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Deep learning as a tool for the classification of selected types of astronomical objects

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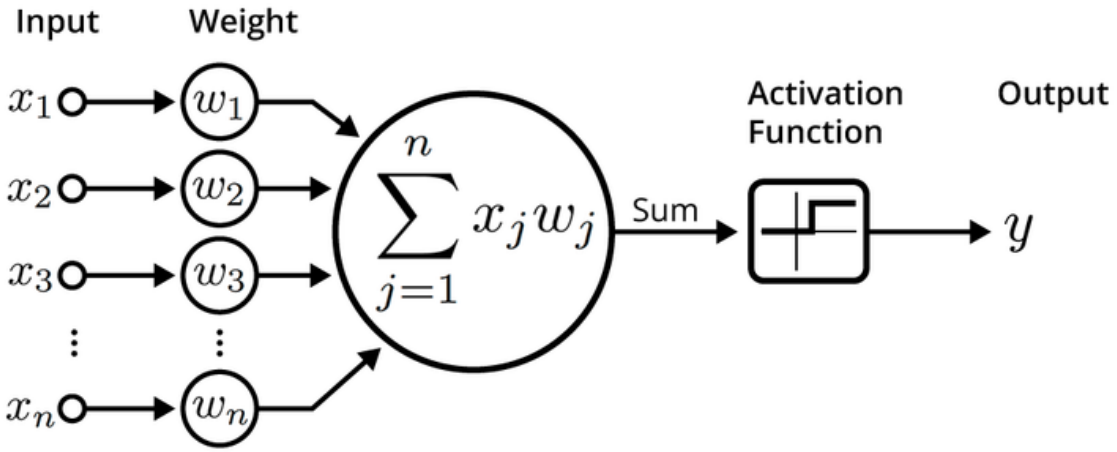
BEZOVEC 2021

Konferencia mladých astronómov

11. September 2021

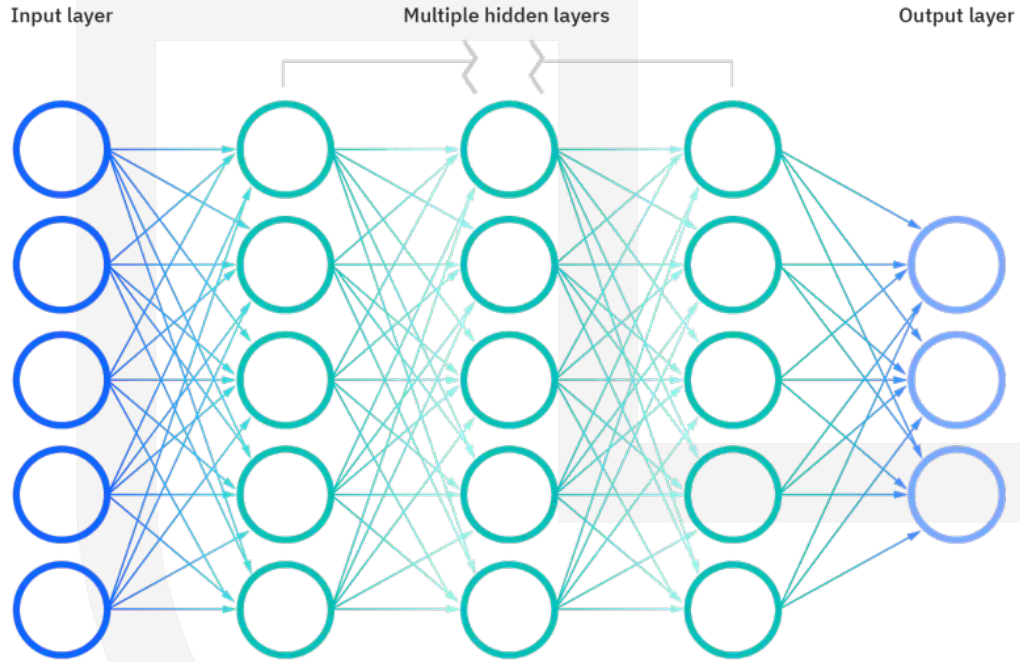
NEURAL NETWORKS

Perceptron / simple (artificial) neuron



Layers of neurons => more learning capacity

Feed Forward Neural Network



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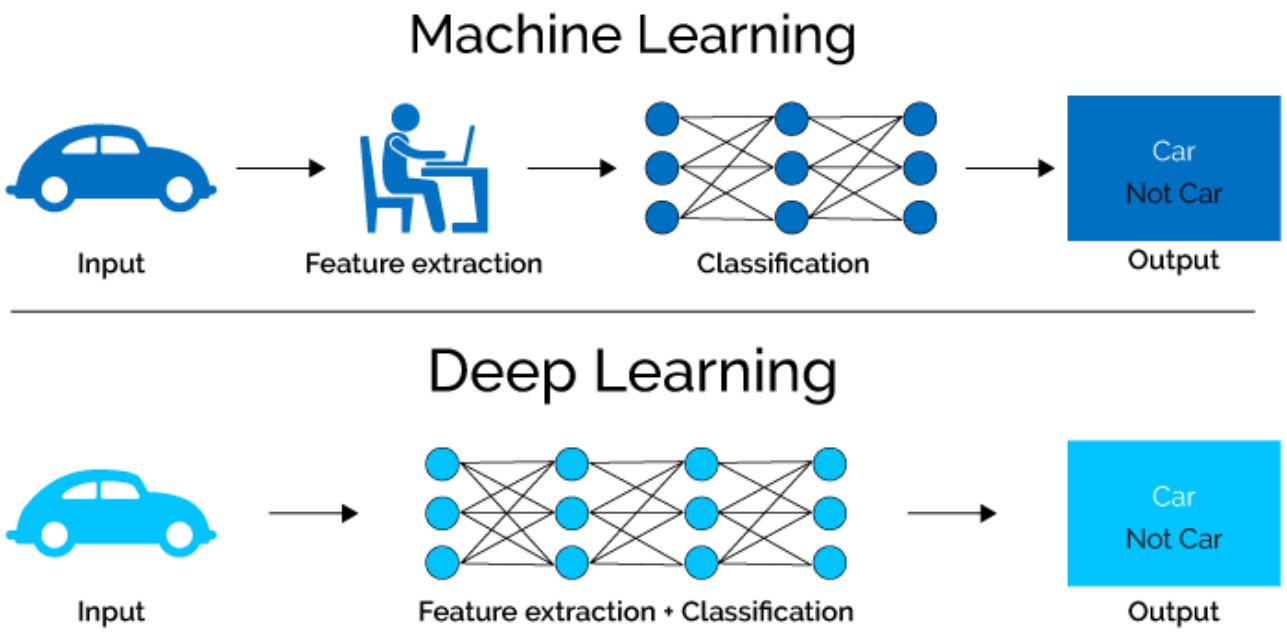
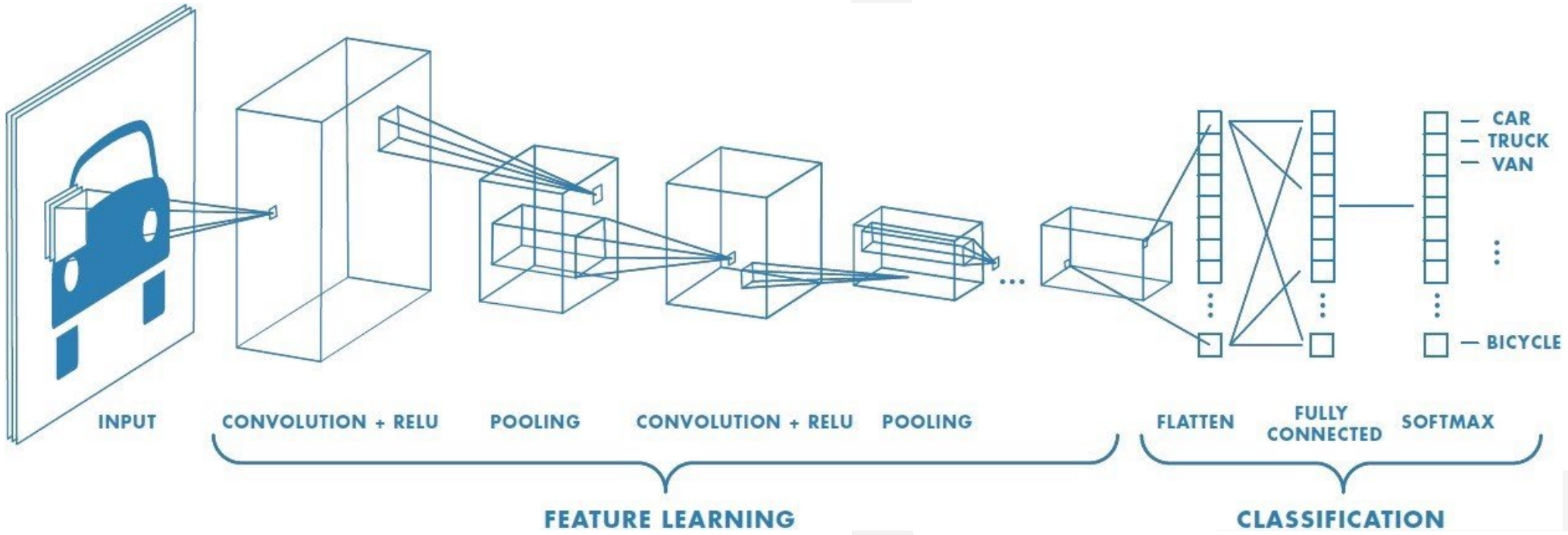
FEATURE EXTRACTION



CONVOLUTIONAL NEURAL NETWORK



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Morphological classification of compact and extended radio galaxies using convolutional neural networks and data augmentation techniques

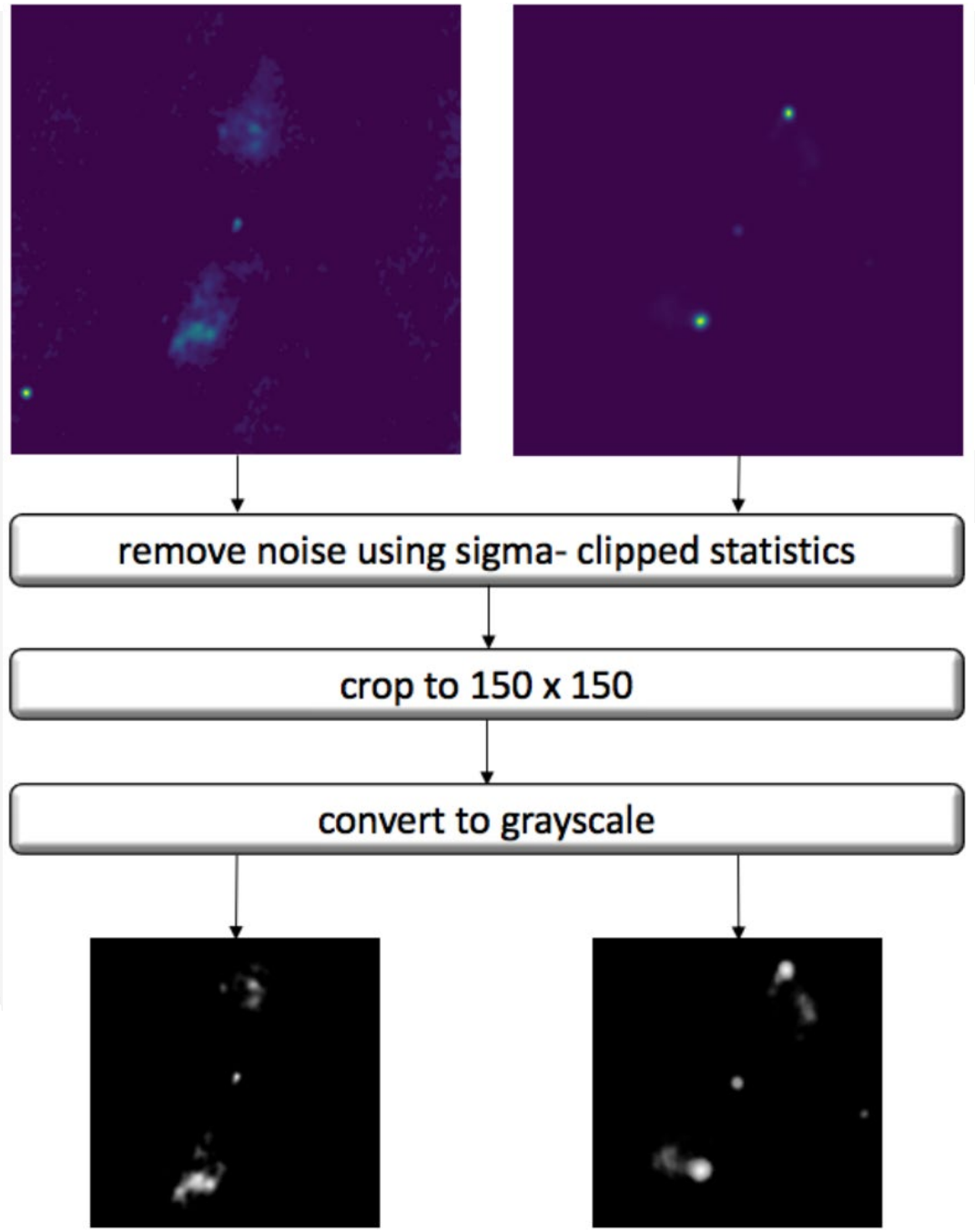
Maslej-Krešňáková, V., El Bouchefry, K., & Butka, P. (2021). Morphological classification of compact and extended radio galaxies using convolutional neural networks and data augmentation techniques. *Monthly Notices of the Royal Astronomical Society*, *505*(1), 1464-1475.

- Fanaroff-Riley I
- Fanaroff-Riley II
- Bent-tailed
- Compact

DATASET

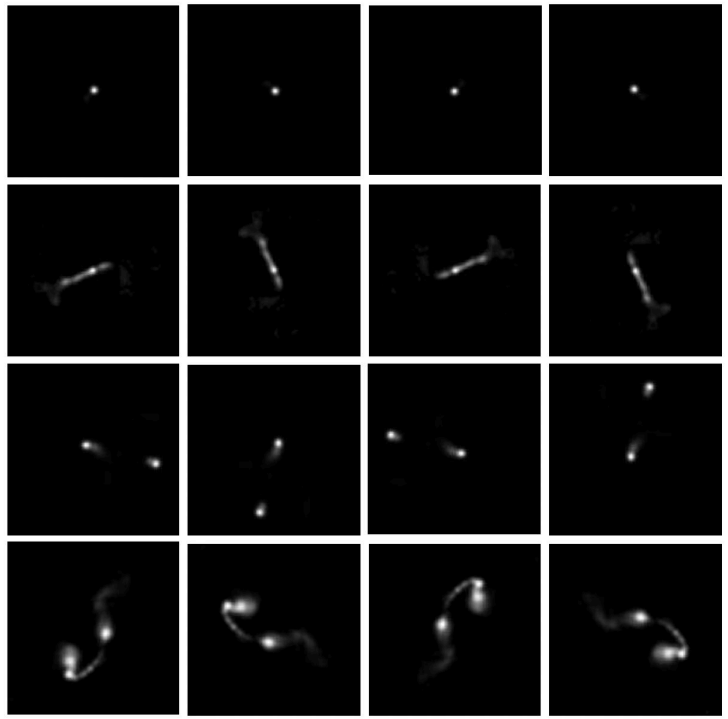
FIRST catalog (Faint Images of the Radio Sky at Twenty Centimeters)

- BENT: 104
- FR I: 125
- FR II: 214
- COMPT: 83

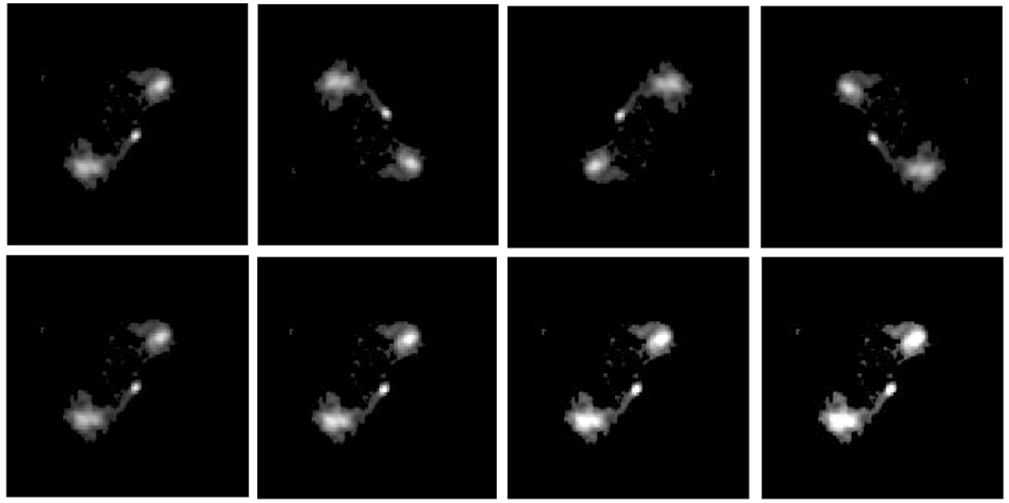


DATA AUGMENTATION TECHNIQUES

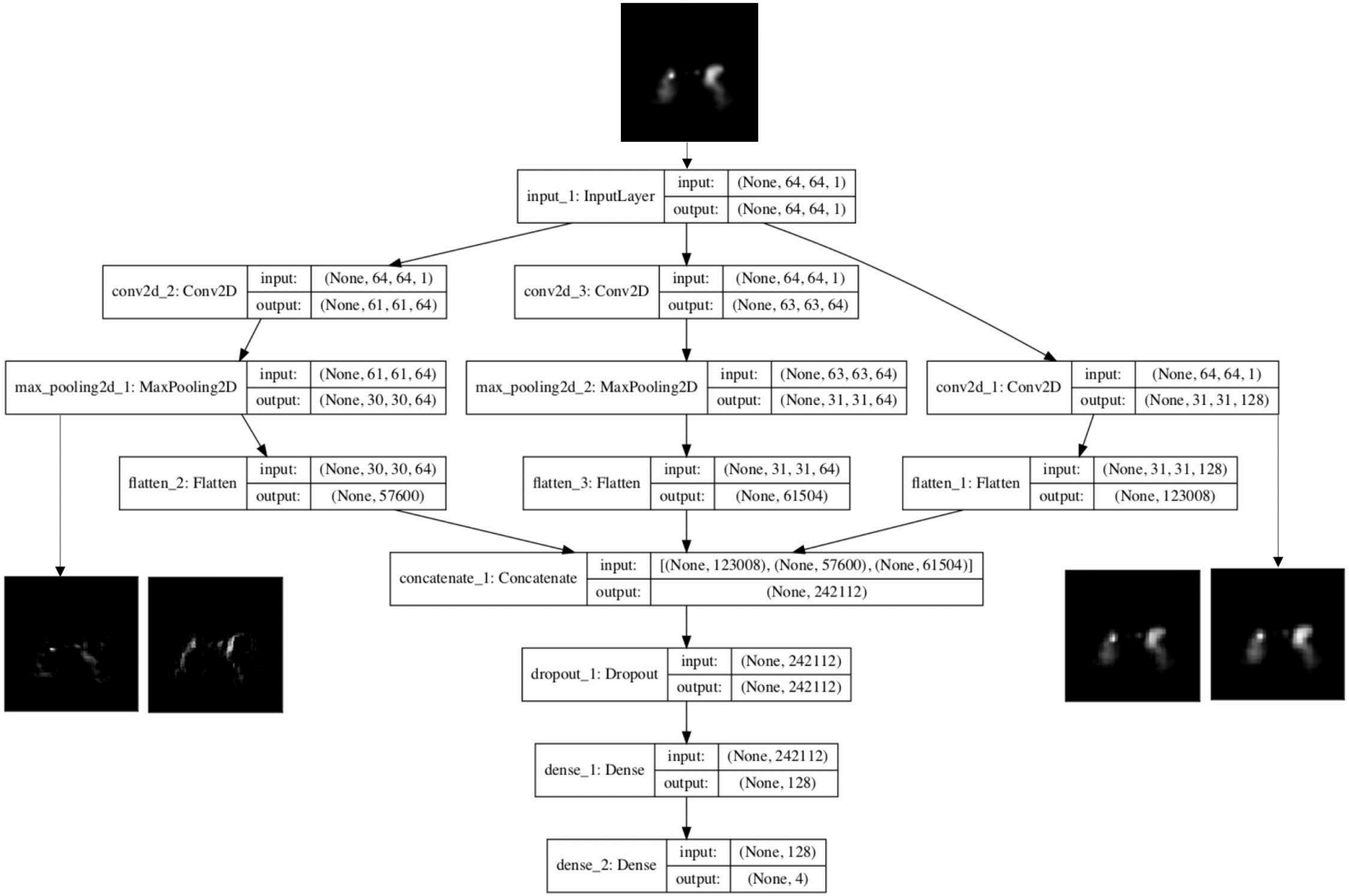
Rotate



ImageDataGenerator – real time augmenation



MODEL



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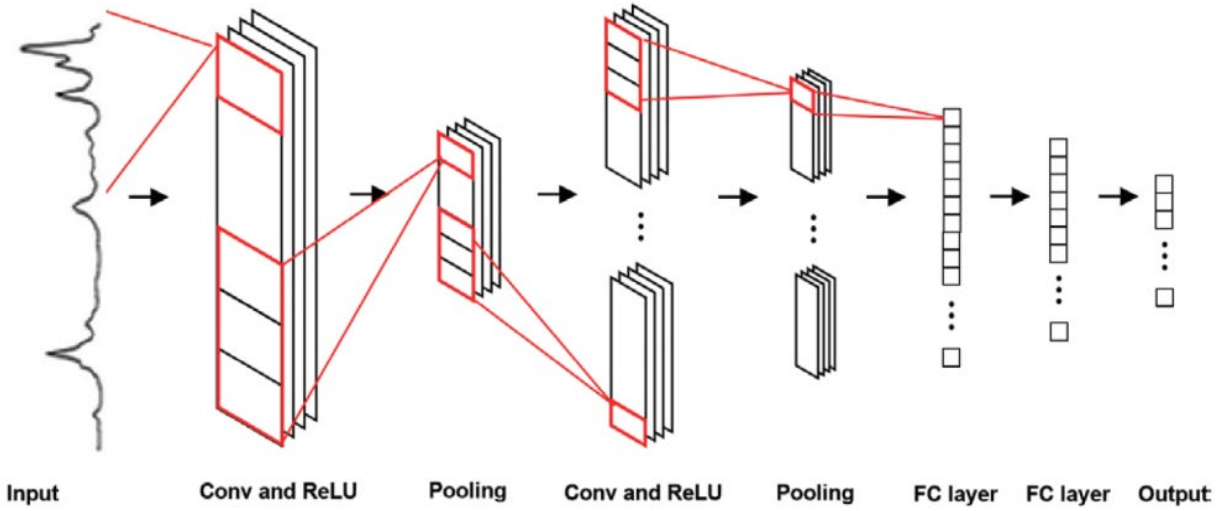
RESULTS

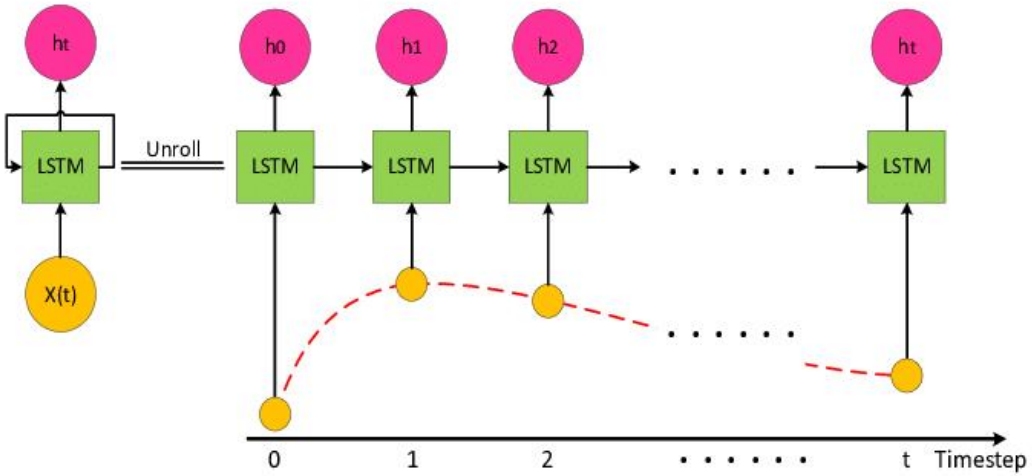
		Actual			
		BENT	**COMPT**	**FRI**	**FRII**
Predicted	**BENT**	21	0	0	0
	COMPT	0	17	0	0
	FRI	0	0	24	1
	FRII	0	0	2	42

Data augmentation – Average – accuracy: 0.95

BENT	0.96	0.97	0.97	21
COMPT	0.98	1.00	0.99	17
FRI	0.93	0.94	0.93	25
FRII	0.96	0.94	0.95	44
avg	**0.96**	**0.96**	**0.96**	**total: 107**

TIME SERIES CLASSIFICATION – 1-D CNN or LSTM





1-D Convolutional Neural Network

- convolution + pooling extracts different characteristics using windowing similarly to 2-D case with images

- Good for identification of local features within series

- extracted features are flattened and used as features for classification

LSTM (Long Short-Term Memory)

- Recurrent Neural Network – LSTM block contains different gates to help “memorize” sequences
- Good for identification of sequence elements which influence more distanced values (more un-local features can be identified)
- We can use similar chains of elements in forward and backward direction => bidirectional LTSM

… And we can use both in parallel ☺

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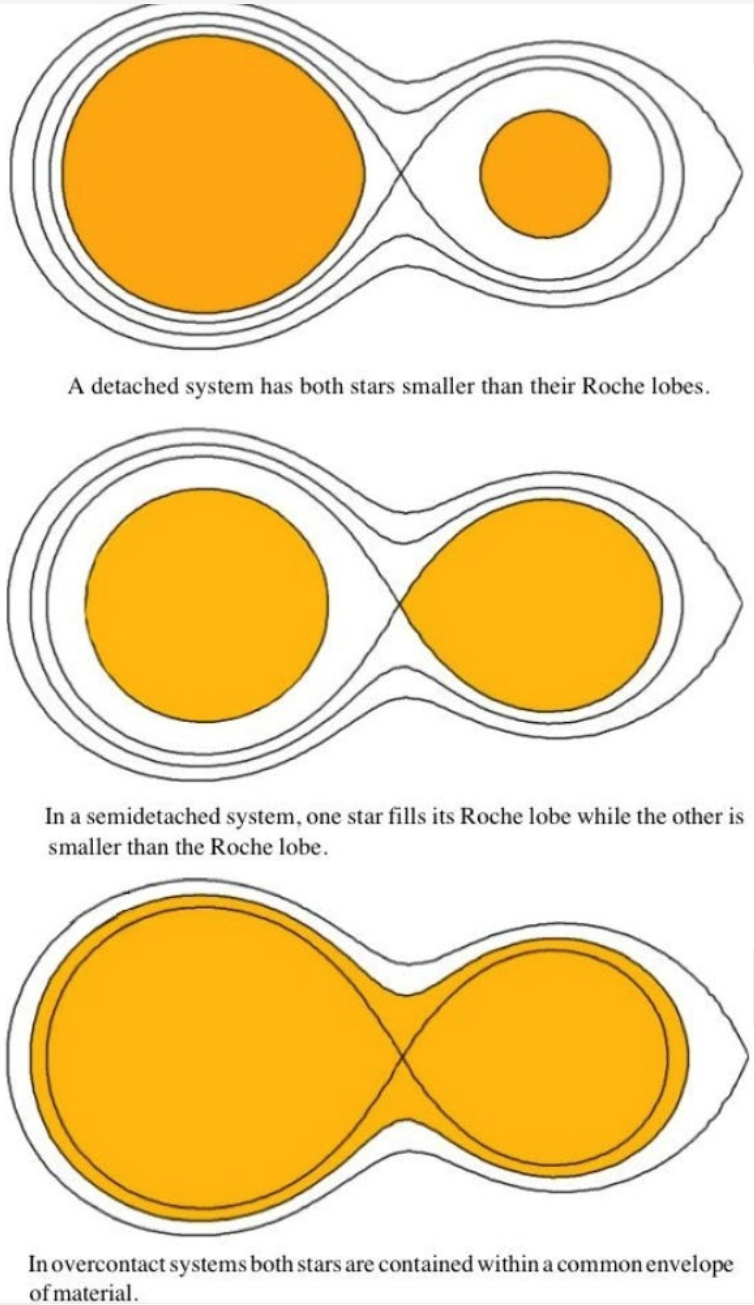
Automatic classification of eclipsing binary stars using deep learning methods

Čokina, M., Maslej-Krešňáková, V., Butka, P., Parimucha, Š. (2021). Automatic classification of eclipsing binary stars using deep learning methods. *Astronomy and Computing*, *36*, 100488.



A detached system has both stars smaller than their Roche lobes.

In a semidetached system, one star fills its Roche lobe while the other is smaller than the Roche lobe.

In overcontact systems both stars are contained within a common envelope of material.

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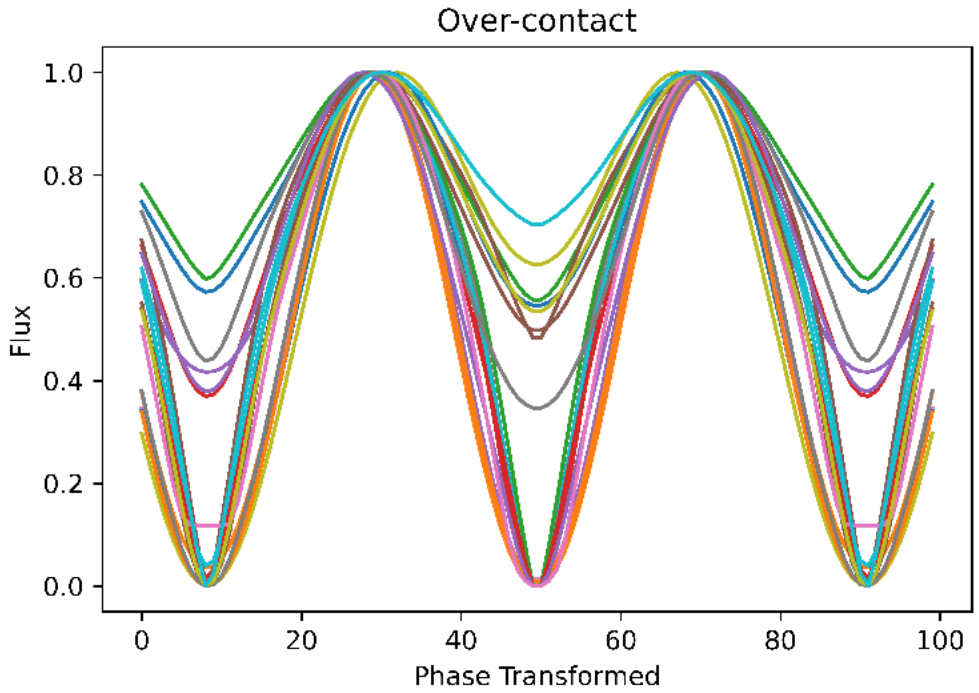
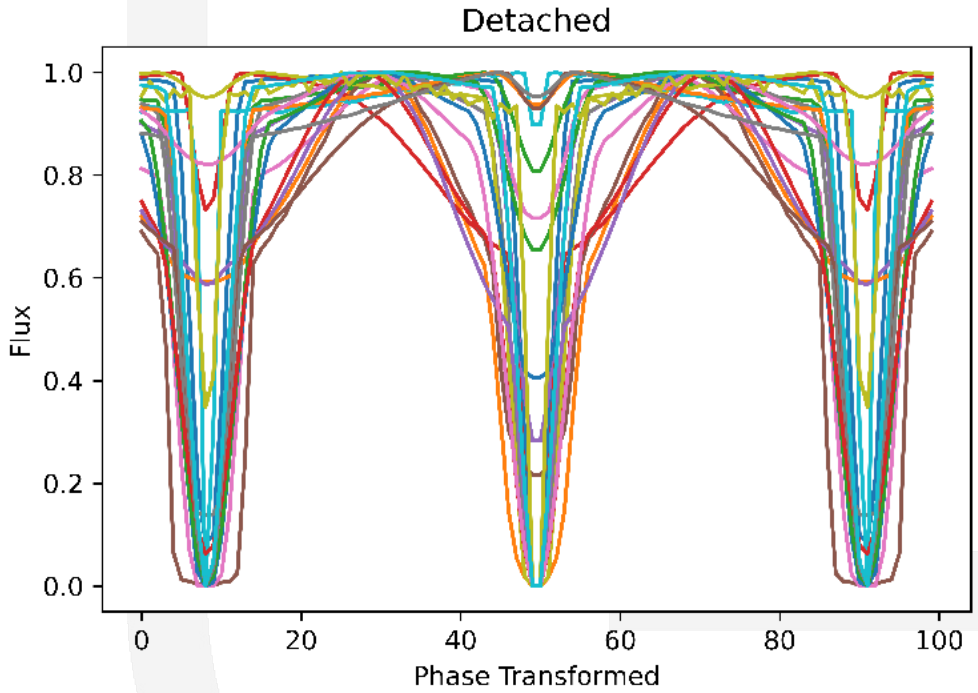
Demonstration of **synthetic** light curves of eclipsing binary stars generated by **ELISa** software





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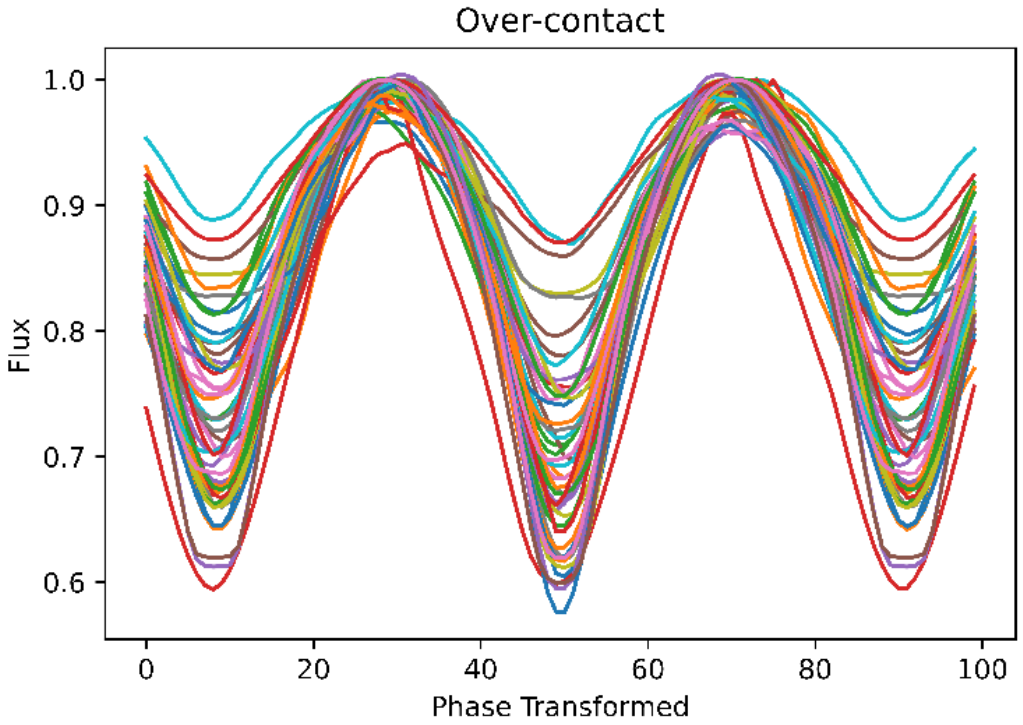
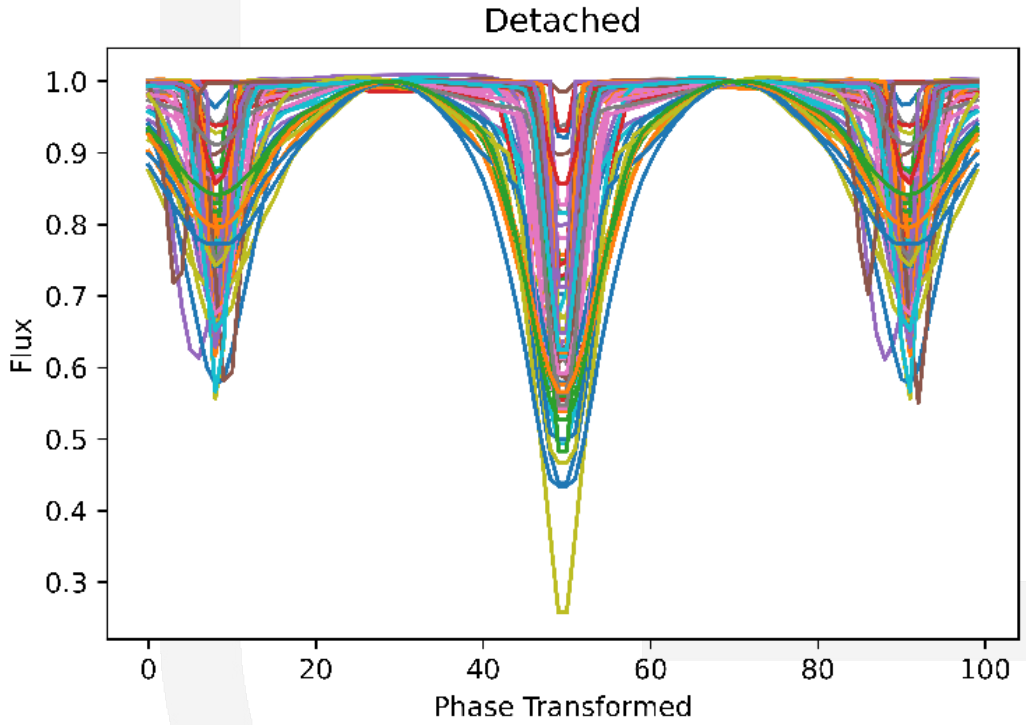
Demonstration of **observational** light curves of eclipsing binary stars





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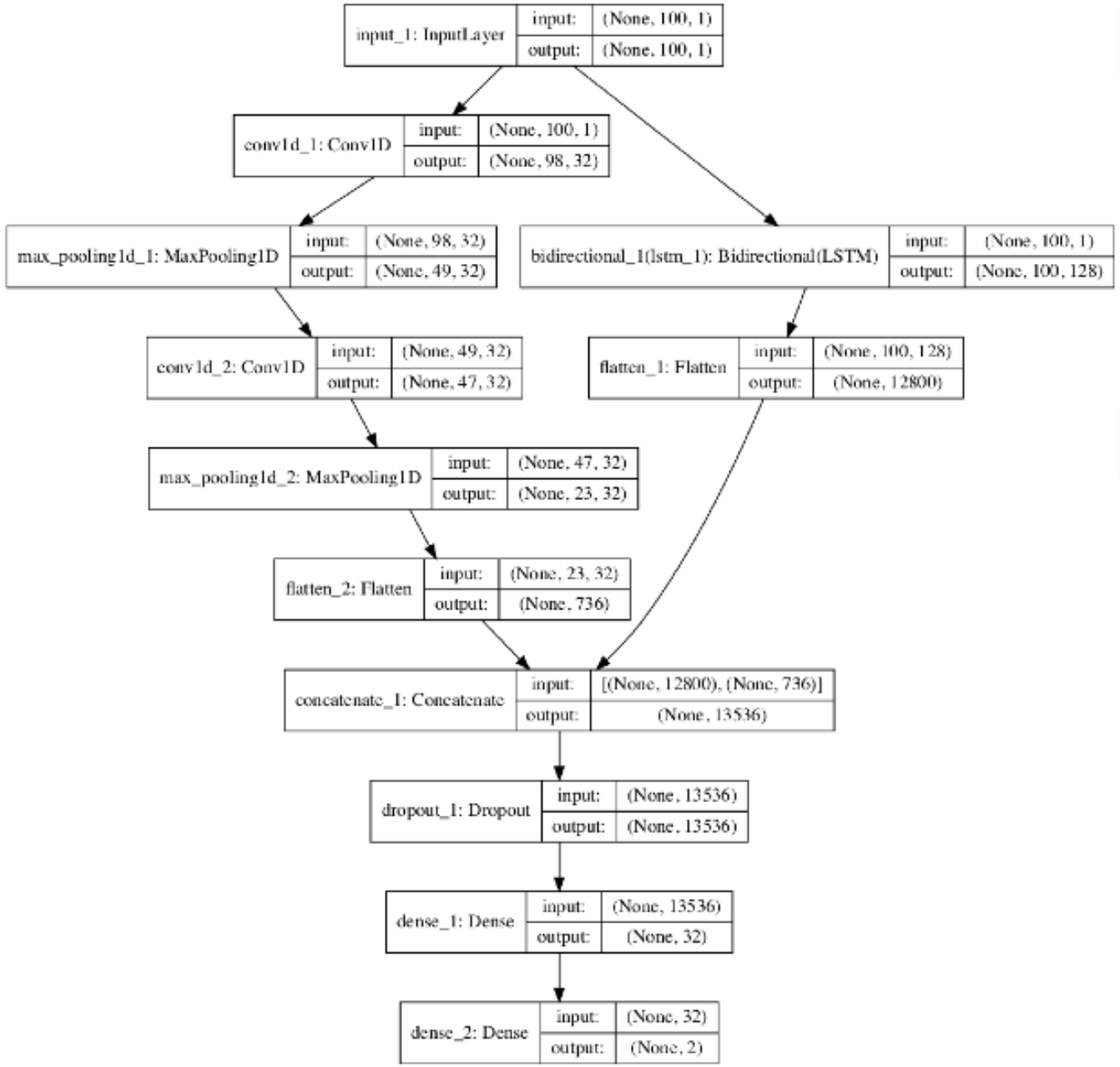
MODEL

- **Combination of convolution and bidirectional LSTM network**
- **Activation function:** ReLU
- **Optimizer:** Adam
- **Loss function:** Categorical cross entropy
- **Regularization:** Dropout and early stopping
- **Metrics:** accuracy, precison, recall, f1 score



TWO EXPERIMENTS

- test set with semi-detached tested as detached binaries
- test set without semi-detached binaries

Detached – tested as Detached					
AD And	AD Boo	AQ Ser	AR Aur	AS Cam	ASAS J045304-0700.4
BK Peg	CD Tau	CF Tau	CO And	CV Boo	CoRoT 102918586
HD 71636	HS Aur	HY Vir	IM Vir	MY Cyg	NY Cep
PT Vel	PV Cas	RT And	RT CrB	UZ Dra	V1229 Tau
V364 Lac	V396 Cas	V442 Cyg	V459 Cas	V624 Her	V785 Cep
V885 Cyg	VV Crv	VV Mon	VZ Cep	WX Cep	WZ Oph
Z Her	ZZ Boo	β Aur			

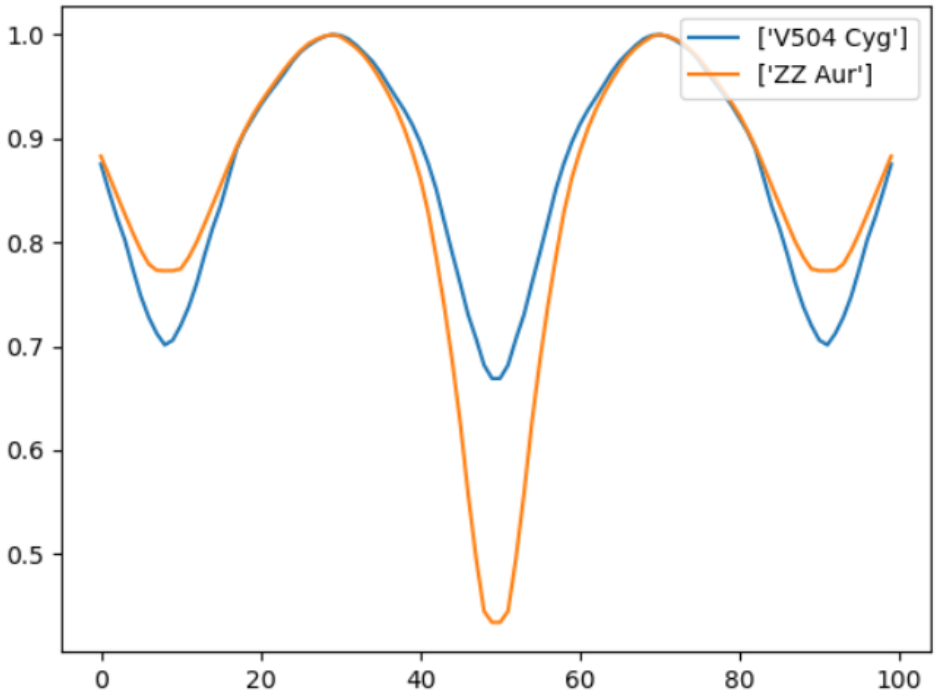
Semi-detached – tested as Detached					
AS Eri	AT Peg	AX Dra	DD Mon	DL Cyg	TX Cet
V Crt	V1241 Tau	V504 Cyg	XZ Cep	XZ Cmi	Z Vul
ZZ Aur	μ^1 Sco				

Over-contact – tested as Over-contact					
AA UMa	AB And	AD Phe	AH Aur	AO Cam	AO Cas
AP Aur	AQ Tuc	AU Ser	AW UMa	BH Cas	BI CVn
BL And	BO CVn	BV Eri	CC Com	CE Leo	CN And
CT Tau	DK Cyg	EK Com	EQ Tau	FT Lup	QX And
RS Col	RT LMi	RW Com	RZ Com	SS Ari	SW Lac
SY Hor	TU Boo	TW Cet	TY Boo	UZ Leo	V1073 Cyg
V535 Ara	V676 Cen	V677 Cen	V752 Cen	V728 Her	V729 Cyg
V861 Her	V857 Her	WZ Cyg	XY Boo	YY CrB	

FIRST EXPERIMENT – semi-detached are detached

Type	Precision	Recall	F1 score	Support
Over-contact	0.96	1.00	0.98	47
Detached	1.00	0.96	0.98	53

		Predicted	
		Over-contact	Detached
Actual	Over-contact	47	0
	Detached	2	51



SECOND EXPERIMENT – semi-detached removed

Type	Precision	Recall	F1 score	Support
Over-contact	1.00	1.00	1.00	47
Detached	1.00	1.00	1.00	39

		Predicted	
		Over-contact	Detached
Actual	Over-contact	47	0
	Detached	0	39

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