Supplementary material of “EEGSym: Overcoming Inter-subject Variability in Motor Imagery Based BCIs with Deep Learning”

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S.I. EEGSym 8-electrode architecture details

EEGSym stage	Block	Name	Type	Filters	Groups	Kernel	Padding	Output shape	Connected to
Symmetric division (SD)	-	SD Input	Input	-	-	-	-	384x8x1	-
	-	SD Expand_dims	Expand_dims	-	-	-	-	1x384x8x1	SD Input
	-	SD gather_left	Gather	-	-	-	-	1x384x3x1	SD Expand_dims
	-	SD gather_central	Gather	-	-	-	-	1x384x2x1	SD Expand_dims
	-	SD gather_right	Gather	-	-	-	-	1x384x3x1	SD Expand_dims
	-	SD concatenate_left	Concatenate	-	-	-	-	1x384x5x1	SD gather_left SD gather_central
	-	SD concatenate_right	Concatenate	-	-	-	-	1x384x5x1	SD gather_right SD gather_central
	-	SD concatenate_sym	Concatenate	-	-	-	-	2x384x5x1	SD concatenate_left SD concatenate_right
Tempospatial analysis (TA)	Inception block 1 (IB1)	IB1 conv_temporal1	Conv3D	24		1x16x1	same	2x384x5x24	SD concatenate_sym
		IB1 conv_temporal2	Conv3D	24		1x32x1	same	2x384x5x24	SD concatenate_sym
		IB1 conv_temporal3	Conv3D	24		1x64x1	same	2x384x5x24	SD concatenate_sym
		IB1 concatenate	Concatenate	-	-	-	-	2x384x5x72	IB1 conv_temporal1 IB1 conv_temporal2 IB1 conv_temporal3
		IB1 Add1	Add	-	-	-	-	2x384x5x72	SD concatenate_sym IB1 concatenate
		IB1 AvPool	AveragePooling3D	-	-	1x2x1	-	2x192x5x72	IB1 Add
		IB1 gconv_spatial	Conv3D	72	72	1x1x5	valid	2x192x1x72	IB1 AvPool
		IB1 Add2	Add	-	-	-	-	2x192x5x72	IB1 AvPool IB1 gconv_spatial
	Inception block 2 (IB2)	IB2 conv_temporal1	Conv3D	24		1x4x1	same	2x192x5x24	IB1 Add2
		IB2 conv_temporal2	Conv3D	24		1x8x1	same	2x192x5x24	IB1 Add2
		IB2 conv_temporal3	Conv3D	24		1x16x1	same	2x192x5x24	IB1 Add2
		IB2 concatenate	Concatenate	-	-	-	-	2x192x5x24	IB2 conv_temporal1 IB2 conv_temporal2 IB2 conv_temporal3
		IB2 Add1	Add	-	-	-	-	2x192x5x24	IB1 Add2 IB2 concatenate
		IB2 AvPool	AveragePooling3D	-	-	1x2x1	-	2x96x5x72	IB2 Add
		IB2 gconv_spatial	Conv3D	72	72	1x1x5	valid	2x96x1x72	IB2 AvPool
		IB2 Add2	Add	-	-	-	-	2x96x5x72	IB2 AvPool IB2 gconv_spatial

EEGSym stage	Block	Name	Type	Filters	Groups	Kernel	Padding	Output shape	Connected to
Tempospatial analysis (TA)	Residual block 1 (RB1)	RB1 conv_shortcut	Conv3D	36	-	1x1x1	same	2x96x5x36	IB2 Add2
		RB1 conv_temporal	Conv3D	36	-	1x16x1	same	2x96x5x36	IB2 Add2
		RB1 Add1	Add	-	-	-	-	2x96x5x36	RB1 conv_shortcut RB1 conv_temporal
		RB1 AvPool	AveragePooling3D	-	-	1x2x1	-	2x48x5x36	RB1 Add
		RB1 conv_spatial	Conv3D	36	-	1x1x5	valid	2x48x1x36	RB1 AvPool
		RB1 Add2	Add	-	-	-	-	2x48x5x36	RB1 AvPool RB1 conv_spatial
	Residual block 2 (RB2)	RB2 conv_shortcut	Conv3D	36	-	1x1x1	same	2x48x5x36	RB1 Add2
		RB2 conv_temporal	Conv3D	36	-	1x8x1	same	2x48x5x36	RB1 Add2
		RB2 Add1	Add	-	-	-	-	2x48x5x36	RB2 conv_shortcut RB2 conv_temporal
		RB2 AvPool	AveragePooling3D	-	-	1x2x1	-	2x24x5x36	RB2 Add
		RB2 conv_spatial	Conv3D	36	-	1x1x5	valid	2x24x1x36	RB2 AvPool
		RB2 Add2	Add	-	-	-	-	2x24x5x36	RB2 AvPool RB2 conv_spatial
	Residual block 3 (RB3)	RB3 conv_shortcut	Conv3D	18	-	1x1x1	same	2x24x5x18	RB2 Add2
		RB3 conv_temporal	Conv3D	18	-	1x4x1	same	2x24x5x18	RB2 Add2
		RB3 Add1	Add	-	-	-	-	2x24x5x18	RB3 conv_shortcut RB3 conv_temporal
		RB3 AvPool	AveragePooling3D	-	-	1x2x1	-	2x12x5x18	RB3 Add
		RB3 conv_spatial	Conv3D	18	-	1x1x5	valid	2x12x1x18	RB3 AvPool
		RB3 Add2	Add	-	-	-	-	2x12x5x18	RB3 AvPool RB3 conv_spatial
	-	TA conv_temporal	Conv3D	18	-	1x4x1	same	2x12x5x18	RB3 Add2
	-	TA Add	Add	-	-	-	-	2x12x5x18	RB3 Add2 TA conv_temporal
	-	TA AvPool	AveragePooling3D	-	-	1x2x1	-	2x6x5x18	TA Add
Channel merging (CM)	-	CM conv_temporal1	Conv3D	18	-	1x4x1	same	2x6x5x18	TA AvPool
	-	CM Add1	Add	-	-	-	-	2x6x5x18	RB3 Add2 CM conv_temporal1
		CM conv_temporal2	Conv3D	18	-	1x4x1	same	2x6x5x18	CM Add1
	-	RB3 Add1	Add	-	-	-	-	2x6x5x18	CM Add1 CM conv_temporal2
	-	CM gconv_spatial	Conv3D	18	9	2x1x5	valid	1x6x1x18	CM Add1
Temporal merging (TM)	-	TM conv_temporal	Conv3D	18	-	1x4x1	same	1x6x1x18	CM gconv_spatial
	-	TM Add	Add	-	-	-	-	1x6x1x18	TM conv_temporal CM gconv_spatial
		TM gconv_temporal	Conv3D	36	18	1x6x1	valid	1x1x1x36	TM Add

EEGSym stage	Block	Name	Type	Filters	Groups	Kernel	Padding	Output shape	Connected to
Output module (OM)	-	OM conv1	Conv3D	36	-	1x1x1	same	1x1x1x36	TM gconv_temporal
	-	OM Add1	Add	-	-	-	-	1x1x1x36	TM gconv_temporal OM conv1
	-	OM conv2	Conv3D	36	-	1x1x1	same	1x1x1x36	OM Add1
	-	OM Add2	Add	-	-	-	-	1x1x1x36	OM Add1 OM conv2
	-	OM conv3	Conv3D	36	-	1x1x1	same	1x1x1x36	OM Add2
	-	OM Add3	Add	-	-	-	-	1x1x1x36	OM Add2 OM conv3
	-	OM conv4	Conv3D	36	-	1x1x1	same	1x1x1x36	OM Add3
	-	OM Add4	Add	-	-	-	-	1x1x1x36	OM Add3 OM conv4
		OM Flatten	Flatten	-	-	-	-	36	OM Add4
		OM Softmax	Dense	-	-	-	-	2	OM Flatten

Column "Type" describes the class used to implement each operation in Tensorflow. All convolutional operations are followed by batch normalization, 'elu' activation and dropout regularization. The model has 142784 trainable parameters.

S.II. EEGSym 16-electrode architecture details

EEGSym stage	Block	Name	Type	Filters	Groups	Kernel	Padding	Output shape	Connected to
Symmetric division (SD)	-	SD Input	Input	-	-	-	-	384x16x1	-
	-	SD Expand_dims	Expand_dims	-	-	-	-	1x384x16x1	SD Input
	-	SD gather_left	Gather	-	-	-	-	1x384x7x1	SD Expand_dims
	-	SD gather_central	Gather	-	-	-	-	1x384x2x1	SD Expand_dims
	-	SD gather_right	Gather	-	-	-	-	1x384x7x1	SD Expand_dims
	-	SD concatenate_left	Concatenate	-	-	-	-	1x384x9x1	SD gather_left SD gather_central
	-	SD concatenate_right	Concatenate	-	-	-	-	1x384x9x1	SD gather_right SD gather_central
	-	SD concatenate_sym	Concatenate	-	-	-	-	2x384x9x1	SD concatenate_left SD concatenate_right
Tempospatial analysis (TA)	Inception block 1 (IB1)	IB1 conv_temporal1	Conv3D	24		1x16x1	same	2x384x9x24	SD concatenate_sym
		IB1 conv_temporal2	Conv3D	24		1x32x1	same	2x384x9x24	SD concatenate_sym
		IB1 conv_temporal3	Conv3D	24		1x64x1	same	2x384x9x24	SD concatenate_sym
		IB1 concatenate	Concatenate	-	-	-	-	2x384x9x72	IB1 conv_temporal1 IB1 conv_temporal2 IB1 conv_temporal3
		IB1 Add1	Add	-	-	-	-	2x384x9x72	SD concatenate_sym IB1 concatenate
		IB1 AvPool	AveragePooling3D	-	-	1x2x1	-	2x192x9x72	IB1 Add
		IB1 gconv_spatial	Conv3D	72	72	1x1x9	valid	2x192x1x72	IB1 AvPool
		IB1 Add2	Add	-	-	-	-	2x192x9x72	IB1 AvPool IB1 gconv_spatial
	Inception block 2 (IB2)	IB2 conv_temporal1	Conv3D	24		1x4x1	same	2x192x9x24	IB1 Add2
		IB2 conv_temporal2	Conv3D	24		1x8x1	same	2x192x9x24	IB1 Add2
		IB2 conv_temporal3	Conv3D	24		1x16x1	same	2x192x9x24	IB1 Add2
		IB2 concatenate	Concatenate	-	-	-	-	2x192x9x24	IB2 conv_temporal1 IB2 conv_temporal2 IB2 conv_temporal3
		IB2 Add1	Add	-	-	-	-	2x192x9x24	IB1 Add2 IB2 concatenate
		IB2 AvPool	AveragePooling3D	-	-	1x2x1	-	2x96x9x72	IB2 Add
		IB2 gconv_spatial	Conv3D	72	72	1x1x9	valid	2x96x1x72	IB2 AvPool
		IB2 Add2	Add	-	-	-	-	2x96x9x72	IB2 AvPool IB2 gconv_spatial

EEGSym stage	Block	Name	Type	Filters	Groups	Kernel	Padding	Output shape	Connected to
Tempospatial analysis (TA)	Residual block 1 (RB1)	RB1 conv_shortcut	Conv3D	36	-	1x1x1	same	2x96x9x36	IB2 Add2
		RB1 conv_temporal	Conv3D	36	-	1x16x1	same	2x96x9x36	IB2 Add2
		RB1 Add1	Add	-	-	-	-	2x96x9x36	RB1 conv_shortcut RB1 conv_temporal
		RB1 AvPool	AveragePooling3D	-	-	1x2x1	-	2x48x9x36	RB1 Add
		RB1 conv_spatial	Conv3D	36	-	1x1x9	valid	2x48x1x36	RB1 AvPool
		RB1 Add2	Add	-	-	-	-	2x48x9x36	RB1 AvPool RB1 conv_spatial
	Residual block 2 (RB2)	RB2 conv_shortcut	Conv3D	36	-	1x1x1	same	2x48x9x36	RB1 Add2
		RB2 conv_temporal	Conv3D	36	-	1x8x1	same	2x48x9x36	RB1 Add2
		RB2 Add1	Add	-	-	-	-	2x48x9x36	RB2 conv_shortcut RB2 conv_temporal
		RB2 AvPool	AveragePooling3D	-	-	1x2x1	-	2x24x9x36	RB2 Add
		RB2 conv_spatial	Conv3D	36	-	1x1x9	valid	2x24x1x36	RB2 AvPool
		RB2 Add2	Add	-	-	-	-	2x24x9x36	RB2 AvPool RB2 conv_spatial
	Residual block 3 (RB3)	RB3 conv_shortcut	Conv3D	18	-	1x1x1	same	2x24x9x18	RB2 Add2
		RB3 conv_temporal	Conv3D	18	-	1x4x1	same	2x24x9x18	RB2 Add2
		RB3 Add1	Add	-	-	-	-	2x24x9x18	RB3 conv_shortcut RB3 conv_temporal
		RB3 AvPool	AveragePooling3D	-	-	1x2x1	-	2x12x9x18	RB3 Add
		RB3 conv_spatial	Conv3D	18	-	1x1x9	valid	2x12x1x18	RB3 AvPool
		RB3 Add2	Add	-	-	-	-	2x12x9x18	RB3 AvPool RB3 conv_spatial
	-	TA conv_temporal	Conv3D	18	-	1x4x1	same	2x12x9x18	RB3 Add2
	-	TA Add	Add	-	-	-	-	2x12x9x18	RB3 Add2 TA conv_temporal
	-	TA AvPool	AveragePooling3D	-	-	1x2x1	-	2x6x9x18	TA Add
Channel merging (CM)	-	CM conv_temporal1	Conv3D	18	-	1x4x1	same	2x6x9x18	TA AvPool
	-	CM Add1	Add	-	-	-	-	2x6x9x18	RB3 Add2 CM conv_temporal1
		CM conv_temporal2	Conv3D	18	-	1x4x1	same	2x6x9x18	CM Add1
	-	RB3 Add1	Add	-	-	-	-	2x6x9x18	CM Add1 CM conv_temporal2
	-	CM gconv_spatial	Conv3D	18	9	2x1x9	valid	1x6x1x18	CM Add1
Temporal merging (TM)	-	TM conv_temporal	Conv3D	18	-	1x4x1	same	1x6x1x18	CM gconv_spatial
	-	TM Add	Add	-	-	-	-	1x6x1x18	TM conv_temporal CM gconv_spatial
		TM gconv_temporal	Conv3D	36	18	1x6x1	valid	1x1x1x36	TM Add

EEGSym stage	Block	Name	Type	Filters	Groups	Kernel	Padding	Output shape	Connected to
Output module (OM)	-	OM conv1	Conv3D	36	-	1x1x1	same	1x1x1x36	TM gconv_temporal
	-	OM Add1	Add	-	-	-	-	1x1x1x36	TM gconv_temporal OM conv1
	-	OM conv2	Conv3D	36	-	1x1x1	same	1x1x1x36	OM Add1
	-	OM Add2	Add	-	-	-	-	1x1x1x36	OM Add1 OM conv2
	-	OM conv3	Conv3D	36	-	1x1x1	same	1x1x1x36	OM Add2
	-	OM Add3	Add	-	-	-	-	1x1x1x36	OM Add2 OM conv3
	-	OM conv4	Conv3D	36	-	1x1x1	same	1x1x1x36	OM Add3
	-	OM Add4	Add	-	-	-	-	1x1x1x36	OM Add3 OM conv4
		OM Flatten	Flatten	-	-	-	-	36	OM Add4
		OM Softmax	Dense	-	-	-	-	2	OM Flatten

Column "Type" describes the class used to implement each operation in Tensorflow. All convolutional operations are followed by batch normalization, 'elu' activation and dropout regularization. The model has 160496 trainable parameters.