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A review of computer graphics approaches to urban modeling from a machine learning perspective

Key words: Urban modeling; Computer graphics; Machine learning; Deep learning

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Motivation

1. Urbanization has transformed cities into an integral part of human society, and therefore the demand for visualizing, simulating, and perceiving urban areas is growing for numerous purposes. Stakeholders continue to discover practical solutions to urban modeling.
2. Breakthroughs in machine learning facilitate urban modeling in terms of manipulating rules and parameters to achieve satisfactory results. Nevertheless, a significant survey about the participation of machine learning in urban modeling has not been found.

Main idea

1. We provide a literature review on computational approaches to urban modeling from a machine learning perspective. Instead of enumerating the entire collection of related works, this review was intentionally limited to research articles in the area of computer graphics, which were published between 2010 and 2019, while machine learning was acquiring widespread adaption and popularity.
2. Symbolic research articles in urban modeling, which do not involve machine learning, were also discussed in the review for comparison.

Research articles in the review by application class and participation of machine learning

Table 1 Research articles in the review by application class and participation of machine learning

	Layout modeling	Architectural modeling
With machine learning	Vanegas et al. (2012a), Hartmann et al. (2017)	Lafarge and Mallet (2011), Lin et al. (2013), Demir et al. (2014), Guerrero et al. (2015), Nan et al. (2015), Affara et al. (2016), Nishida et al. (2016b), Kelly et al. (2017, 2018), Kim et al. (2020), Newton (2019)
Without machine learning	Galin et al. (2010, 2011), Lipp et al. (2011), Emilien et al. (2012), Vanegas et al. (2012b), Yu and Steed (2012), Yang et al. (2013), Beneš et al. (2014), Garcia-Dorado et al. (2014, 2017), Peng et al. (2014, 2016), Nishida et al. (2016a), Fernandes and Fernandes (2018), Mathew et al. (2019)	Krecklau et al. (2010), Nan et al. (2010), Vanegas et al. (2010), Zheng et al. (2010), Shen et al. (2011), Ceylan et al. (2012), Musialski et al. (2012), AlHalawani et al. (2013), Bao et al. (2013a, 2013b), Besuievsky and Patow (2013), Lin et al. (2013), Zhang et al. (2013), Ceylan et al. (2014), Dang et al. (2014), Wu FZ et al. (2014), Ilčík et al. (2015), Kelly et al. (2015), Schwarz and Müller (2015), Li ML et al. (2016), Lienhard et al. (2017), Smith et al. (2018)

Number of research articles by application class and year

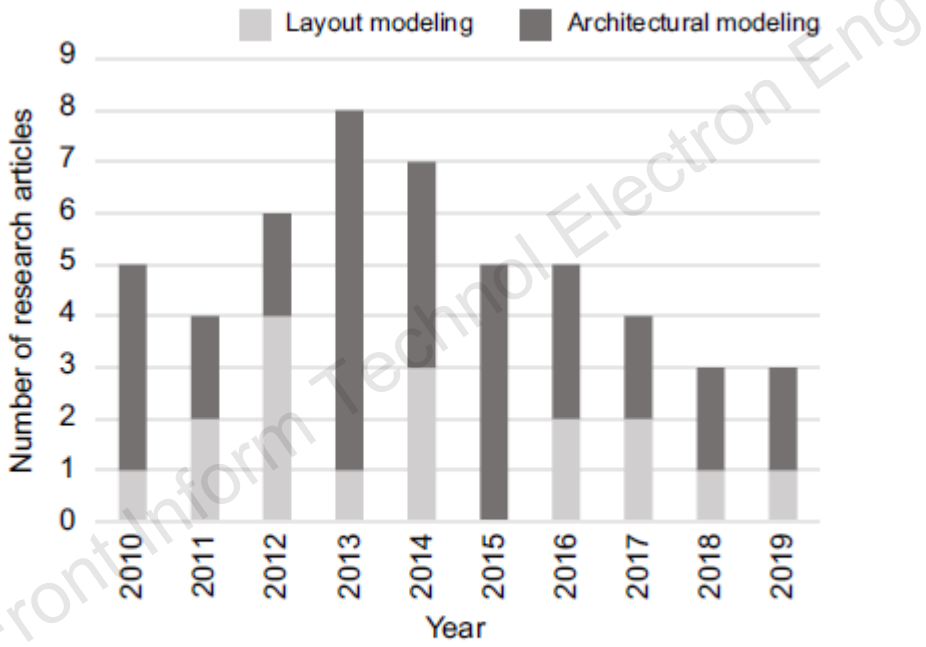

Fig. 1 Number of research articles by application class and year

The increasing attention was given to architectural modeling rather than layout modeling.

Number of research articles by participation of machine learning and year

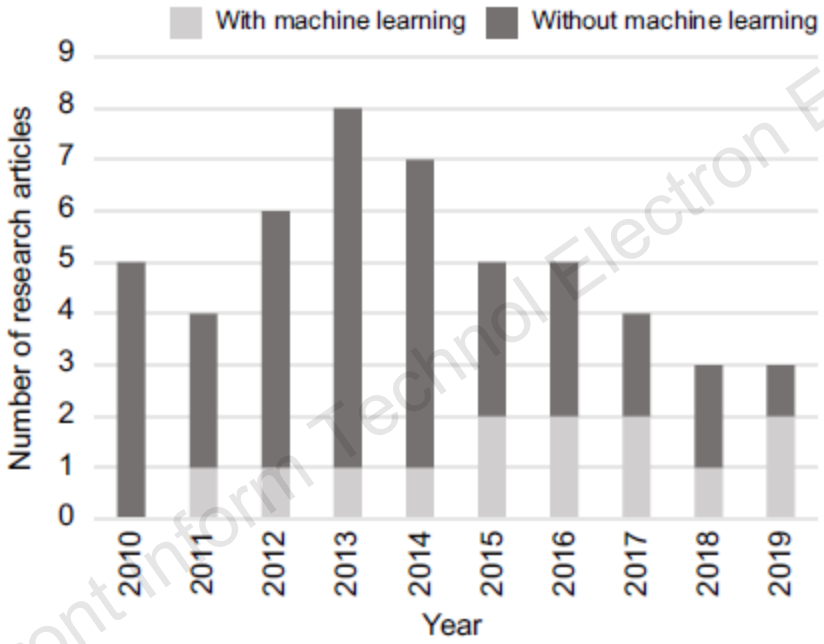

Fig. 2 Number of research articles by participation of machine learning and year

The participation of machine learning was expanding in recent years.

Conclusions

1. Unsupervised learning algorithms were considerably employed instead of supervised learning algorithms, likely due to the shortage of meaningfully labeled urban data.
2. An urban modeling task was associated with a huge solution space, especially depending on rules and objectives with non-linear relationships and high-dimensional parameters. Machine learning is believed to address the issues on complexity and the cost of computation.
3. Urban perception in computer vision is expected to provide sophisticated and in-depth information for urban modeling.