Superpixel Correlation for Explainable Image Classification

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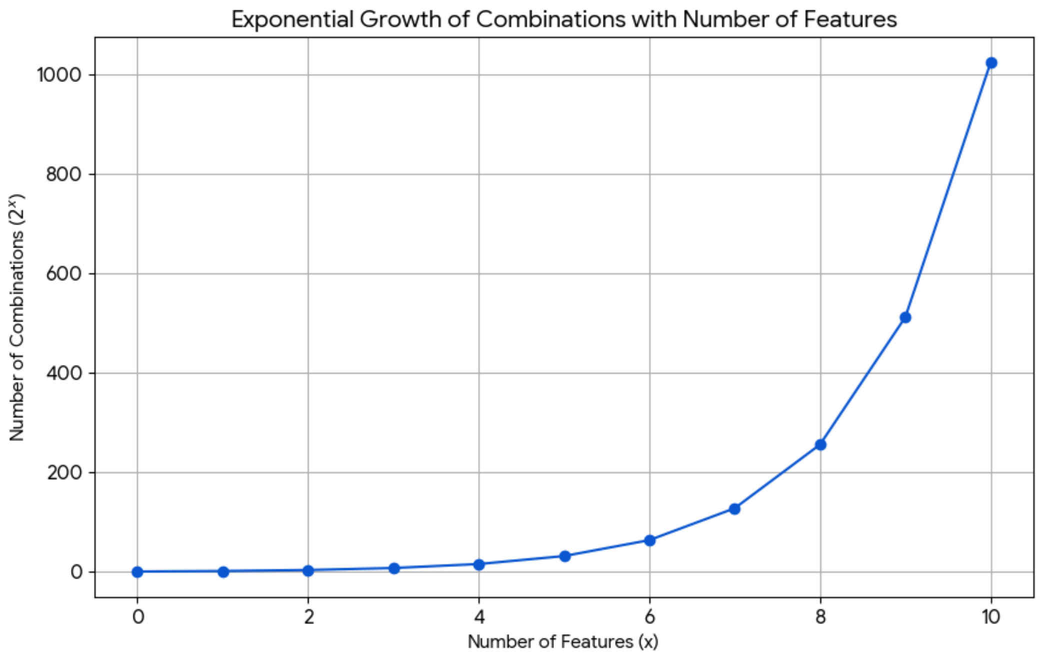
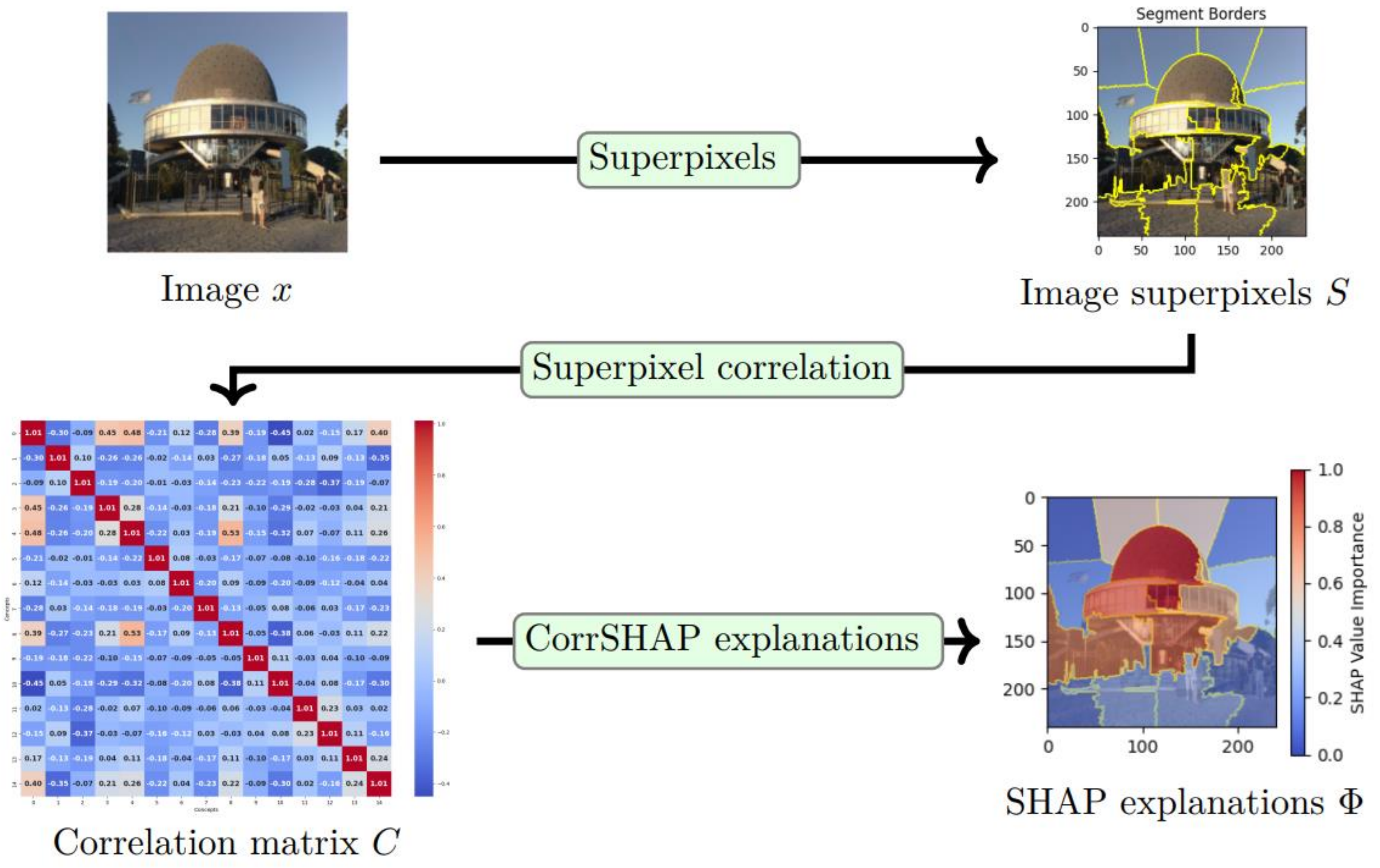
Introduction

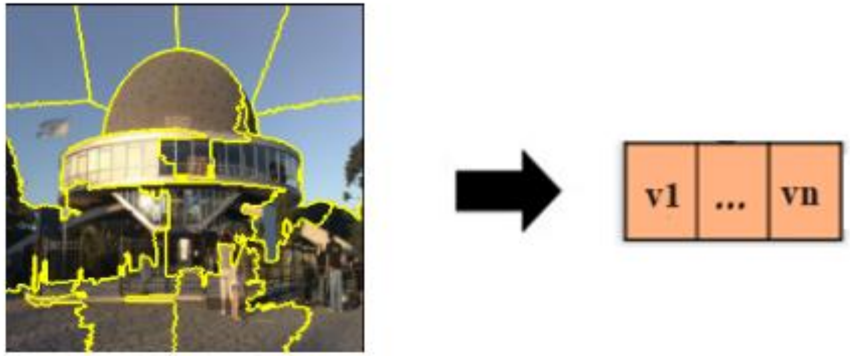
- Motivation:
  - SHAP:
    - Pixel-level explanations
    - Exponential computational complexity
  - Image superpixels are correlated
- Our contribution:
  - Novel SHAP approximation method CorrSHAP:
    - High-level superpixel explanations
    - Fast execution using novel superpixel correlation approach



Correlation SHAP (CorrSHAP)



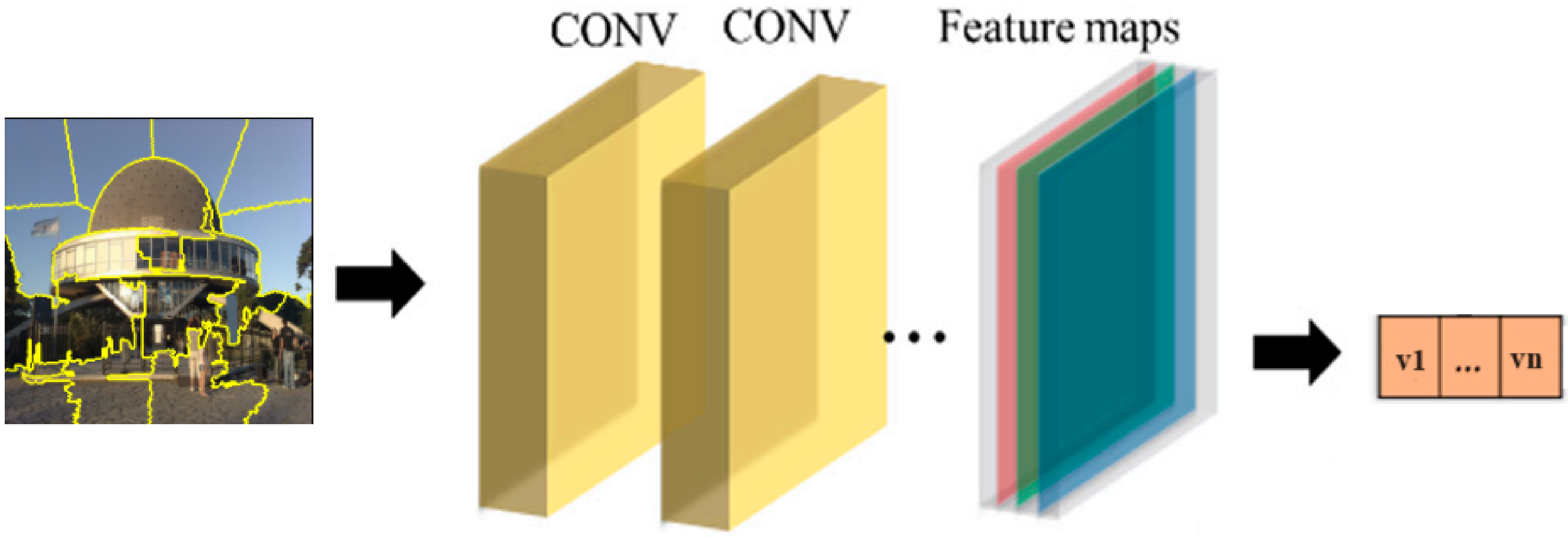
Raw Pixel Vectorization



$$v_i = \text{flatten}(s_i) = \text{flatten}(x \odot m_i)$$

$$v_i \in \mathbb{R}^d, x \in \mathbb{R}^{H \times W \times K}, m_i \in \{0,1\}^{H \times W \times K}, d = H \cdot W \cdot K.$$

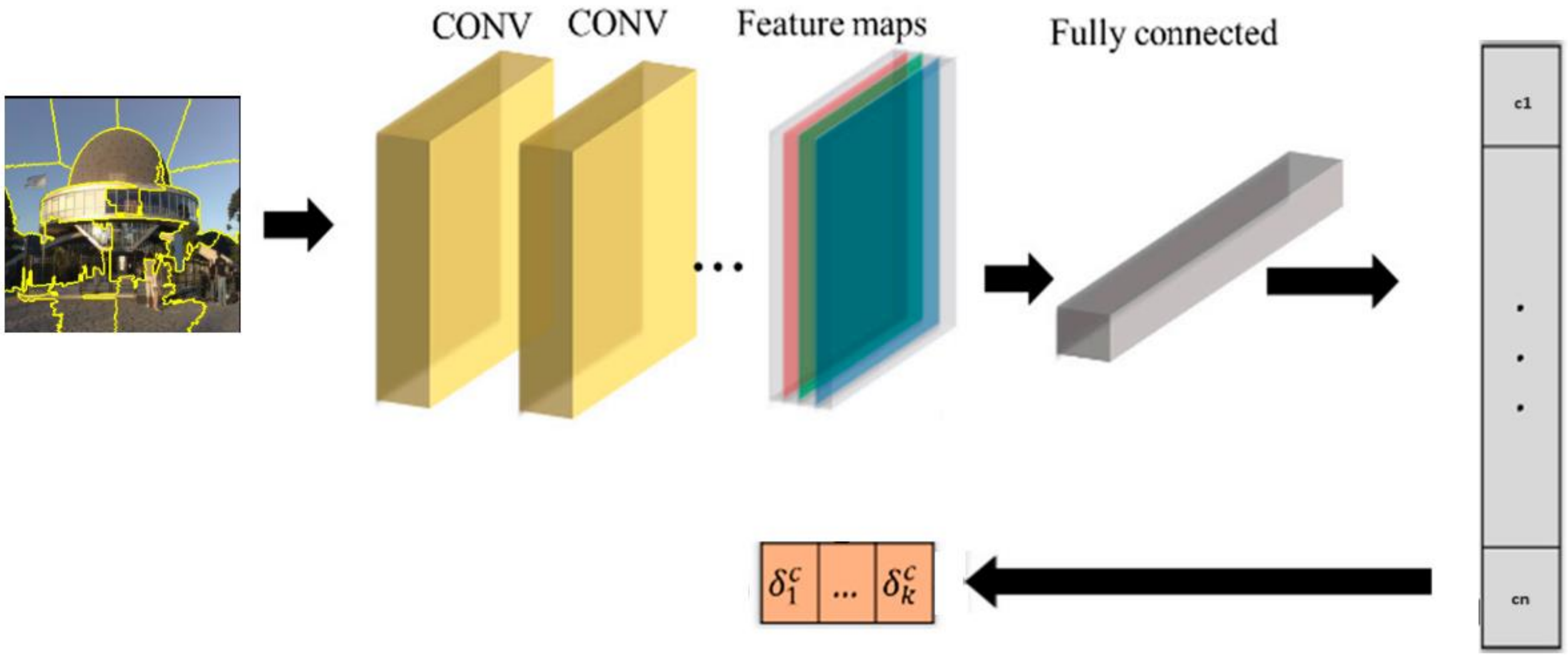
Feature Map Vectorization



$$v_i = \text{flatten}(g(s_i))$$

$$f(x) = h(g(x)), g : \mathcal{X} \to \mathcal{Z}, h : \mathcal{Z} \to \mathcal{Y}.$$

Gradient Vectorization



$$v_i = \nabla_\theta f_\theta(s_i).$$

CorrSHAP

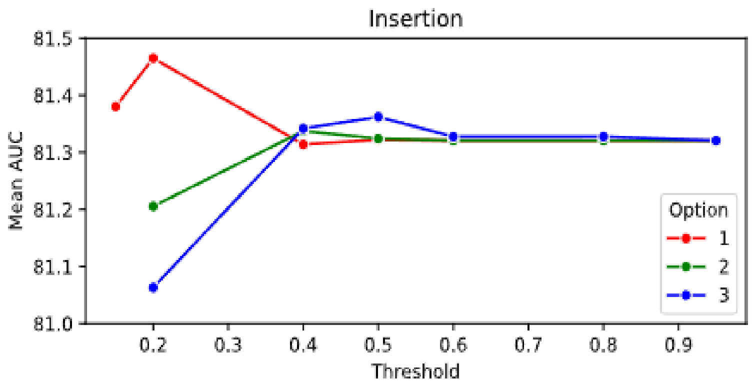
Algorithm 1 Correlation SHAP (CorrSHAP)

Input: Model f, Image x, ImageSegmentation q, Option ω
Output: SHAP superpixel attribution values $\hat{\phi}$

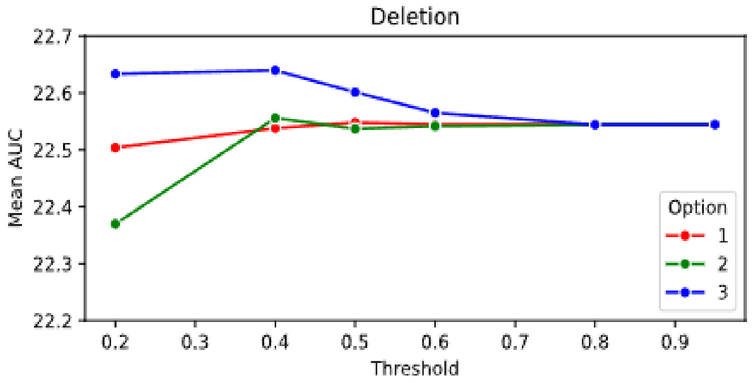
$g \leftarrow \text{FeatureExtractor}(f)$ $\{f(x) = h(g(x))\}$
$\mathcal{N} \leftarrow q(x)$ {Image segmentation}
if $\omega = 1$ **then**
    $V \leftarrow \text{flatten}(\mathcal{N})$ {Raw pixel vectorization}
else if $\omega = 2$ **then**
    $V \leftarrow \text{flatten}(g(\mathcal{N}))$ {Feature map vectorization}
else if $\omega = 3$ **then**
    $V \leftarrow \nabla_\theta f_\theta(\mathcal{N})$ {Gradient vectorization}
end if
$V' \leftarrow \text{Centralize(V)}$ {Vectors centralization}
$C = \{\cos(\mathbf{v}'_i, \mathbf{v}'_j) \mid \mathbf{v}'_i, \mathbf{v}'_j \in V'\}$ {Superpixel correlation matrix calculation}
$\hat{\phi} \leftarrow SHAP(\mathcal{N}, C)$ {Calculate SHAP values}
return $\hat{\phi}$

Ablation study

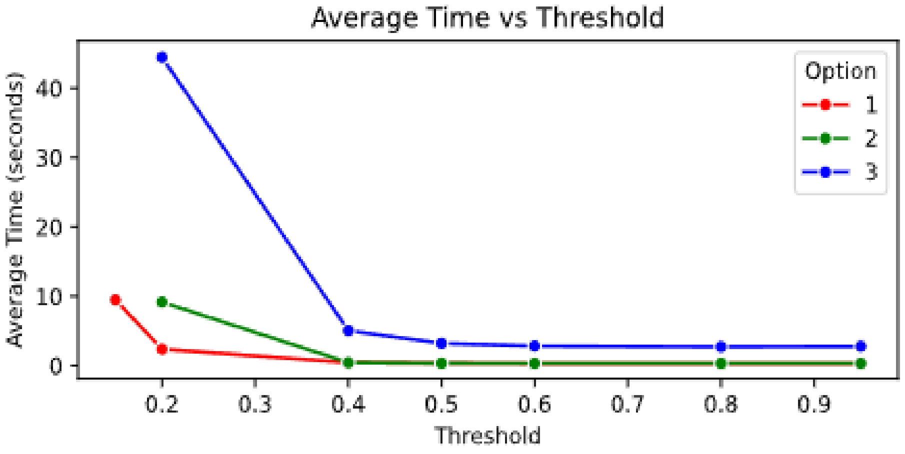
Option 1 – raw pixel vectorization
Option 2 – feature map vectorization
Option 3 – gradient vectorization



(a) Mean AUC insertion performance depending on threshold.

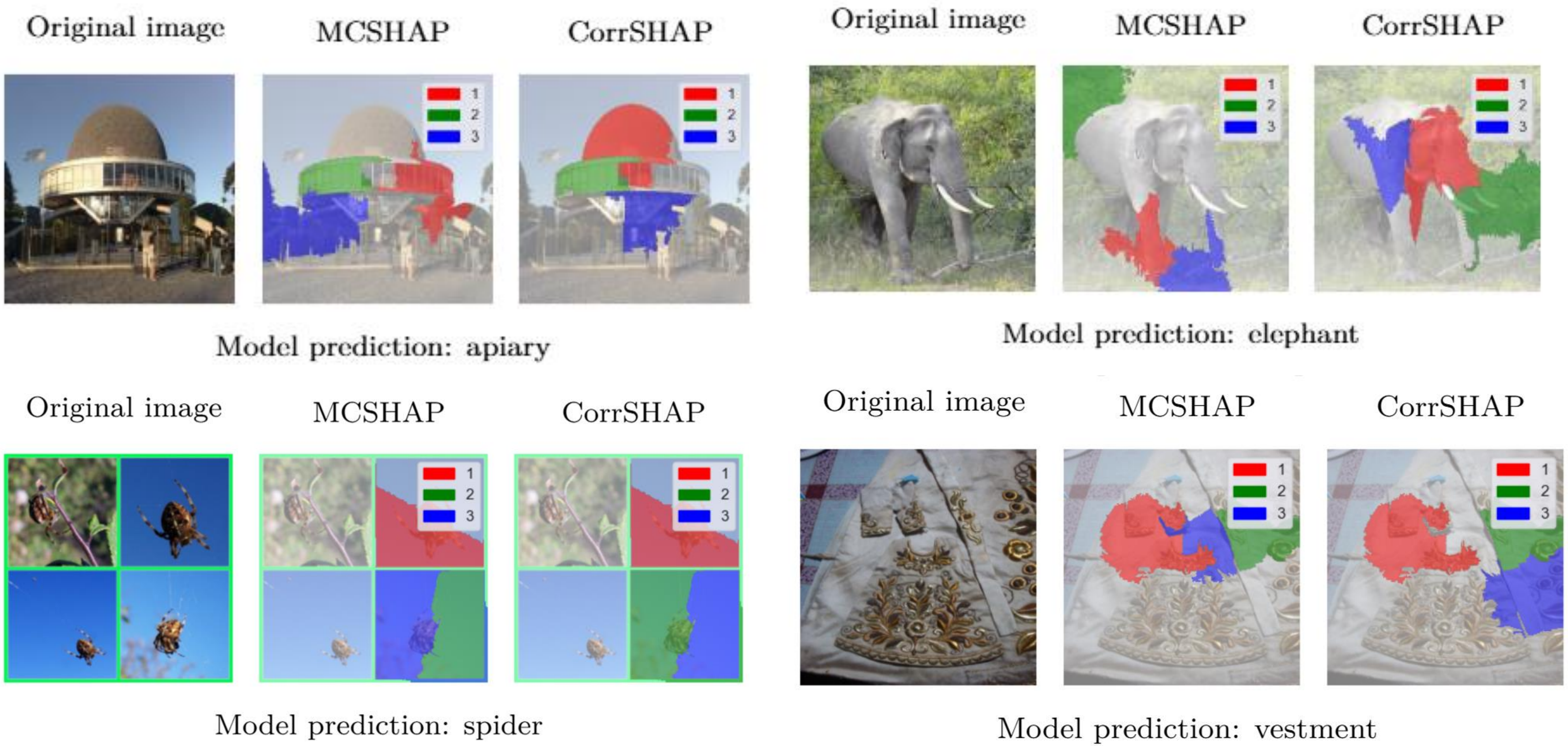


(b) Mean AUC deletion performance depending on threshold.



(c) Execution time depending on threshold.

Qualitative Results



Quantitative Results

- Speedup of 55x
- Higher faithfulness
- Vectorization approach 1 achieved the best performance overall

Area Under the Curve (AUC) Insertion ↑					
Model	Superpixels	CorrSHAP 1	CorrSHAP 2	CorrSHAP 3	MCSHAP
MobileNet-v2	Quickshift	80.4	80.37	80.29	**80.89**
	SLIC	**78.12**	78.13	78.15	77.79
ResNet-18	Quickshift	60.21	60.23	60.21	**61.60**
	SLIC	54.66	54.65	54.65	**55.41**
ResNet-50	Quickshift	**82.63**	82.61	82.63	82.27
	SLIC	**81.20**	81.20	81.20	80.66
ViT-b16	Quickshift	80.83	80.83	80.74	**81.84**
	SLIC	76.36	76.33	76.41	**76.82**
Area Under the Curve (AUC) Deletion ↓					
MobileNet-v2	Quickshift	**20.14**	20.14	20.16	20.93
	SLIC	**19.48**	19.48	19.48	21.40
ResNet-18	Quickshift	8.25	8.25	8.25	**8.03**
	SLIC	9.06	9.06	9.06	**9.01**
ResNet-50	Quickshift	**22.79**	22.79	22.79	24.16
	SLIC	**22.36**	22.36	22.39	23.79
ViT-b16	Quickshift	17.20	17.17	17.13	**16.86**
	SLIC	20.53	20.53	20.53	**20.48**
Execution Time (seconds) ↓					
MobileNet-v2	Quickshift	**0.42**	0.54	1.15	16.13
	SLIC	**0.74**	0.89	1.86	14.98
ResNet-18	Quickshift	**0.43**	0.50	1.09	7.85
	SLIC	0.66	**0.51**	1.91	13.82
ResNet-50	Quickshift	**0.46**	0.58	2.76	25.16
	SLIC	**0.78**	0.93	5.93	36.49
ViT-b16	Quickshift	**0.40**	0.52	5.41	7.26
	SLIC	**0.73**	1.01	10.53	18.00

Conclusion

- Novel SHAP approximation method CorrSHAP:
  - High-level, user understandable explanations – utilising superpixels
  - Fast SHAP calculation – utilising novel superpixel correlation approach

- Future work:
  - Alternative correlation measures
  - Integrating the superpixel correlation idea in other XAI methods

Thank you!

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