ShapeStacks

Learning Vision-Based Physical Intuition for Generalised Object Stacking

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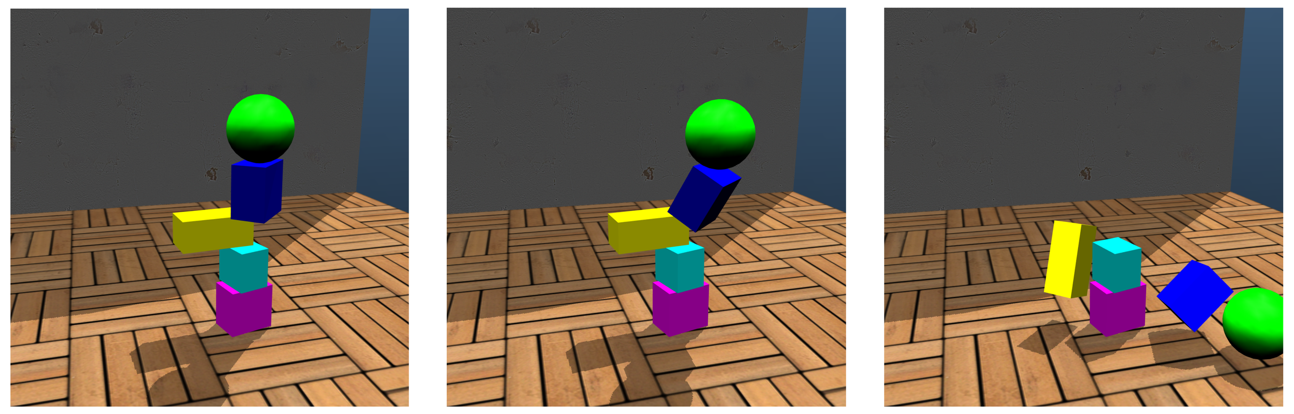
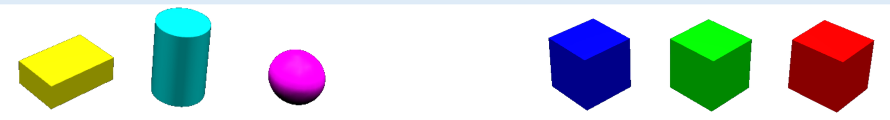
Introduction



ShapeStacks is a **simulation dataset** for the learning of **vision-based physical intuition**.
We present a model for **visual stability prediction** and demonstrate its **applicability in an object stacking task**.

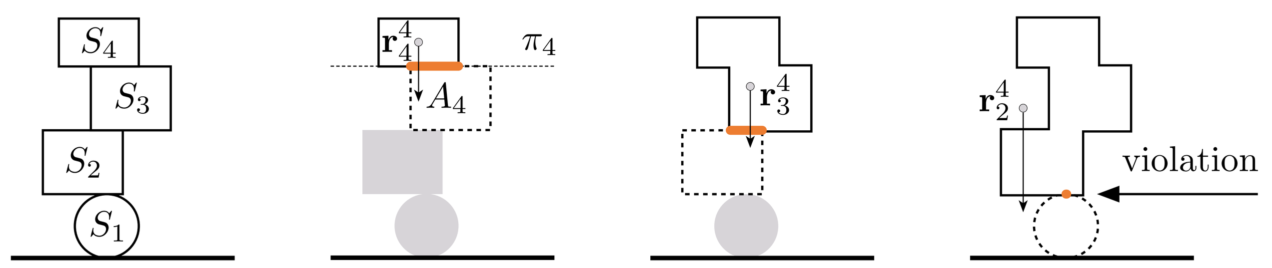
Dataset

The ShapeStacks dataset is openly available at **http://shapestacks.robots.ox.ac.uk/**



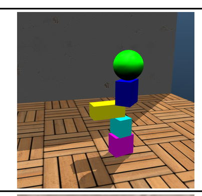
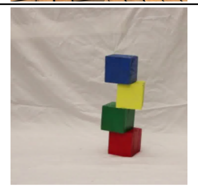
Height	CCS (# Scenarios) Train	CCS (# Scenarios) Test	Cubes (# Scenarios) Train	Cubes (# Scenarios) Test
h = 2	1,626	286	2,040	360
h = 3	2,992	528	2,040	360
h = 4	2,084	368	1,890	332
h = 5	822	144	1,546	272
h = 6	234	40	1,250	220
# Scenarios	7,758	1,366	8,766	1,544

Each scenario features a unique object stack and is available as **MuJoCo [1] simulation environment and RGB-D image sequence.**



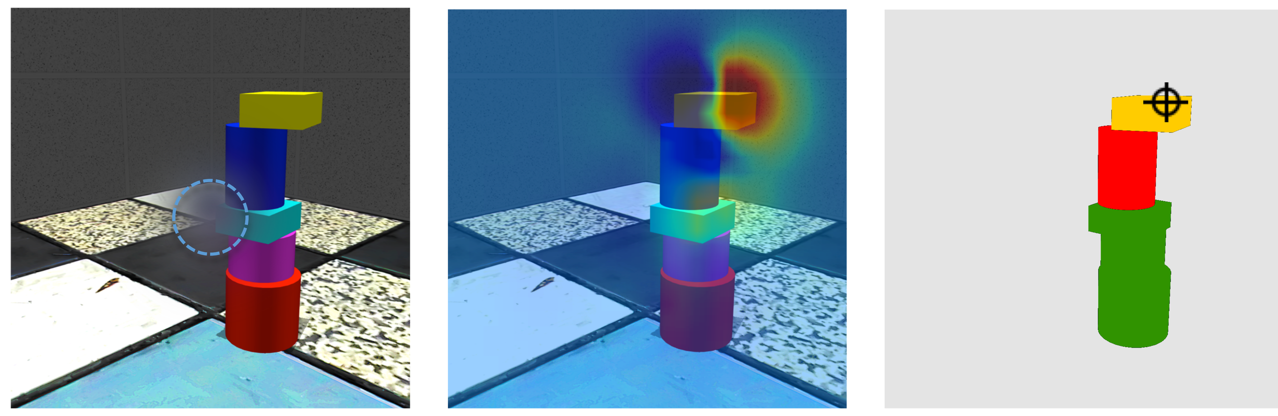
Segmentation maps annotate **each object's mechanical contribution to tower stability.**

Stability Prediction

		ShapeStack Inception [2]	PhysNet [3] (trained on RGB images and segmentation maps)	VDA [4] (requires physics simulator during prediction)
SIM		**84.9%**	N/A	N/A
REAL		74.7%	66.7%	**75.0%**

Our model achieves **state-of-the-art stability prediction accuracy** on simulated and real images [2] with a simplified training and inference setup compared to related work.

Structure Analysis



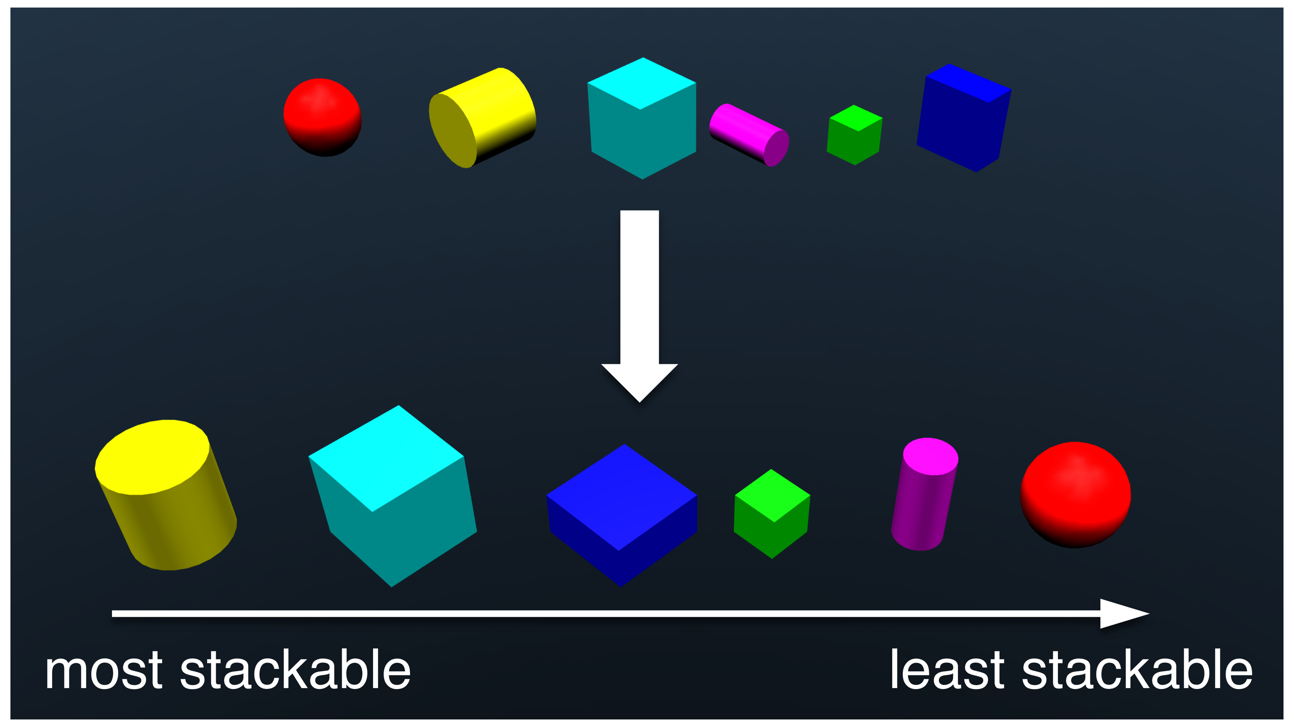
An **attention analysis** of the stability predictor was conducted via a blur study and compared to the annotation of the **stack mechanics** via the ground truth segmentation maps.

	Violating object	First object to fall	Rest of tower	Back-ground
VCOM & VPSF	38.9%	29.3%	11.4%	20.4%
VCOM	32.7%	30.8%	13.8%	22.7%
VPSF	52.1%	26.3%	6.3%	15.4%
Random chance	1.6%	1.9%	3.5%	93.0%
Random in tower	19.3%	22.9%	42.2%	14.5%

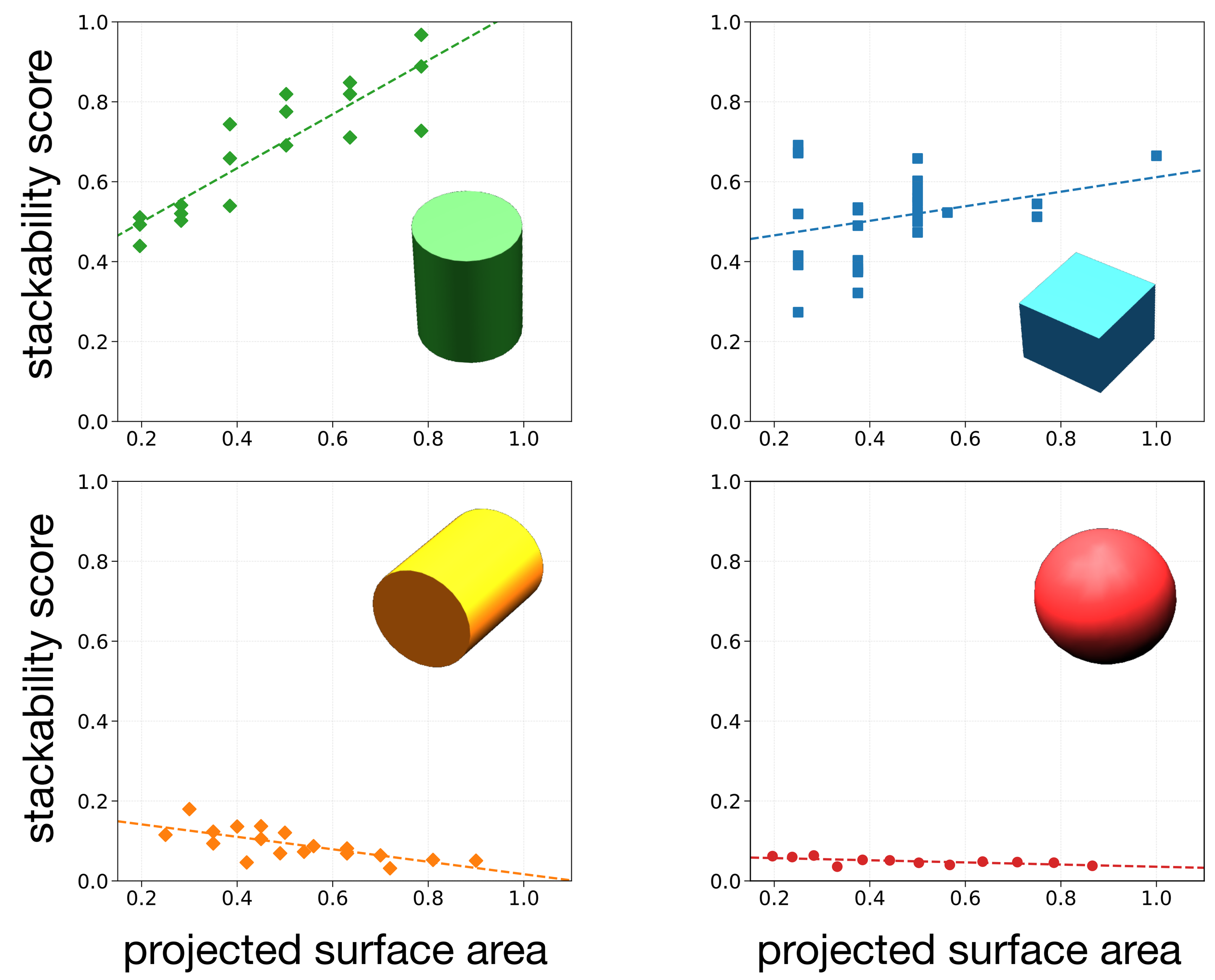
VCOM = tower with COM violation; VPSF = tower with non-planar support interfaces

Significant **focus on mechanically relevant regions** implies an intuitive understanding of the ***centre-of-mass principle (COM)***.

Stackability Score

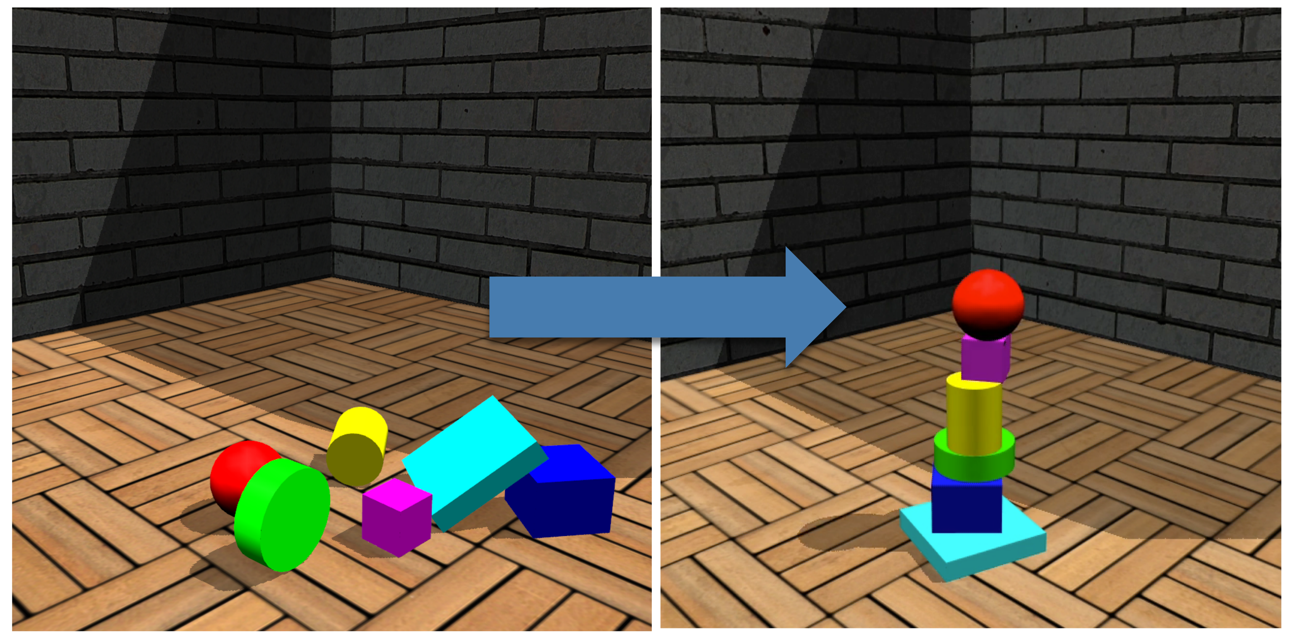


Ranking of random object set with respect to ***stackability***, i.e. the stacking order of objects which affords the highest possible tower.

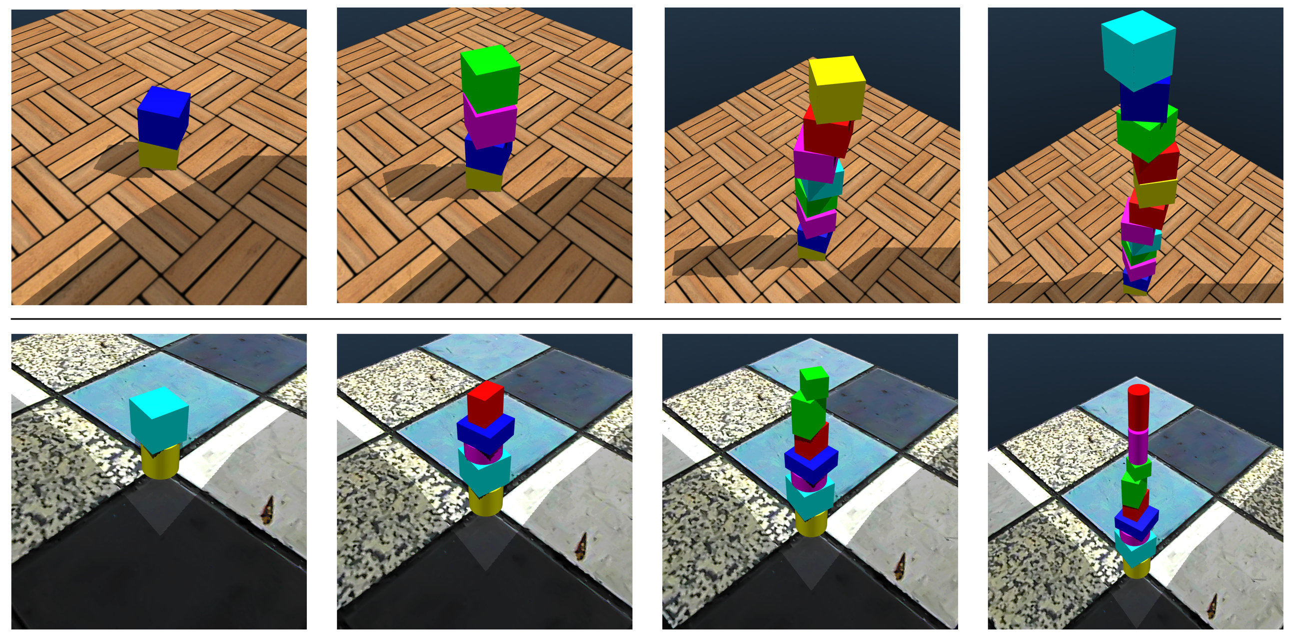


Stackability indicates the **capability of an object to support** the others in the set.
The score **correlates positively with the projected surface area** as long as the support interface is planar.

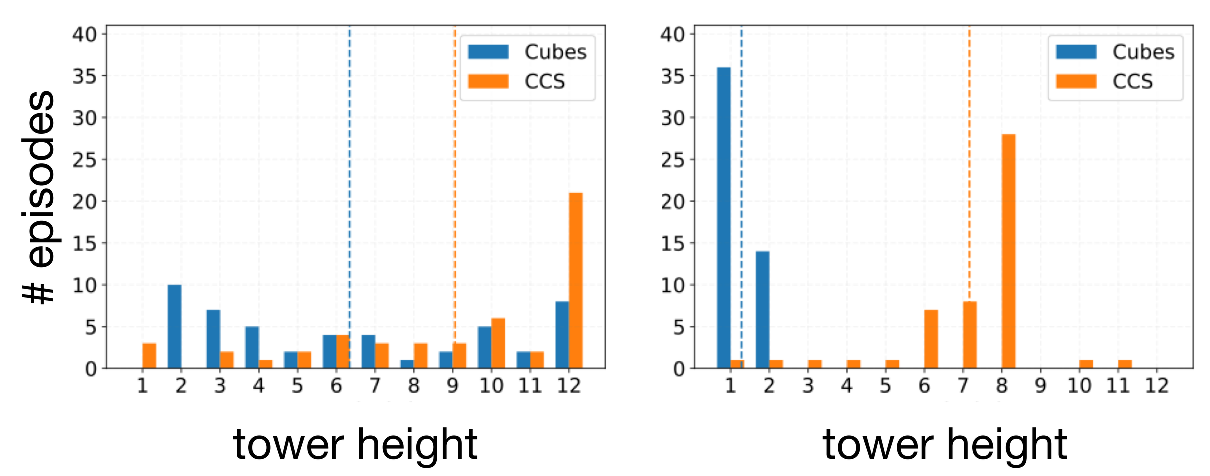
Stacking Task



Ranking, orientation and placement of objects in a tower based on the stability prediction via a **simulated annealing process**.



The **stability predictor** is used to **determine stable stacking positions.** Predictors trained on diverse towers (**C**uboids-**C**ylinders-**S**pheres) perform best building stacks with an **average height of eight objects**.



Dataset, code and models available!
RGB images, segmentation & depth maps
MJCF environments & simulation code
ShapeStacks scenario generator
pre-trained models for stability predictor

References
[1] Todorov, E., Erez, T., Tassa, Y.: *MuJoCo: A physics engine for model-based control.* IROS, 2012.
[2] Szegedy, C., Ioffe, S., Vanhoucke, V., Alemi, A. A.: *Inception-v4, Inception-ResNet and the Impact of Residual Connections on Learning.* AAAI, 2017.
[3] Lerer, A., Gross, S., Fergus, R.: *Learning Physical Intuition of Block Towers by Example.* ICML, 2016.
[4] Wu, J., Lu, E., Kohli, P., Freeman, W. T., Tenenbaum, J. B.: *Learning to See Physics via Visual De-animation.* NIPS, 2017.

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