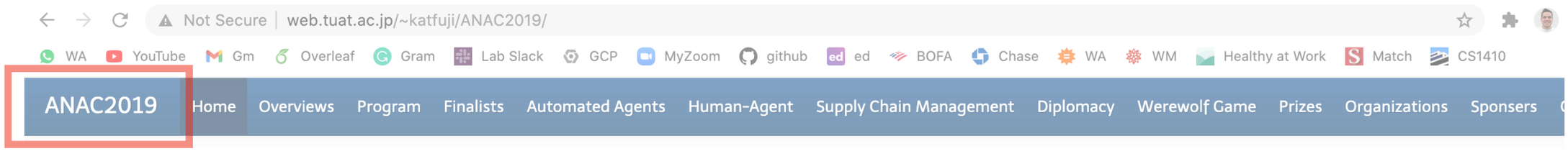
Collusion Category

1st	IFFM	Masanori Hirano, Taisei Mukai, Hiroyasu Matsushima, Kiyoshi Izumi	University of Tokyo	Japan
2nd	NVM	Enrique Areyan Viqueira, Amy Greenwald	AIST and Brown University	Japan and USA
3rd	FJ2	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan

Sabotage Category

Honorable Mention Award	Monopoly	Ryoto Ishikawa and Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Our Agents for SCML - Results So Far



Winners

Automated Agents League

Individual Utility

Winner	AgentGG	Shaobo Xu and Peihao Ren	University of Southampton	UK
2nd	KakeSoba	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan
3rd	SAGA	Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Joint Utility

Winner	winkyAgent	Siqi Chen and Jie Lin	Tianjin University	China
2nd	FSEGA2019	Stancu Anca	Bábes Bolyai University	România
3rd	AgentGP	Tomoya Fukui	Nagoya Institute of Technology	Japan

Human-Agent League

1st	Draft	Bohan Xu and Shadow Pritchard and James Hale and Sandip Sen	University of Tulsa	USA
2nd	Dona	Eden Shalom Erez, Inon Zuckerman, Galit Haim	Ariel University and The College of Management Academic Studies	Israel

Supply

Standard

1st	IFFM	M
2nd	NVM	E
3rd	SAHA	N

MONTY HALL: BROWN UNIVERSITY'S AGENT FOR THE SUPPLY CHAIN MANAGEMENT LEAGUE OF THE 2020 AUTOMATED NEGOTIATING AGENTS COMPETITION

Enrique Areyan Viqueira, Edward Li, Daniel Silverston, Amrita Sridhar, James Tsatsaros, Andrew Yuan, and Amy Greenwald

OVERVIEW. At a high level, MontyHall's strategy is to buy inputs, immediately convert them into outputs, and then sell said outputs. Monty begins its day by computing a business plan. For each day into the future (up to some

Collusion Category

1st	IFFM	Masanori Hirano, Taisei Mukai, Hiroyasu Matsushima, Kiyoshi Izumi	University of Tokyo	Japan
2nd	NVM	Enrique Areyan Viqueira, Amy Greenwald	AIST and Brown University	Japan and USA
3rd	FJ2	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan

Sabotage Category

Honorable Mention Award	Monopoly	Ryoto Ishikawa and Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Our Agents for SCML - Results So Far

Not Secure | web.tuat.ac.jp/~katfuji/ANAC2019/

WA YouTube Gm Overleaf Gram Lab Slack GCP MyZoom github ed BOFA Chase WA WM Healthy at Work Match CS1410

ANAC2019 Home Overviews Program Finalists Automated Agents Human-Agent Supply Chain Management Diplomacy Werewolf Game Prizes Organizations Sponsers

Winners

Automated Agents League

Individual Utility

Winner	AgentGG	Shaobo Xu and Peihao Ren	University of Southampton	UK
2nd	KakeSoba	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan
3rd	SAGA	Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Joint Utility

Winner	winkyAgent	Siqi Chen and Jie Lin	Tianjin University	China
2nd	FSEGA2019	Stancu Anca	Bábes Bolyai University	România
3rd	AgentGP	Tomoya Fukui	Nagoya Institute of Technology	Japan

Human-Agent League

1st	Draft	Bohan Xu and Shadow Pritchard and James Hale and Sandip Sen	University of Tulsa	USA
2nd	Dona	Eden Shalom Erez, Inon Zuckerman, Galit Haim	Ariel University and The College of Management Academic Studies	Israel

Supply

Standard

1st	IFFM	M
2nd	NVM	E
3rd	SAHA	N

MONTY HALL: BROWN UNIVERSITY'S AGENT FOR THE SUPPLY CHAIN MANAGEMENT LEAGUE OF THE 2020 AUTOMATED NEGOTIATING AGENTS COMPETITION

Enrique Areyan Viqueira, Edward Li, Daniel Silverston, Amrita Sridhar, James Tsatsaros, Andrew Yuan, and Amy Greenwald

OVERVIEW. At a high level, MontyHall's strategy is to buy inputs, immediately convert them into outputs, and then sell said outputs. Monty begins its day by computing a business plan. For each day into the future (up to some

Collusion Category

1st	IFFM	Masanori Hirano, Taisei Mukai, Hiroyasu Matsushima, Kiyoshi Izumi	University of Tokyo	Japan
2nd	NVM	Enrique Areyan Viqueira, Amy Greenwald	AIST and Brown University	Japan and USA
3rd	FJ2	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan

Sabotage Category

Honorable Mention Award	Monopoly	Ryoto Ishikawa and Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Our Agents for SCML - Results So Far

Not Secure | web.tuat.ac.jp/~katfuji/ANAC2019/

WA YouTube Gm Overleaf Gram Lab Slack GCP MyZoom github ed BOFA Chase WA WM Healthy at Work Match CS1410

ANAC2019 Home Overviews Program Finalists Automated Agents Human-Agent Supply Chain Management Diplomacy Werewolf Game Prizes Organizations Sponsers

Winners

Automated Agents League

Individual Utility

Winner	AgentGG	Shaobo Xu and Peihao Ren	University of Southampton	UK
2nd	KakeSoba	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan
3rd	SAGA	Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Joint Utility

Winner	winkyAgent	Siqi Chen and Jie Lin	Tianjin University	China
2nd	FSEGA2019	Stancu Anca	Bábes Bolyai University	România
3rd	AgentGP	Tomoya Fukui	Nagoya Institute of Technology	Japan

Human-Agent League

1st	Draft	Bohan Xu and Shadow Pritchard and James Hale and Sandip Sen	University of Tulsa
2nd	Dona	Eden Shalom Erez, Inon Zuckerman, Galit Haim	Ariel University and The College of Manag

Supply

Standard

1st	IFFM	M
2nd	NVM	E
3rd	SAHA	N

Collusion Category

1st	IFFM	Masanori Hirano, Taisei Mukai, Hiroyasu Matsushima, Kiyoshi Izumi	University of Tokyo	Japan
2nd	NVM	Enrique Areyan Viqueira, Amy Greenwald	AIST and Brown University	Japan and USA
3rd	FJ2	Ryohei Kawata	Tokyo University of Agriculture and Technology	Japan

Sabotage Category

Honorable Mention Award	Monopoly	Ryoto Ishikawa and Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

ugrads!

MONTY HALL: BROWN UNIVERSITY'S AGENT FOR THE SUPPLY CHAI… LEAGUE OF THE 2020 AUTOMATED NEGOTIATING AGENTS COMPETITION

Enrique Areyan Viqueira, Edward Li, Daniel Silverston, Amrita Sridhar, James Tsatsaros, Andrew Yuan, and Amy Greenwald

OVERVIEW. At a high level, MontyHall's strategy is to buy inputs, immediately convert them into outputs, and then sell said outputs. Monty begins its day by computing a business plan. For each day into the future (up to some

Our Agents for SCML - Results So Far

Not Secure | web.tuat.ac.jp/~katfuji/ANAC2019/

[scml] Results of the Qualifications Round of ANAC 2020 SCML League (Standard)

Brown ×

Yasser Mohammad (SCML Organization Committee) yasserfarouk@gmail.com via lists.cs.brown.edu Wed, Aug 26, 6:29 AM

to scml

Dear Enrique Areyan

We are happy to inform you that your agent MontyHall was qualified for the final round of ANAC 2020 SCM league (Standard track).

We received 22 submissions, 19 entered the qualifications after removing agents that did not fully comply with all submission requirements.

Twelve agents were qualified for the Standard track and 6 agents were qualified for the Collusion track.

We are looking forward to seeing (or virtually meeting) you at IJCAI 2020 in January.

The final results of the league will be announced at the ANAC session as part of IJCAI's official competitions track.

We thank you again for the time and effort you put into this agent.

Best Regards

Yasser Mohammad

representing the SCML Organization Commmittee

Sent via Mail Merge for Gmail

Reply Reply all Forward

ugrads!

MONTY HALL: BROWN UNIVERSITY'S AGENT FOR THE SUPPLY CHAIN MANAGEMENT LEAGUE OF THE 2020 AUTOMATED NEGOTIATING AGENTS COMPETITION

Enrique Areyan Viqueira, Edward Li, Daniel Silverston, Amrita Sridhar, James Tsatsaros, Andrew Yuan, and Amy Greenwald

OVERVIEW. At a high level, MontyHall's strategy is to buy inputs, immediately convert them into outputs, and then sell said outputs. Monty begins its day by computing a business plan. For each day into the future (up to some

Sabotage Category

Honorable Mention Award	Monopoly	Ryoto Ishikawa and Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Our Agents for SCML - Results So Far

Not Secure | web.tuat.ac.jp/~katfuji/ANAC2019/

[scml] Results of the Qualifications Round of ANAC 2020 SCML League (Standard)

Brown ×

Yasser Mohammad (SCML Organization Committee) yasserfarouk@gmail.com via lists.cs.brown.edu Wed, Aug 26, 6:29 AM

to scml

Dear Enrique Areyan

We are happy to inform you that your agent MontyHall was qualified for the final round of ANAC 2020 SCM league (Standard track).

We received 22 submissions, 19 entered the qualifications after removing agents that did not fully comply with all submission requirements.

Twelve agents were qualified for the Standard track and 6 agents were qualified for the Collusion track.

We are looking forward to seeing (or virtually meeting) you at IJCAI 2020 in January.

The final results of the league will be announced at the ANAC session as part of IJCAI's official competitions track.

We thank you again for the time and effort you put into this agent.

Best Regards

Yasser Mohammad

representing the SCML Organization Commmittee

Sent via Mail Merge for Gmail

Reply Reply all Forward

ugrads!

MONTY HALL: BROWN UNIVERSITY'S AGENT FOR THE SUPPLY CHAIN MANAGEMENT LEAGUE OF THE 2020 AUTOMATED NEGOTIATING AGENTS COMPETITION

Enrique Areyan Viqueira, Edward Li, Daniel Silverston, Amrita Sridhar, James Tsatsaros, Andrew Yuan, and Amy Greenwald

OVERVIEW. At a high level, MontyHall's strategy is to buy inputs, immediately convert them into outputs, and then sell said outputs. Monty begins its day by computing a business plan. For each day into the future (up to some

Sabotage Category

Honorable Mention Award	Monopoly	Ryoto Ishikawa and Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Our Agents for SCML - Results So Far

Not Secure | web.tuat.ac.jp/~katfuji/ANAC2019/

[scml] Results of the Qualifications Round of ANAC 2020 SCML League (Standard)

Brown ×

Yasser Mohammad (SCML Organization Committee) yasserfarouk@gmail.com via lists.cs.brown.edu Wed, Aug 26, 6:29 AM

to scml

Dear Enrique Areyan

We are happy to inform you that your agent MontyHall was qualified for the final round of ANAC 2020 SCM league (Standard track).

We received 22 submissions, 19 entered the qualifications after removing agents that did not fully comply with all submission requirements.

Twelve agents were qualified for the Standard track and 6 agents were qualified for the Collusion track.

We are looking forward to seeing (or virtually meeting) you at IJCAI 2020 in January.

The final results of the league will be announced at the ANAC session as part of IJCAI's official competitions track.

We thank you again for the time and effort you put into this agent.

Best Regards

Yasser Mohammad

representing the SCML Organization Commmittee

Sent via Mail Merge for Gmail

Reply Reply all Forward

ugrads!

MONTY HALL: BROWN UNIVERSITY'S AGENT FOR THE SUPPLY CHAIN MANAGEMENT LEAGUE OF THE 2020 AUTOMATED NEGOTIATING AGENTS COMPETITION

Enrique Areyan Viqueira, Edward Li, Daniel Silverston, Amrita Sridhar, James Tsatsaros, Andrew Yuan, and Amy Greenwald

OVERVIEW. At a high level, MontyHall's strategy is to buy inputs, immediately convert them into outputs, and then sell said outputs. Monty begins its day by computing a business plan. For each day into the future (up to some

Sabotage Category

Honorable Mention Award	Monopoly	Ryoto Ishikawa and Yuta Hosokawa	Tokyo University of Agriculture and Technology	Japan

Image credit: http://theracquet.org/4747/news/ask-5-uwl-students-tell-their-future-plans/

Part 3: Future Research Plans

We are no where near done!

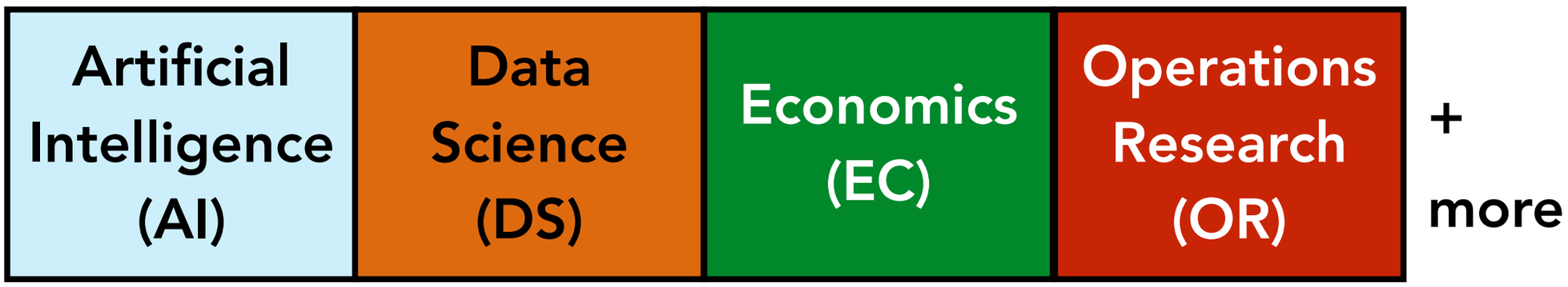
There are lots of research directions to pursue…

A bit about other related and tangential research.

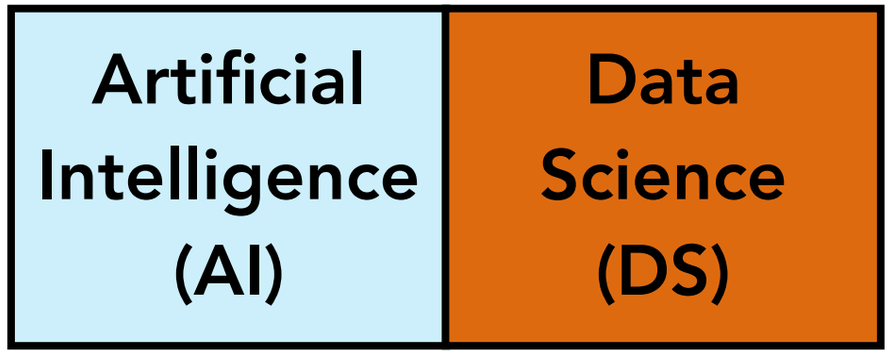
Future Plans

We have an **agent architecture**, but many pieces need more work!

This research is **open-ended** and **interdisciplinary** by nature!



Future Plans (cont.)



Our current prediction module (prices, supply, demand) just counts data.

Can we use machine learning techniques that provably “learn” from data?

In my research, I work on developing **machine learning** algorithms that **provably** learn concepts from data.

Improved Algorithms for Learning Equilibria in Simulation-Based Games.
Enrique Areyan Viqueira, Cyrus Cousins, Amy Greenwald.
19th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS20).

Future Plans (cont. 2.)

Economics (EC)

Are current rules of the ANAC SCML game the “right” ones?

In my research, I also develop machine learning techniques to design games (**mechanism design**). This is a **big**, open opportunity!

Empirical Mechanism Design: Designing Mechanisms from Data.
Enrique Areyan Viqueira, Cyrus Cousins, Yasser Mohammad, Amy Greenwald.
Uncertainty in Artificial Intelligence (UAI19).

Future Plans (cont. 2.)

Economics (EC)

Incentives players (researchers) to do their best and not just "hack" the game!

Are current rules of the ANAC SCML game the "right" ones?

In my research, I also develop machine learning techniques to design games (**mechanism design**). This is a **big**, open opportunity!

Empirical Mechanism Design: Designing Mechanisms from Data.
Enrique Areyan Viqueira, Cyrus Cousins, Yasser Mohammad, Amy Greenwald.
Uncertainty in Artificial Intelligence (UAI19).

Future Plans (cont. 3.)

The techniques and ideas develop for ANAC SCML extend **beyond**!

Other domains we have tackled: **advertisement exchange markets**.

On Approximate Welfare-and Revenue-Maximizing Equilibria for Size-Interchangeable Bidders.
Enrique Areyan Viqueira, Amy Greenwald, Victor Naroditskiy.
16th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS17).

Future Plans (cont. 3.)

The techniques and ideas develop for ANAC SCML extend **beyond**!

Other domains we have tackled: **advertisement exchange markets**.

On Approximate Welfare-and Revenue-Maximizing Equilibria for Size-Interchangeable Bidders.
Enrique Areyan Viqueira, Amy Greenwald, Victor Naroditskiy.
16th International Conference on Autonomous Agents and MultiAgent Systems (AAMAS17).

As our economies grow more sophisticated, multi-agent systems research will become **even more important**.

Collaborators

Amy Greenwald

Yasser Mohammad

Cyrus Cousins

Marilyn George

Collaborators

Amy Greenwald

Yasser Mohammad

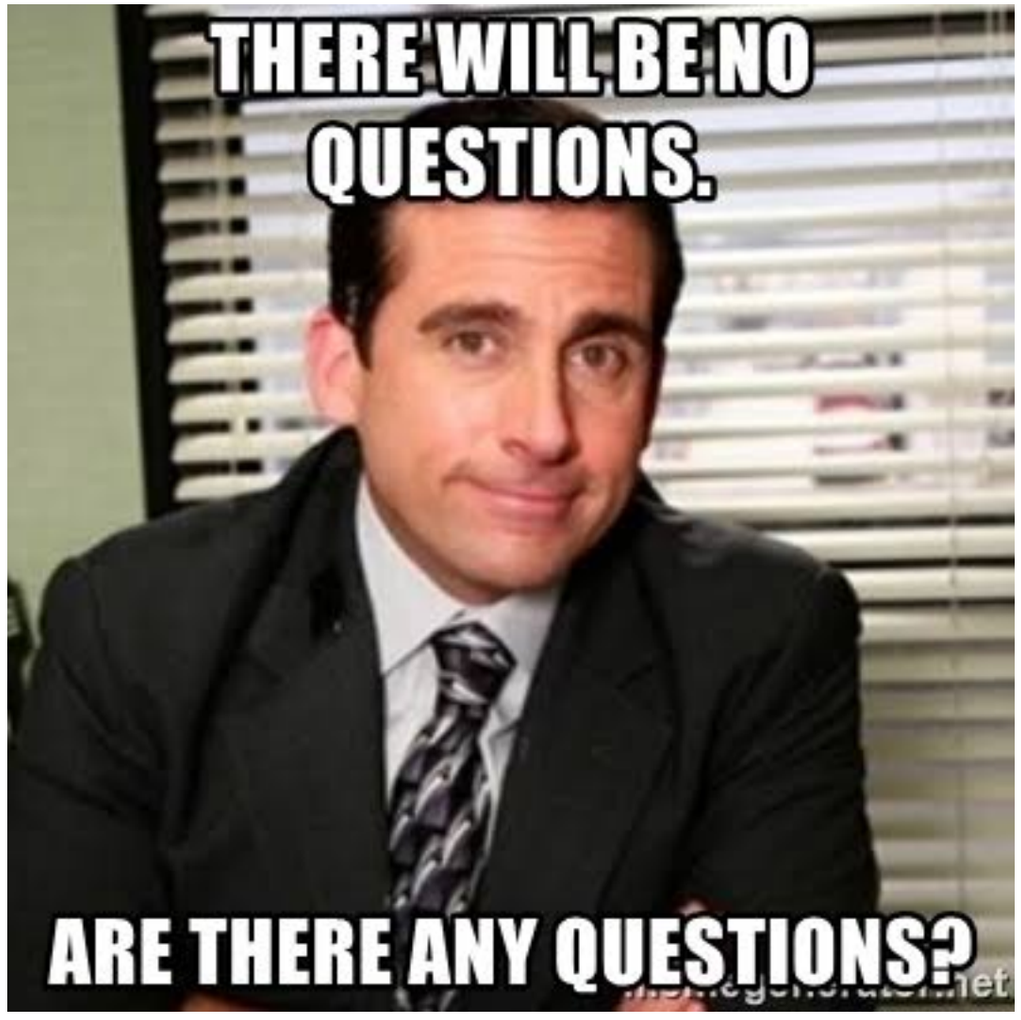
?

Future Collaborators!
Students
Colleagues
Researchers
All are welcome!

Cyrus Cousins

Marilyn George

Thank you for your attention!



References

[1] Mohammad, Y., Viqueira, E. A., Ayerza, N. A., Greenwald, A., Nakadai, S., and Morinaga, S. (2019). Supply chain management world. In International Conference on Principles and Practice of Multi-Agent Systems, pages 153–169. Springer.

[2] World Trade Organization. Supply Chain Perspectives.

[3] Mohammad, Y. PRIMA 2020 SCML Tutorial.

[4] Faratin, P., Sierra, C., & Jennings, N. R. (1998). Negotiation decision functions for autonomous agents. Robotics and Autonomous Systems, 24(3-4), 159-182

[5] Hadfi, R., & Ito, T. (2015). Complex multi-issue negotiation using utility hyper-graphs. Journal of Advanced Computational Intelligence and Intelligent Informatics, 19(4), 514-522.