Supplementary materials

SM1 Construction of reference dataset

The construction of reference dataset consists of following steps:

- Reference to previous research. By reviewing existing research concerning about large-scale 3D building information mapping (Li et al., 2020a; Cao and Huang, 2021), we first summarized sample cities used in these works and included them into our dataset if we could still download corresponding raw data in the format of ESRI shapefile. 18 sample cities were collected in this step.
- Additional search in ArcGIS Hub. Based on preliminary experiments, the limited number of samples collected from previous works cannot guarantee satisfactory training results of DL models. Thus, to further enlarge our dataset, we conducted an additional search in ArcGIS Hub (https://hub.arcgis.com/). We manually checked the contents of related datasets containing keywords such as "building height" and finally gathered 21 sample cities to our best efforts.
- Incorporation with high-quality data. Considering inherent noises in open-source datasets, we further included high-quality cadastral data of London and Glasgow prepared by Digimap (https://digimap.edina.ac.uk/) to improve the training quality and evaluation reliability of our developed models.

After above steps, we prepared a reference dataset for 3D building information mapping which consists of 41 cities worldwide. Key information of the reference dataset is summarized in Fig. S1 and Table S1.

Figure S1: Geolocations of sample cities. Source of base map in North America: ESRI.

Table S1: Sample cities with their country, representative year and data source

Country	City	Year	Data source
Canada	Airdrie	2018	https://hub.arcgis.com/datasets/airdrie::airdrie-2018-building-footprints
Canada	Kamloops	2019	https://hub.arcgis.com/datasets/kamloops::building
Canada	Moncton	2020	https://hub.arcgis.com/datasets/moncton::buildings
Canada	Orangeville	2020	https://hub.arcgis.com/datasets/orangeville::building-footprints
Canada	PrinceGeorge	2019	https://hub.arcgis.com/datasets/CityofPG::building-outlines
Canada	Toronto	2020	https://open.toronto.ca/dataset/3d-massing/

China	Beijing	2020	https://amap.com
Czech	Brno	2020	https://hub.arcgis.com/datasets/b8dfa4c2e7bc4ca6981764be30ab778f_0
New Zealand	Porirua	2020	https://hub.arcgis.com/datasets/PCC::building-footprints
United Kingdom	London	2020	https://digimap.edina.ac.uk/
United Kingdom	Glasgow	2020	https://digimap.edina.ac.uk/
United States	Albuquerque	2012	http://data-cabq.opendata.arcgis.com/datasets/e65e375b680345e0b21fa7585d83ce9c_0?uiTab=table
United States	Arlington	2018	https://hub.arcgis.com/datasets/bac045c94c144838a7e65fbcf7aa939c_0?page=1532
United States	Aurora	2014	https://hub.arcgis.com/datasets/AuroraCo::building-roofprints
United States	Austin	2013	https://data.austintexas.gov/browse?q=footprint&sortBy=relevance
United States	Baton Rouge	2021	https://hub.arcgis.com/datasets/ebrgis::building-footprint
United States	Boston	2011	http://boston.maps.arcgis.com/home/item.html?id=c423eda7a64b49c98a9ebdf5a6b7e135
United States	BoulderCO	2016	https://hub.arcgis.com/datasets/0d43652d038a4a0dbca68f0501151bb0_0
United States	Bozeman	2019	https://hub.arcgis.com/datasets/bozeman::buildings-1
United States	Centennial	2020	https://hub.arcgis.com/datasets/Centennial::building-footprints
United States	Chicago	2015	https://data.cityofchicago.org/Buildings/Building-Footprints-current-/hz9b-7nh8
United States	Chattanooga	2017	https://hub.arcgis.com/datasets/IGTLab::chattanooga-downtown-building-with-heights
United States	Cincinnati	2021	https://hub.arcgis.com/datasets/CAGISPortal::building-footprints
United States	Dodge County	2017	https://hub.arcgis.com/datasets/7548b7a4407f48fcb55fa3b5b5f118ff_3
United States	Des Moines	2020	https://www.dsm.city/city_of_des_moines_gis_data/
United States	Eaton County	2020	https://hub.arcgis.com/datasets/ecGIS::building-footprint
United States	Fort Collins	2014	https://hub.arcgis.com/datasets/7e577a14c83f4d83a6b58657c48027da_0/explore
United States	Hayward	2021	https://hub.arcgis.com/datasets/Hayward::hayward-building-footprints

United States	Henderson	2017	http://hub.arcgis.com/datasets/23e5f3506f034c3d99b84e54fce51584_11
United States	Jefferson County	2016	https://hub.arcgis.com/datasets/LOJIC::jefferson-county-ky-buildings-2016
United States	Lincoln	2018	http://hub.arcgis.com/datasets/1b6a5a2ef1b34c28950c4e720e8d7a3d_0
United States	Los Angeles	2017	https://egis-lacounty.hub.arcgis.com/maps/countywide-building-outlines-2017
United States	Montpelier	2016	https://hub.arcgis.com/datasets/VCGI::vt-data-2016-3d-building-roofprints/explore
United States	New York	2016	https://data.cityofnewyork.us/Housing-Development/Building-Footprints/nqwf-w8eh
United States	Newport News	2020	https://hub.arcgis.com/datasets/nngov::building-footprints
United States	Norman	2018	http://hub.arcgis.com/datasets/d68b0defa057465db7167d9260c90ad9_0
United States	Peoria County	2018	https://hub.arcgis.com/datasets/peoriacountygis::building-outlines
United States	Portland	2020	https://hub.arcgis.com/datasets/PDX::buildings
United States	Reedsburg	2018	https://hub.arcgis.com/datasets/dbe64a71897e4982934dbd7637d576d5_0/explore
United States	Richardson	2020	https://hub.arcgis.com/datasets/richardson::building-footprints
United States	Roanoke	2020	https://hub.arcgis.com/datasets/198c95ddd5f749ca9fc851dd64ba6ff0_32/explore
United States	San Francisco	2010	https://data.sfgov.org/Housing-and-Buildings/Building-Footprints-File-Geodatabase-Format-/asx6-3trm
United States	Santa Clara	2015	http://hub.arcgis.com/datasets/ee83a3518a7249fda22866117463de3f_0?page=10
United States	Sarasota	2020	https://hub.arcgis.com/datasets/6c679d2949544274aee3bee8182c5611_0/explore
United States	Sarpy	2020	https://hub.arcgis.com/datasets/1109224811aa404383c44cd84bf62a84_42
United States	Westchester	2018	https://hub.arcgis.com/datasets/wcgis::buildings

SM2 Comparison with the CNN models without DEM information

To verify the effectiveness of the introduction of DEM information for 3D building information mapping, we conducted experiments for comparing proposed CNN models with the one without DEM information, i.e., without the input branch of SRTM data. Since standard ML/DL model development requires model selection based on the validation dataset, we present the training and validation curves of two types of CNN models in Fig. S2 for the case of 100 m.

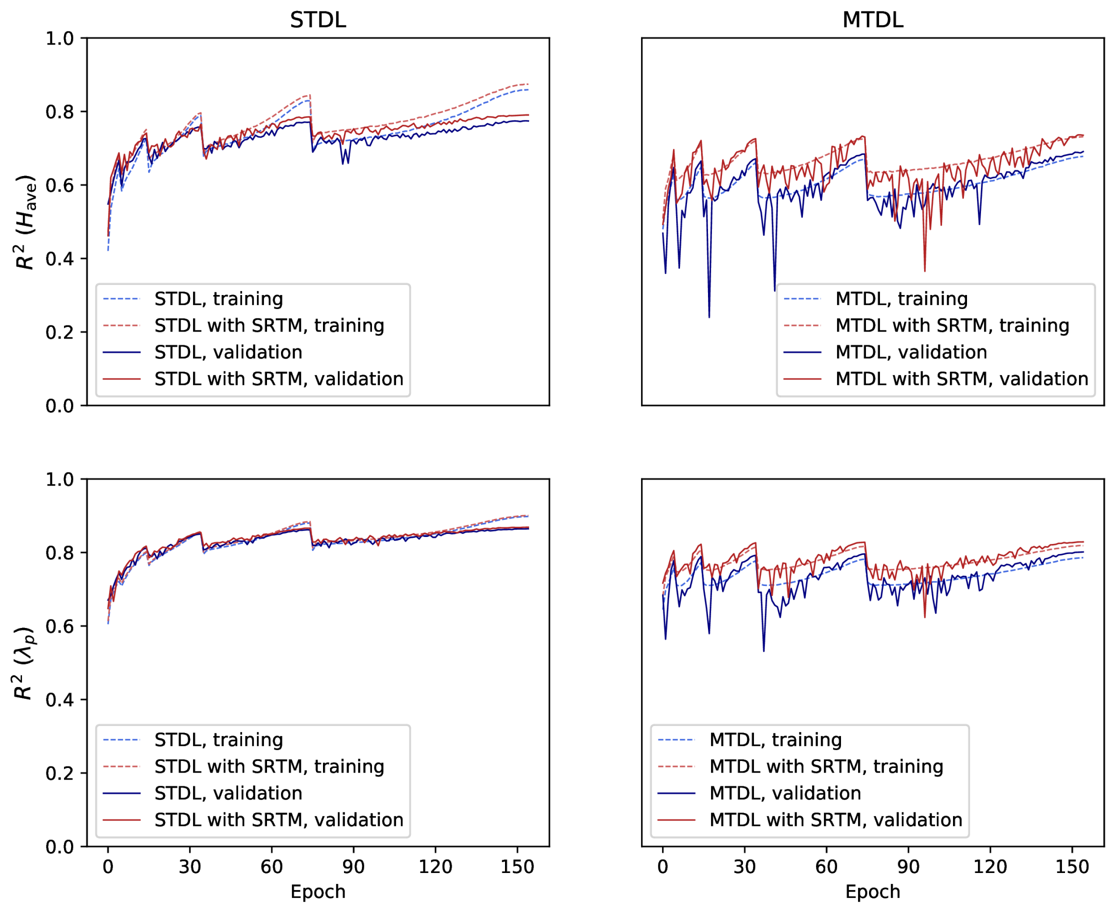

Figure S2: Training and validation curves of CNN models using DEM information and not.

According to Fig. S2, both STDL and MTDL models using DEM information achieve better performance, especially in building heigh prediction, which validates the benefits brought by DEM information for 3D building information mapping. Improvement of model performance can also be found in the cases of 250 m, 500 m and 1000 m though with a decreasing tendency. Thus, we conclude that the introduction of DEM information mainly helps building height prediction at a refined scale.

SM3 Determination of fixed weight ratio for the composite loss function

For the settings of fixed weight ratio for the composite loss function, we trained models using dynamic weight scheme first and then plotted dynamics of w_1/w_2 in Fig. S3.

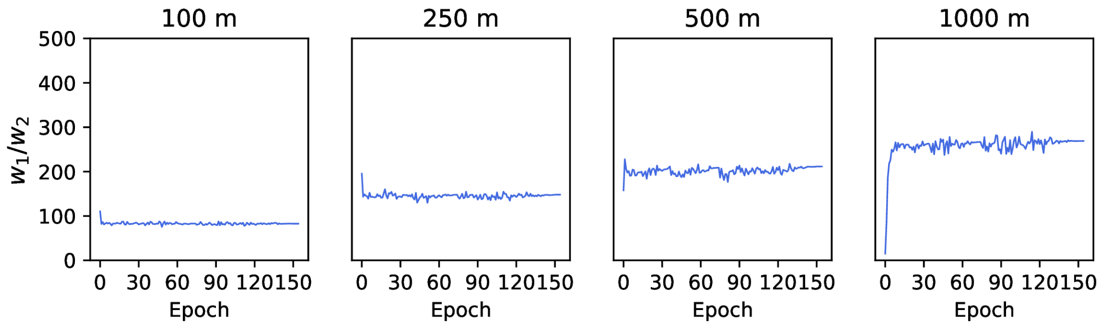

Figure S3: Dynamics of w_1/w_2 during training using dynamic weight scheme.

According to Fig. S3, w_1/w_2 can converge to a relatively stable constants ranging from 100 to 300 for all cases. Thus, without loss of generality, we set $w_1/w_2 = 100$ in fixed weight scheme for all cases.

SM4 Quantification results of model performance over representative intervals

Table S2: RMSE of building height and footprint prediction over representative intervals

Resolution	100 m			250 m			500 m			1000 m		
Model	SVR	STDL	MTDL	SVR	STDL	MTDL	SVR	STDL	MTDL	SVR	STDL	MTDL
$0 \le H_{ave} < 5$	4.88	3.10	3.50	5.88	3.44	3.84	4.60	2.62	2.87	5.07	2.49	3.06
$5 \le H_{ave} < 40$	7.69	4.61	5.05	7.47	4.83	5.18	6.75	4.50	4.66	6.23	3.21	4.02
$40 \le H_{ave} \le 1000$	63.18	31.69	38.43	50.47	26.42	31.30	39.16	22.71	26.90	33.75	17.67	18.54
$0 \le \lambda_p < 0.05$	0.06	0.04	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
$0.05 \le \lambda_p < 0.25$	0.06	0.05	0.05	0.06	0.04	0.04	0.05	0.03	0.03	0.05	0.02	0.02
$0.25 \le \lambda_p \le 1$	0.20	0.10	0.12	0.22	0.10	0.12	0.11	0.05	0.06	0.09	0.03	0.04

Table S3: NMAD of building height and footprint prediction over representative intervals

Resolution	100 m			250 m			500 m			1000 m		
Model	SVR	STDL	MTDL	SVR	STDL	MTDL	SVR	STDL	MTDL	SVR	STDL	MTDL
$0 \leq H_{\mathrm{ave}} < 5$	2.27	1.20	1.31	2.32	1.29	1.60	2.01	1.10	1.19	2.35	0.94	1.01
$5 \leq H_{\mathrm{ave}} < 40$	4.44	3.31	3.68	4.22	3.54	3.85	4.23	3.22	3.28	3.84	2.29	2.79
$40 \leq H_{\mathrm{ave}} \leq 1000$	13.52	21.72	22.21	9.94	17.74	14.05	7.45	13.59	11.83	9.25	8.07	10.12
$0 \leq \lambda_p < 0.05$	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
$0.05 \leq \lambda_p < 0.25$	0.05	0.03	0.04	0.04	0.03	0.03	0.04	0.02	0.02	0.04	0.01	0.02
$0.25 \leq \lambda_p \leq 1$	0.12	0.08	0.08	0.10	0.06	0.07	0.07	0.03	0.05	0.06	0.03	0.03

References

Cao, Y. and Huang, X., 2021. A deep learning method for building height estimation using high-resolution multi-view imagery over urban areas: A case study of 42 Chinese cities. Remote Sensing of Environment. 264, 112590. https://doi.org/10.1016/j.rse.2021.112590.

Li, M., Koks, E., Taubenböck, H., and Vliet, J. van, 2020a. Continental-scale mapping and analysis of 3D building structure. Remote Sensing of Environment. 245, 111859.