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Learning fuzzy spatial relations for image semantic analysis with justification

Context

- In the last few years, deep learning has led to impressive results in image recognition tasks.
- However, deep learning algorithms are black boxes and thus are not capable of explaining their outputs.
- Fields like healthcare, security or autonomous driving need justified decisions.
- Understanding a scene requires recognizing shapes, lengths and spatial relations between the recognized objects [1].
- Fuzzy logic enables to manage both the uncertainty brought by segmentation and the vagueness of the knowledge.
- Our approach consists in inducing fuzzy spatial relations over a dataset. The semantic analysis relies on these induced fuzzy spatial relations for providing an understanding of the scene.

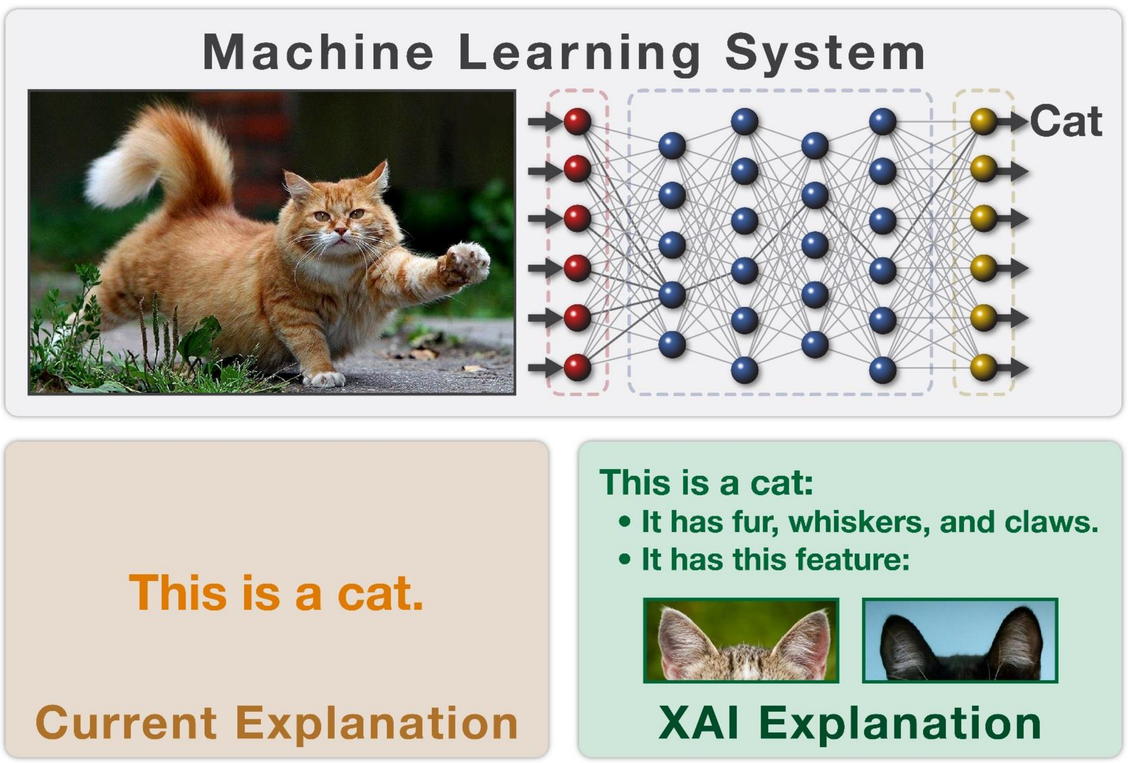

Fig. 1 – Example of justified classification [2]. XAI means explainable artificial intelligence.

Fig. 2 – Before learning relations, images are segmented [3].

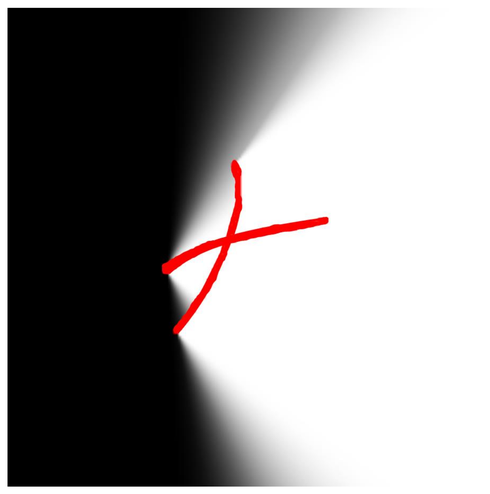

Fig. 3 – This fuzzy landscape corresponds to the fuzzy spatial relation *on the right of* (the red object is the reference) [4]. Each pixel gets a degree of membership ranging from 0 (black) to 1 (white).

Objectives

The goal is to induce relevant fuzzy spatial relations over a dataset. Several issues are raised:

- How to assess the relevance of a relation?
- How to efficiently search for spatial relations among a list of implemented relations?
- How to assess the interdependence of two learnt relations?
- How to tune the hyperparameters of the relations?
- How to manage the knowledge uncertainty with fuzzy logic?

Scene understanding is linked to the spatial coherence of the scene [5]. Applying these induced spatial relations enables to perform spatial intelligence in order to justify decisions.

Optionally, an optimization phase of the induced relations can be achieved by reinforcement learning or genetic algorithms to improve the use of these relations in a given application.

Applications

The induced spatial relations are used for explaining new unknown images. This ability to explain helps in several kinds of situation:

- *Classification*: some fields (like computer-aided medical diagnosis) require justified classification so that an expert can assess how relevant the classification is.
- *Automatic image annotation*: the spatial structure of an image can be helpful for defining each element of this image. For example, in figure 4, the definition of one organ could help to define every other organ.
- *Semantic analysis*: overall, the induced relations enable to get an analysis of the spatial links between each element of an image.

Fig. 4 – Automatic image annotation of a cross-section view of the abdomen [6].

Fig. 5 – Detection of an alignment of planes [7].

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