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Multiple knowledge representation for big data artificial intelligence: framework, applications, and case studies

Key words: Multiple knowledge representation; Artificial intelligence; Big data

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Motivation

1. There are significant gaps between **comprehensive cognition** in the real-world and the symbolic system derived from human knowledge.

2. Computer-abstracted knowledge or deep representation is complementary.

3. Humans tend to **combine multiple knowledge** including intuitive perception, cognition, highly abstract knowledge, and logic.

Knowledge representations

1. Canonical knowledge representation
    1) declarative knowledge
    2) procedural knowledge
    3) heuristic knowledge
    4) structural knowledge
2. Modern deep representation
    1) data-driven
    2) end-to-end representation learning
    3) black-box nature and may not be explainable
    4) limited reasoning capacity

Multiple knowledge representations (MKR)

1. Multi-representation integration
   - Compound symbolic knowledge representation, knowledge graph representation, visual knowledge, handcrafted feature representation, and deep representation

2. Multi-level knowledge abstraction
   - Knowledge fusion at multiple abstraction levels
   - Integration of multiple abstractions yields a more comprehensive representation compared with using any one abstraction alone

3. Multi-modal knowledge reinforcement
   - Reinforce each knowledge representation through effective interactions and deep entanglement of multiple representations

Early MKR attempts

1. Visual understanding
   - Structured representation represents visual scenes as graphs (Xu et al., 2017)
   - Leverage extra cues as privileged information (Yan et al, 2016)
   - Two-stream fusion of video backbones (Simonyan and Zisserman, 2014; Zhu et al., 2021)
   - Multi-stream framework for ego-centric action recognition (Wang et al., 2020)
   - Knowledge transfer for better dialog modeling (Fan et al., 2020)

Early MKR attempts

2. Visual-knowledge-assisted computer graphics

- Controlled scene generation from structure knowledge using GAN (Johnson et al., 2018; Gogoglou et al., 2019)

3. Multimedia knowledge graph with abundant knowledge resources

4. Neural-symbolic network

- Implement “logic” in DNNs to simultaneously benefit from the deductive reasoning of symbolic knowledge and data-driven machine learning (França et al., 2014; Serafini and d’Avila Garcez, 2016)

MKR advances big data AI

1. MKR improves generalization.
2. MKR improves explainability.
3. MKR reduces data bias and enables explicit reasoning.

Real world applications

- Injecting symbolic knowledge into synthetic images for robustness
- Tackling automated student grouping for intelligent AI education
- Sound explainability provides better FinTech for assessing investment opportunities

Conclusions

1. MKR is a new knowledge representation paradigm.
   - It learns from different abstraction levels, different sources, and different perspectives.
   - These knowledge representations are deeply entangled with, and reinforced by, each other.
2. MKR equips an AI system with better generalization ability, explainable outputs, and stronger reasoning capacity.
3. We expect that MKR will become a new tool of the AI 2.0 evolution and beyond.

Yi YANG is a professor with the College of Computer Science and Technology, Zhejiang University, Hangzhou, China. His research interest is applied AI such as intelligent multimedia processing, computer vision and information retrieval. His research papers have received over 33 000 citations, with an *H*-index of 94. He received the Australian Research Council Discovery Early Career Research Award, Zhejiang Provincial Science Award First Prize, the Google Faculty Research Award, the AWS Machine Learning Awards, and the Australian Computer Society Gold Digital Disruptor Award. He and his team achieved the champion in many international competitions, such as the TRECVID MED, the THUMOS Action recognition challenge, and the MSR-Bing image retrieval challenge. He served as area chairs for ICCV 2019, IJCAI 2020, AAAI 2020, CVPR 2021, etc.