AI^3 2024, November 28th 2024

Argumentation for Informed Decisions with Applications to Energy Consumption in Computing (Project Overview)

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The AIDECC Project

- A cascade Project:

  - Spoke 9: Green-aware AI, chaired by UNICAL

- UNIBS Members: Federico Cerutti (Principal investigator), Pietro Baroni, Massimiliano Giacomin, Gian Franco Lamperti, Marina Zanella

Motivation

- Widespread application of **Deep Neural Networks (DNNs)**

  - computer vision, NLP, speech recognition, …

- Parallel **GPU clusters**

  ⇒ high energy consumption for training

  (e.g. GPT-3: electricity used by an average US household for 120 years)

- **AIDECC:**

  Argumentation for **I**nformed **D**ecisions with Applications to **E**nergy **C**onsumption in **C**omputing

- Aim of the project:

  - Investigating causal relationships related to energy consumption in DNN training

  - Design interventions to reduce energy use

Objectives

1. Devising a human-centric and ethically aligned approach
   - system's decisions subject to human review and interpretation
2. Acquiring a situational understanding of energy consumptions
   - identifying which variables affect energy use
   - understanding the causal relationships behind these effects
3. Identifying strategies to reduce energy consumption and waste in DNN training
   - understanding computational and energy dynamics
   - taking into account practical constraints and operational environment (e.g. hardware limitations, scalability, nature of neural networks applications)

The role of Argumentation

- Argumentation theory adopted as a fundamental component for causal discovery
  - a causal link is considered as a provisional argument subject to dialectical interaction (more on this later)
- Why argumentation?
  - to foster a balance and comprehensive view: potential compromises performance vs accuracy through a nuanced discussion (see OBJ 1)
  - in scenarios with scarce data, to enhance causal discovery between architectural choices / hyperparameteres / process efficiency (OBJ 2)
  - to engage in informed discussions about interventions'merits and potential trade-offs (OBJ 3)

Structure of the project

WP1: Theoretical investigation of argumentative techniques for informed decision

- theoretical foundations of argumentation for identifying and evaluating causal relationships from data
- integrating argumentative methods with ML algorithms to achieve more robust ad transparent models

WP2: Argumentative analysis of neural network energy consumption

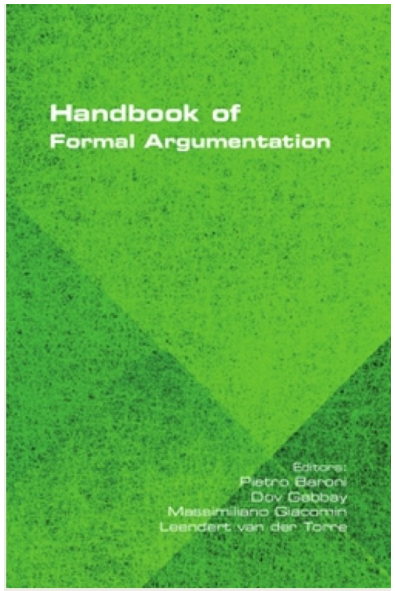
- Analyzing datasets (e.g. Zeus Power Trace) using WP1 results

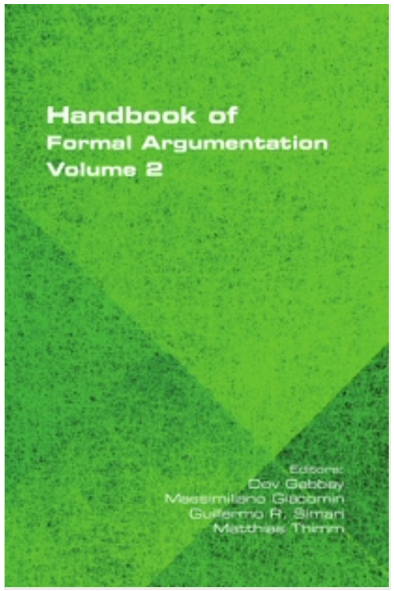
WP3: Argumentative-causal reasoning to reduce DNN energy consumption

- Building on WP1 and WP2: developing a structural causal model
- Causal relationships used to build arguments supporting the claim that certain variables influence energy consumption

Current stage of the project (1)

WP1: Theoretical investigation of argumentative techniques for informed decision





VOLUME 3

to appear

CAUSATION AND ARGUMENTATION

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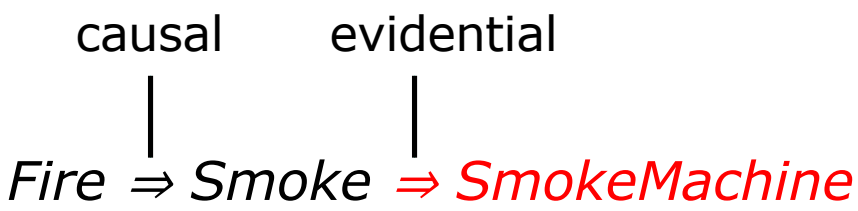
Causal reasoning vs Causal discovery

Causal Reasoning

- Allows to reason with causal knowledge
  - causal rules (inferring an effect from its cause)
  - evidential rules (ascribing causes to the observed phenomena)
- Pearl's C-E system
  - a set of inference schemes for reasoning with a mix of causal and evidential defeasible rules
  - constraint: an evidential rule should not "follow" a causal one
- Example



Argumentation-based accounts of Causal Reasoning

Rule-based approaches

[Bex, 2015]

- Adopt ASPIC+ as the underlying argumentation system
- Explictly accounts for causal and evidential rules
- Pearl's constraint is satisfied by justified arguments

[Wieten et al., 2020]

- Assumes an information graph and contructs ASPIC$^+$-like arguments
- Explictly accounts for causal and evidential rules
- All arguments satisfy Pearl's constraint by construction

Assumption-based structured causal argumentation

[Bengel et al, 2022]

- Structural equation models are encoded in ABA
- Assumptions represent beliefs about exogenous variables

Causal Discovery

- Statistical algorithms for causal discovery
- From the argumentation point of view:

  causal link = tentative argument, subject to dialectical interaction

  (see e.g. *Argument from cause to effect* by D. Walton)
- (Oestermeier and Hesse, 2000):

  - A taxonomy of 27 identified causal arguments
  - Classification:

    PRO ARGUMENTS (circumstantial evidence, contrastive evidence, causal explanation)

    ARGUMENTS AGAINST CAUSAL CLAIMS (counterevidence, alternative explanation, insufficiency of evidence)

    ARGUMENTS QUALIFYING CAUSAL CLAIMS

Examples of PRO arguments

Circumstantial evidence

1. Spatio-temporal contiguity (Einhorn & Hogarth, 1986; Hume, 1739/1978)

A caused B because B happened at A/at nearly the same time as A
Example: It was probably the drink because he fell in love when he was drinking the cocktail
Premises: Spatial or temporal knowledge about the contiguity or simultaneity of two objects or events
Inferences: Inference from contiguity to causality

Contrastive evidence

5. Statistical covariation (Cheng, 1993; Eells, 1991)

A caused B because A increases the probability/ risk/percentage of B. Special case of (4) stressing a probabilistic regularity between A and B
Example: Smoking causes cancer because smokers have a much higher risk of getting cancer
Premises: Episodic knowledge about multiple observations under different conditions
Inferences: Statistical generalization about multiple observations, comparison of outcomes, and inference from covariation to causality

Examples of counterarguments

12. Wrong temporal order	A has not caused B because A happened after B *Example:* The server problems have not caused your system crash, the server problems occurred afterwards *Premises:* Episodic knowledge about the observed temporal order of the events A and B *Inferences:* Inference from a temporal relation to the negation of a causal relation
Alternative explanation 17. More plausible alternative (Thagard, 1999)	A has not caused B but C (because C is more probable, because C was contiguous to B etc.) *Example*: It was not the snow but rather his risky driving that caused the accident *Premises:* Specific knowledge about alternative explanations of B *Inferences:* Negation of a causal conclusion by search for a competing better explanation

Current stage of the project (2)

WP2: Argumentative analysis of neural network energy consumption (just started)

- Dataset: Combines deep learning hyperparameters, execution environment, and energy metrics (e.g., power, runtime).

- Baseline Method: PC algorithm infers causal graphs linking hyperparameters to energy impact.

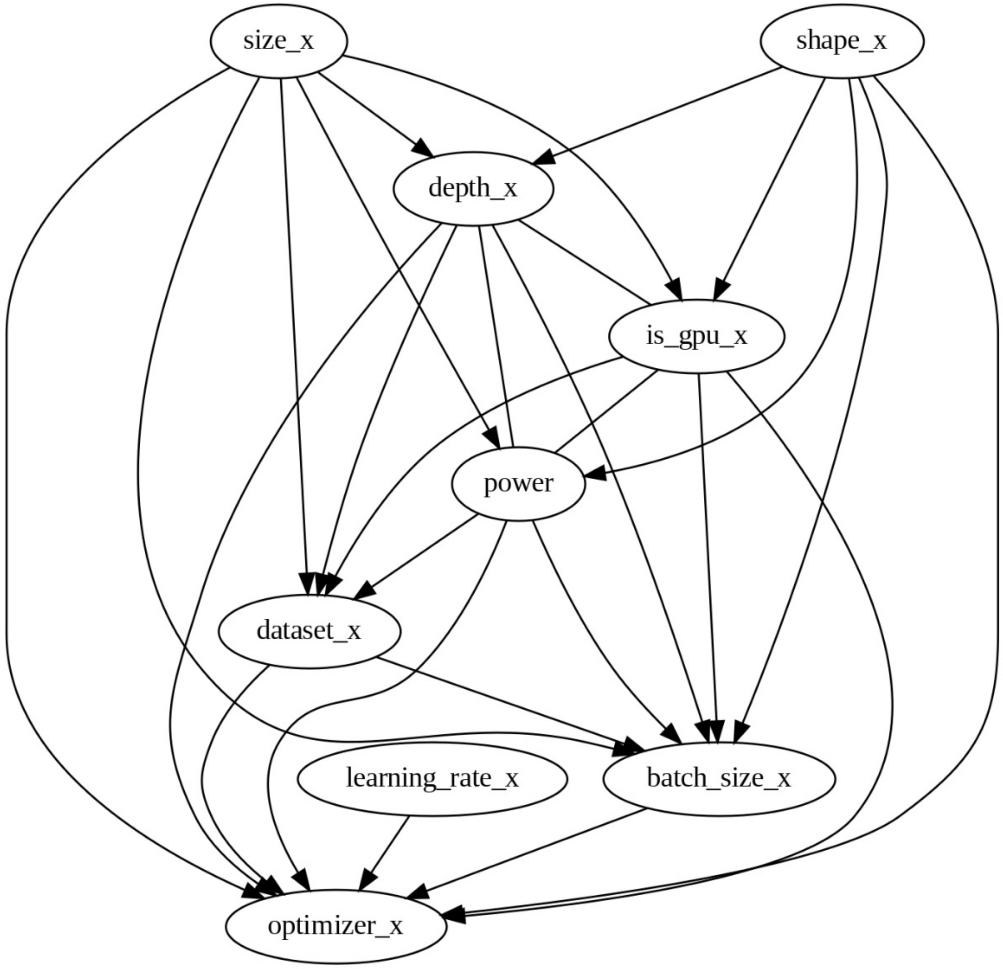
https://arxiv.org/abs/2403.08151

Current stage of the project (3)

WP2: Argumentative analysis of neural network energy consumption (just started)

PC Algorithm

- Identifies causal relationships by testing conditional independencies in the data, producing a directed acyclic graph (DAG).
- Assumes causal sufficiency and uses statistical tests to infer direct and indirect relationships.



Conclusions

- Energy intensive training of complex neural networks
  - substantial carbon footprint associated to high energy consumption
- Through causal studies, AIDECC project aims to:
  - formulate policies and design targeted interventions to reduce energy use
- Contributing to a decrease in pollutant emissions associated with electricity production

THANKS FOR YOUR KIND ATTENTION!

QUESTIONS?

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