PMOD Artificial Intelligence Framework (PAI)

USER MANUAL Version 4.2

PMOD is a software FOR RESEARCH USE ONLY (RUO) and must not be used for diagnosis or treatment of patients.



(C) 1996-2020, Printed on June 7, 2021

1. Int	roduction	3
1.1	PAI Purpose	
1.2	PAI Overview	
1.3	Example included in Distribution	5
2. Ins	tallation of PAI Infrastructure	7
2.1	Windows	7
2.1.1	Python and TensorFlow Installation	7
2.1.2	R Installation	
2.1.	2.1 Default R Configuration	
2.1.		
2.1.3	Selection of Python installation	17
2.2	MacOS	18
2.2.1	Python and TensorFlow Installation	
2.2.2	R Installation	19
2.2.		
2.2.		
2.2.3	Selection of Python installation	
2.3	Linux Platforms	30
2.3.1	R Installation	
2.3.2	Python and TensorFlow Installation	
3. Pre	paration of Training Data and Neural Network	34
3.1	Data Preparation	
3.2	Control Mechanism	
3.3	Learning Sets	
4. Tra	ining of Neural Network	44
	-	
4.1	Exporting an R workspace	
5. Use	e of Trained Neural Network for Prediction	53
6. Cas	e Study - Rat Brain Dopaminergic PET Model	57
6.1	Sample Preparation	57
6.2	Training and Validation	
7. PN	OD Copyright Notice	63
Index		64
much		54

1 Introduction

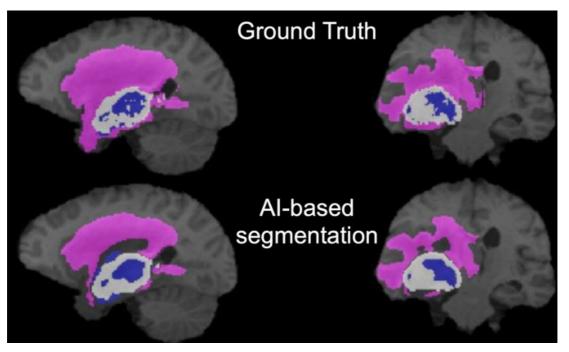
Computer algorithms based on Artificial Intelligence (AI) have become a success story and are now part of daily life. Machine Learning (ML) is a subset of AI in which humans provide the input data and expected results, and the computer determines "rules" with which it can process the data to approach the expected results. These "rules" may be considered as representations of the data. Deep Learning (DL) is considered a further subset of ML, in which there are successive layers of representations. ML methods have resulted in solutions ranging from facial recognition to web-based language translation. They have also been applied in many domains of biomedical research. However, the setup and use of ML toolkits is a task requiring a lot of methodological insight as well as specialized IT expertise.

The aim of PAI is to drastically lower the entry barrier to the ML methodology for researchers analyzing biomedical images. PAI is designed as a framework, allowing users to develop their own tailored ML-based image segmentation solution while working entirely within the familiar PMOD environment.

1.1 PAI Purpose

Segmentation of pathology or of organs/regions that do not conform to common templates can be a tedious, time-consuming and subjective procedure. The use of machine learning to automatically perform such a segmentation has the potential to save large amounts of time and improve reproducibility.

In the example shown below, regions of necrotic, gadolinium-enhancing and penumbra of a brain tumor are shown in color on a gray-scale anatomical T1-weighted MR image. Contrast from four MR series (T1-weighted, T2-weighted, T2-FLAIR, gadolinium-enhanced T1-weighted) were used to define these regions. For the top row, created by an expert reviewer using manual segmentation, this process takes many minutes or even hours. In the bottom row, the broadly similar segmentation result was generated by a trained convolutional neural network and took seconds.



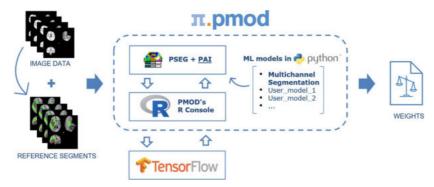
However, training a convolutional neural network to perform such a segmentation task requires a substantial amount of data, time and effort.

PMOD's PAI framework aims to make training and deploying ML-based segmentation more accessible to non-expert users. PMOD's well-tested tools for image processing and traditional

segmentation provide an excellent base to prepare the training data needed for supervised machine learning.

1.2 PAI Overview

The structure of the PAI framework is illustrated below.



The actual ML platform used by PAI is the well-known <u>TensorFlow</u> solution. The neural network structure and the training method are correspondingly developed as Python scripts suitable for TensorFlow and constitute the ML model. The data for supervised learning are prepared in PAI, communication with TensorFlow is implemented via the R console in PMOD.

Learning Set

The **Learning Set** in PAI consists of references to the training data (i.e. Links to the input series in a PMOD database) and a specification of the preprocessing steps required to bring the data into a format suitable for machine learning. The training data itself consists of data samples. Each data sample consists of an input (one or several images) and its expected segmentation result (one or several segments, in the format of label maps that can be associated with the input images).

Training

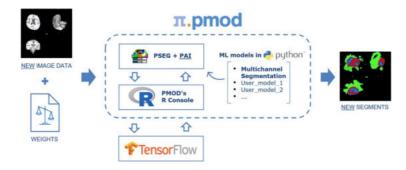
Training is performed in TensorFlow using a Learning Set and an ML model. There are different mechanisms available, which will be explained below. Basically, training can be performed locally in PSEG, or delegated to a more powerful infrastructure such as Cloud-Computing.

Training Result

The result of training is a "trained model" - a set of **Weights** for the layers in neural network, and a **Manifest** file containing information about the training process. These results are added to the **Learning Set**, making it ready for use in **Prediction** (i.e. automated segmentation). As new training data become available, it can be added to the Learning Set and incremental training performed to improve prediction. An export functionality allows transfer of the result to other PMOD installations for prediction (sometimes known as Deployment).

Prediction

Prediction applies the trained model, in PSEG, to a new set of input image data, resulting in a segmentation result. The segments may then be converted to VOIs and used for quantification.



Implementation in PSEG

All PAI functionality is integrated in PSEG. If PAI has been licensed, a **+ AI** indication appears next to **PSEG** in the main PMOD ToolBox:

		Pmod			
4	36	PMOD V	ersio	on 4.2	201
P ċ _A	aPa	•	•	2	R
	<u>K</u> inetic				
	P <u>X</u> Mod				
1	View				
3	Fusjon				
4	<u>S</u> egmer	nt + Al			
R					

Similarly, in PSEG the Segment tab becomes Segment + AI

and the menu button as well:

🔺 Segment + Al »

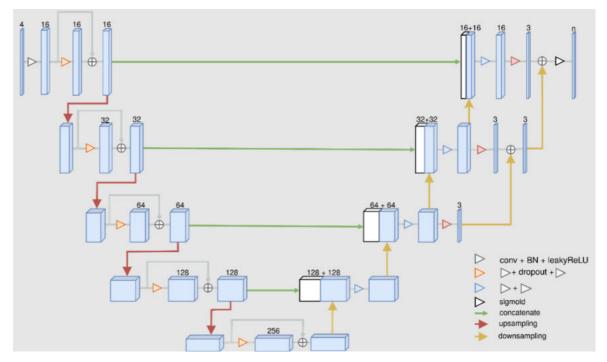
1.3 Example included in Distribution

PAI is provided with a demonstration neural network architecture designed for multichannel segmentation. This architecture expects one or more 3D input series and generates segmentation results with one or more segments/VOIs.

The initial application of this architecture was for a case called **Tumor Detection**. A trained model **Tumor Detection** is available in the **Segmentation** tool when PAI is licensed, using the **Multichannel Segmentation** architecture. It is based on the MICCAI Brain Tumor Segmentation (BraTS) Challenge: <u>http://braintumorsegmentation.org</u>. BraTS utilizes multi-institutional pre-operative MRI scans and focuses on the segmentation of intrinsically heterogeneous (in appearance, shape, and histology) brain glioma tumors.

Training and testing of the **Tumor Detection** model in PAI was performed using the data from the <u>2020 BraTS Challenge</u> containing 369 samples. Each sample consists of four MR images (native T1, post-Gd-contrast T1-weighted, T2 FLAIR, T2-weighted) and one image containing three reference segments as label numbers.

The **Multichannel Segmentation** architecture is a modified version of the convolutional neural network U-Net:



The output of the **Tumor Detection** model is a label image with three segments (label 1: nonenhancing tumor; label 2: peritumoral edema; label 4: Gd-enhancing tumor).

A second experimental model based on the **Multichannel Segmentation** architecture is included with PMOD 4.203. This model is called **Rat Brain Dopaminergic PET**. It requires early and late average images derived from PET with tracers such as [¹¹C]-raclopride and [¹¹C]-methylphenidate, and the output is a label image with three segments (label 1: cerebellum; label 2: left striatum; label 3: right striatum). The model was trained using 382 rat brain dopaminergic system dynamic PET datasets. A description of the preparation of the data and process to train and evaluate the model is included later in this documentation as a case study.

BraTS Reference:

Bakas, Spyridon & Reyes Jan. (2019). Identifying the Best Machine Learning Algorithms for Brain Tumor Segmentation, Progression Assessment, and Overall Survival Prediction in the BRATS Challenge. <u>https://arxiv.org/pdf/1811.02629.pdf</u>

2 Installation of PAI Infrastructure

PAI requires the following elements:

- PMOD version 4.2 with PSEG and PAI licensed (please use the latest build available in our download area)
- Local installation of R with the required packages. PMOD uses the <u>R</u> functionality via the <u>Rserve</u> library. Please refer to the *PMOD Base Functionality User Guide* for details about the integration of R with PMOD.
- Configuration of the PMOD R Console to use a local R installation
- Local installation of Python (version 3.8 is required)
- Installation of TensorFlow (version 2.3 or newer) via Python

Please follow the installation instructions applicable for your operating system.

2.1 Windows

Windows 10 or Windows Server 2019 are required as the operating system.

2.1.1 Python and TensorFlow Installation

The additional packages required for PAI on Windows should be installed from their respective websites.

Please follow these steps:

- Install Microsoft Visual Studio 2015, 2017, 2019 Runtime (i.e VC_redist.x86.exe). https://support.microsoft.com/en-us/help/2977003/the-latest-supported-visual-c-downloads
- Check whether you have a compatible GPU. TensorFlow only supports NVIDIA GPUs in combination with NVIDIA's CUDA Toolkit. Tables of compatible GPUs are available on <u>https://developer.nvidia.com/cuda-gpus</u>
- 3. If your GPU is compatible, install NVIDIA drivers, Toolkit and models for TensorFlow 2.4:
 - a. Drivers 11.0: https://www.nvidia.com/download/index.aspx?lang=en-us
 - b. CUDA Toolkit 11.0: https://developer.nvidia.com/cuda-toolkit-archive
 - c. cuDNN 8.0.4 for CUDA 11.0: https://developer.nvidia.com/rdp/cudnn-download
- 4. Install Python 3.8 64-bit (select "Add Python to PATH", enable pip option and long paths). https://www.python.org/downloads/windows/
- 5. Upgrade pip by entering in a command terminal: python -m pip install --upgrade pip
- 6. Install TensorFlow by entering in a command terminal: python -m pip install --upgrade tensorflow
- 7. Check that tensorflow appears in the list of installed packages: python -m pip list
- 8. Test TensorFlow by entering in a command terminal: python -c "import tensorflow as tf;print(\"Num GPUs Available: \", len(tf.config.experimental.list_physical_devices('GPU')))" This test returns the number of compatible GPUs available for PAI. Zero is an acceptable result if you do not have a CUDA-compatible NVIDIA GPU.

Note: GPU support for Windows (point 3. above) was tested for TensorFlow 2.4.

2.1.2 R Installation

Please download and install the most recent R version for Windows from <u>https://cran.r-project.org/</u> (note that our testing to date has used version 4.0.3).

There is no need to manually install additional R packages. PMOD will automatically download and install the necessary packages when the PMOD R Console is started for the first time. If no R functionality besides PAI is used in a particular PMOD installation, the installation can be restricted to a minimal package set as described in <u>Minimal R Configuration</u>^D¹¹ below.

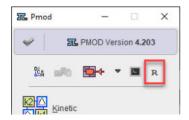
2.1.2.1 Default R Configuration

Following R installation, start PMOD and open the **Configuration** facility from the main ToolBox.

MOD Configuration and User Settings		
🔉 USERS 🛛 🧏 DICOM 🖌 🛃 DATA	BASE @ FTP Nodes On Start	
User1 • • • T Editusername	★ Add new user ▼ × Remove user are saved when switching the user.	
SETTINGS PXMOD Models PKIN Models		
REPORT DATABASES FTP Nodes	APPEARANCE STATISTICS PRESETS	
Hottest Pixels Analysis Number of pixels Peak VOI volume SUV Scan Date / Time)
	Save Patient Info in VOIs (required by DB restoring from file system)	
R Statistics Console	? Port 5999 × Clear packages	
	[>] • Start local R	1
	C/Program Files/R/R-4.0.3/bin/x64/R.exe	
	(Type "R" if R_HOME\bin\x64\ is added to the PATH system variable.) Required packages from repository on start Install to Pmod folder	
	Comprehensive R Archive Network (CRAN) location: Europe	1
	(Sta) O Server	
Address	Image: Serve pmod com Set Local Host Image: Serve pmod com	
Login	(Empty = automatic login	1)
Password	(Empty = automatic login))
Python		
	provide a second s	
▶ 0 🕅 ?	<u>Ok</u> <u>C</u> ancel	

On the **STATISTICS** tab select **Start local R** to ensure local execution and verify that the path to the local R installation is correct. Select **Install to Pmod folder** to avoid permission problems when installing the R packages.

Restart PMOD and wait for the R icon on the main ToolBox to become active.



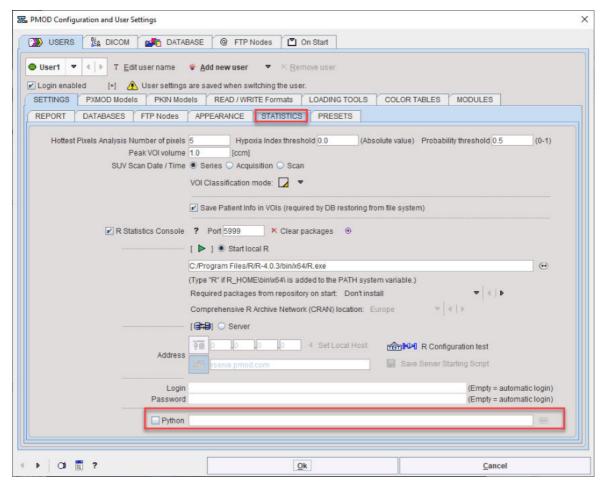
Then click on the **R** icon to open the **PMOD Console**. The required packages are downloaded and installed, followed by an execution test and printing of the R version information:



The settings button indicated above opens the dialog window below.

🖪 R console settings		;
Additional packages > (To load on start)	tseries	
	ार्तका Package manager	R diagnostics
Path to Python:	C:/Users/Intel/AppData/Local/Programs/Python/P Layout:	Python38/python.exe
Tools location	ТОР	·▼ ()
Task tabs location	LEFT	
Initial Workspace Data	Workspace:	< > @
	Save workspace on exit to the selected R Data	
Initial script		
	Use initial script after each workspace is load Editing: Parentheses autocomplete Text output	ied
Font	Fixed	▼ 4 1
Max columns in table Max lines in printout		
	<u>O</u> k	Cancel

Please verify that the **Path to Python** corresponds to your local installation of Python 3.8. If it does not, the Path to Python can be configured in the **Configuration** facility from the main ToolBox:



Next open the Package Manager. All packages should have status OK.

Package doBy psych e1071	CRAN CRAN	OK OK	4.6.9	CRAN version 4.6.9
psych				
		OK	2.1.3	2.1.3
	CRAN	OK	1.7.6	1.7-6
UsingR	CRAN	OK	2.0.6	2.0-6
lawstat	CRAN	OK	3.4	3.4
tseries	CRAN	OK	0.10.48	0.10-48
np	CRAN	OK	0.60.10	0.60-10
openair	CRAN	OK	2.8.3	2.8-3
foreign	CRAN	OK	0.8.80	0.8-81
Hmisc	CRAN	OK	4.5.0	4.5-0
car	CRAN	OK	3.0.10	3.0-10
phia	CRAN	OK	0.2.1	0.2-1
compare	CRAN	OK	0.2.6	0.2-6
reshape	CRAN	OK	0.8.8	0.8.8
sfsmisc	CRAN	OK	1.1.9	1.1-10
Cairo	CRAN	OK	1.5.12.2	1.5-12.2
pROC	CRAN	OK	1.17.0.1	1.17.0.1
survival	CRAN	OK	3.2.7	3.2-10
glmnet	CRAN	OK	4.1.1	4.1-1
stringr	CRAN	OK	1.4.0	1.4.0
mcr	CRAN	OK	1.2.1	1.2.1
session	CRAN	OK	1.0.3	1.0.3
reticulate	CRAN	OK	1.18	1.18
keras	CRAN	OK	2.3.0.0	2.4.0
jsonlite	CRAN	OK	1.7.2	1.7.2
lubridate	CRAN	OK	1.7.10	1.7.10
sfsmisc	CRAN	OK	1.1.9	1.1-10
memuse	CRAN	OK	4.1.0	4.1-0
pm.base	Local	OK	4.201.1	-
pm.ai	Local	OK	4.203.1	-

Note: If package installation fails, please check your firewall settings or contact your IT service.

2.1.2.2 Minimal R Configuration

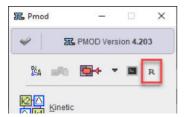
For instances of PMOD that will only be used for PAI it is possible to install a reduced set of R packages. To achieve this, perform the following configuration and installation procedure.

Following R installation, start PMOD and open the **Configuration** facility from the main ToolBox.

USERS BA DICOM	TABASE @ FTP Nodes On Start
ser1 💌 4 🕨 T Edituser name	* Add new user ▼ × <u>R</u> emove user
ogin enabled 🛛 [+] 🛕 User settin	gs are saved when switching the user.
TTINGS PXMOD Models PKIN M	odels READ / WRITE Formats LOADING TOOLS COLOR TABLES MODULES
PORT DATABASES FTP Nodes	APPEARANCE STATISTICS PRESETS
Hottest Pixels Analysis Number of pixe Peak VOI volun SUV Scan Date / Tin	
	 Save Patient Info in VOIs (required by DB restoring from file system)
R Statistics Conso	le ? Port 5999 × Clear packages 🐵
	[🕨] 🖲 Start local R
	C./Program Files/R/R-4.0.3/bin/x64/R.exe
	(Type "R" if R_HOME\bin\x64\ is added to the PATH system variable.) Required packages from repository on start Install to Pmod folder 🗸 4
	Comprehensive R Archive Network (CRAN) location: Europe 🗢 4 🕨
	- (878) O Server
Addres	Image: Serve pmod.com Image: Serve pmod.com Image: Serve pmod.com
Log	(Empty = automatic login)
Passwo	(Empty = automatic login)
Pytho	m 💮

On the **STATISTICS** tab select **Start local R** to ensure local execution and verify that the path to the local R installation is correct. Select **Install to Pmod folder** to install the base required packages on PMOD restart.

Restart PMOD and wait for the R icon on the main ToolBox to become active.



Return to the **Configuration** facility from the main ToolBox and change the R package installation selection to Don't install:

USERS 👫 DICOM 🛃 DATAE	BASE @ FTP Nodes D On Start
	★ Add new user ▼ × Remove user are saved when switching the user. lets ↑ READ / WRITE Formats ↑ LOADING TOOLS ↑ COLOR TABLES ↑ MODULES
EPORT DATABASES FTP Nodes	APPEARANCE STATISTICS PRESETS
Hottest Pixels Analysis Number of pixels Peak VOI volume SUV Scan Date / Time	
R Statistics Console	
	[] Start local R
	C/Program Files/R/R-4.0.3/bin/x64/R.exe
	(Type "R" if R_HOME\bin\s64 is added to the PATH system variable.) Required packages from repository on start: Don't install
	Comprehensive R Archive Network (CRAN) location: Europe
Address	Image: Server Image: Server pmod.com
Login	(Empty = automatic login)
Password	(Empty = automatic login)
Python	

Restart PMOD and wait for the R icon on the main ToolBox to become active.



Then click on the **R** icon to open the **PMOD Console**. The internal packages **pm.base** and **pm.ai** were installed automatically whereas the remaining packages are skipped and **not loaded** messages listed:

MR	Relaxometry 🔻 ? General ANOVA 💌 ? × 🔲		
×	Output 🔒	×	
	Connecting to the server localhost Connected. Loading default settings Loaded. Package doBy not loaded. Package oby not loaded. Package 1071 not loaded. Package lawstat not loaded. Package openair not loaded. Package openair not loaded. Package openair not loaded. Package car not loaded. Package compare not loaded. Package compare not loaded. Package compare not loaded. Package sershape not loaded. Package openair not loaded. Package compare not loaded. Package car not loaded. Package sershape not loaded. Package sershop not loaded. Package sershop not loaded. Package sershop not loaded. Package sersing not loaded. Package steries not load		
1.51	reversion 4.0.5 (2020-10-10) Duniy Wunnes Freak out Windows	-	

The **Settings** button indicated above opens the dialog window below.

R cons	ole settings					
	ional packages > o load on start)	tseries				
		ार्केन Package manager	र्ततेन 🍽 R diagnostics			
	Path to Python:	C/Users/intel/AppData/Local/Programs/Python/Pytho Layout	n38/python.exe			
	Tools location	TOP		-	4	
Т	ask tabs location	LEFT			4	-
		Workspace:				-
Initial	Workspace Data	Save workspace on exit to the selected R Data file		∢.]∶		
	Initial script			-	4	
		Use initial script after each workspace is loaded Editing: Parentheses autocomplete Text output				
	Font	Fixed		~	4	
	columns in table x lines in printout					
	Font columns in table	Fixed Report printout: 9	Cancel	•		•

Please verify the **Path to Python** and open the **Package Manager**. Most packages will have **Requires installation** in the **Status** column

Package	Туре	Status	Installed version	CRAN version
doBy	CRAN	Requires inst.		4.6.8
psych	CRAN	Requires inst.		2.0.12
e1071	CRAN	Requires inst.		17-4
UsingR	CRAN	Requires inst.		2.0-6
lawstat	CRAN	Requires inst.		3.4
tseries	CRAN	Requires inst.		0.10-48
np	CRAN	Requires inst.		0.60-10
openair	CRAN	Requires inst.		28-1
foreign	CRAN	OK	0.8.80	0.8-81
Hmisc	CRAN	Requires inst.		4.4-2
car	CRAN	Requires inst.		3.0-10
phia	CRAN	Requires inst.		0.2-1
compare	CRAN	Requires inst.		0.2-6
reshape	CRAN	Requires inst.	a	0.8.8
sfsmisc	CRAN	Requires inst.		1.1-7
Cairo	CRAN	Requires inst.		1.5-12.2
pROC	CRAN	Requires inst.		1.16.2
survival	CRAN	OK	327	3.2-7
almnet	CRAN	Requires inst.		4.0-2
stringr	CRAN	Requires inst.		1.4.0
mcr	CRAN	Requires inst.		121
session	CRAN	Requires inst.		1.0.3
reticulate	CRAN	Requires inst.		1.18
keras	CRAN	Requires inst.		2.3.0.0
isonlite	CRAN	Requires inst.		1.7.2
lubridate	CRAN	Requires inst.		1.7.9.2
sfsmisc	CRAN	Requires inst.		1.1-7
pm.base	Local	OK	4.201.1	-
pm.ai	Local	OK	4.201.2	-
pm.ai	Local		4.201.2	Al only

To install only the packages necessary for PAI, please select Install PAI only and then Yes

Package	Туре	Status	Installed version	CRAN version
doBy	CRAN	Requires inst.		4.6.8
psych	CRAN	Requires inst.		20.12
e1071	CRAN	Requires inst.		17-4
UsingR	CRAN	Requires inst.		2.0-6
lawstat	CRAN	Requires inst.		3.4
tseries	CRAN	Requires inst.		0.10-48
np	CRAN	Requires inst.		0.60-10
openair	CRAN	Requires inst.		2.8-1
foreign	CRAN	OK	0.8.80	0.8-81
Hmisc	CRAN	Requires inst.		4.4-2
car	q			
phia	C Confirm	nation		×
compare	d			
reshape	d			
sfsmisc	d	The follow	ng packages will be ins	stalled
Cairo	C			
pROC	c	10.000	tringr	
survival	d		ession	
P	d	• re	eticulate	
survival	000	e re e ko	eticulate eras	
survival gimnet	0000	e re e ko e js	eticulate eras conlite	
survival glmnet stringr	00000 ?	e re e ko e js e lu	eticulate eras conlite ibridate	
survival gimnet stringr mcr session reticulate	00000 ?	e re ka js e lu e si	eticulate eras conlite ibridate fsmisc	
survival glmnet stringr mcr session reticulate keras	0000 ?	e re ka js e lu e si	eticulate eras conlite ibridate	
survival glmnet stringr mcr session reticulate keras jsonlite		● re ● k ● js ● lu ● s' ● p	eticulate eras conlite ibridate fsmisc m.al	and can't be stopped
survival glmnet stringr mcr session reticulate keras jsonlite lubridate	°	● re ● ka ● js ● lu ● s ● p This opera	eticulate eras conlite ibridate fsmisc m.al tion is time consuming	and can't be stopped.
survival glmnet stringr mcr session reticulate keras jsonlite lubridate sfsmisc	00000	● re ● ka ● js ● lu ● s ● p This opera	eticulate eras conlite ibridate fsmisc m.al	and can't be stopped.
survival gimnet stringr mcr session reticulate keras jsonlite lubridate sfsmisc pm.base	L	● re ● ka ● js ● lu ● s ● p This opera	eticulate eras conlite ibridate fsmisc m.al tion is time consuming	and can't be stopped.
survival glimnet stringr mcr session reticulate keras jsonlite lubridate sfsmisc		e re k e js lu s p This opera Do you wa	eticulate eras conlite ibridate fsmisc m.al tion is time consuming	and can't be stopped.

Following installation the **Status** entries will be updated:

Package	Type	Status	Installed version	CRAN version
doBy	CRAN	Requires inst		4.6.8
psych	CRAN	Requires inst		2.0.12
e1071	CRAN	OK	1.7.4	1.7-4
UsingR	CRAN	Requires inst		2.0-6
lawstat	CRAN	Requires inst		3.4
tseries	CRAN	Requires inst		0.10-48
an	CRAN	Requires inst		0.60-10
openair	CRAN	Requires inst		2.8-1
foreign	CRAN	OK	0.8.80	0.8-81
Hmisc	CRAN	Requires inst		4.4-2
car	CRAN	Requires inst		3.0-10
phia	CRAN	Requires inst		0.2-1
compare	CRAN	Requires inst		0.2-6
reshape	CRAN	Requires inst		0.8.8
sfsmisc	CRAN	OK	1.1.7	1.1-7
Cairo	CRAN	Requires inst		1.5-12.2
pROC	CRAN	Requires inst		1.16.2
survival	CRAN	OK	3.2.7	3.2-7
glmnet	CRAN	Requires inst		4.0-2
stringr	CRAN	OK	1.4.0	1.4.0
mcr	CRAN	Requires inst		1.2.1
session	CRAN	OK	1.0.3	1.0.3
reticulate	CRAN	OK	1.18	1.18
keras	CRAN	OK	2.3.0.0	2.3.0.0
jsonlite	CRAN	OK	1.7.2	1.7.2
lubridate	CRAN	OK	1.7.9.2	1.7.9.2
sfsmisc	CRAN	OK	1.1.7	1.1-7
pm.base	Local	OK	4.201.1	-
pm.ai	Local	OK	4.201.2	
		Install a	ll packages Install P	Al only 達 Install / Upda

17

Closing the window with Ok completes the installation.

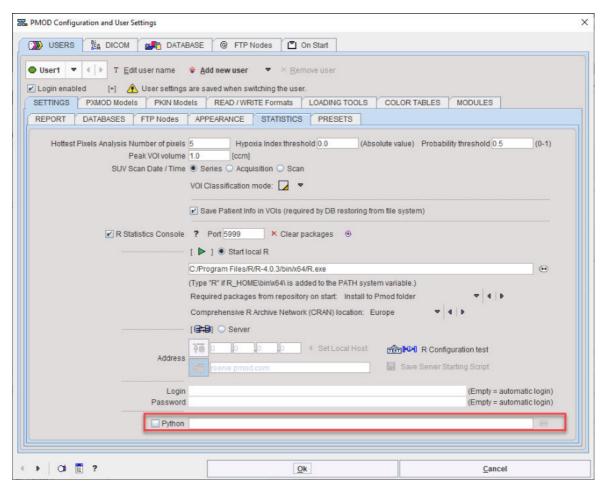
Note: When a prediction will be launched in PSEG at a later timepoint, the R Console will report the packages that were not installed, but the **Execution test** will still pass as illustrated below.

xometry 💌 ?	General	? Set ima ANOVA	ge to R -> Frar	me: 1, slice: 49 ()	38%)	₩ \$
	Output			ß	a ×	
Packa Packa	age doBy not li age psych not age UsingR not age lawstat no age lawstat no age not loar age openair no age drise not age car not loa age car not loa age car not loa age preshape n age Cairo not l age glmnet no age mor not lo age tseries no ution test Pa sion 4.0.3 (202 d PAI diagnosti ing image data	loaded. t loaded. t loaded. ded. t loaded. ded. ded. ded. ded. ded. oated. oatloaded. oaded. loaded. loaded. t loaded. t loaded. t loaded. t loaded.	1 Loaded.	buť Windows		

2.1.3 Selection of Python installation

Multiple installations and versions of Python may cause the PAI infrastructure test to fail.

In this situation you should define the path to Python 3.8 in the **Configuration** facility from the main ToolBox:



Restart PMOD after setting the path to Python 3.8.

2.2 MacOS

MacOS Catalina is recommended for best compatibility with Rserve.

Note: the XQuartz package is required for plotting in the R console (to support X11 libraries). The XQuartz project is officially supported by Apple: <u>https://www.xquartz.org/</u>

2.2.1 Python and TensorFlow Installation

Although MacOS provides Python libraries by default we recommend installing the newest available Python version 3.8 from the website <u>https://www.python.org/downloads/mac-osx/</u>

Install TensorFlow using the Terminal command:

python3 -m pip3 install --upgrade tensorflow

Check that tensorflow appears in the list of installed packages:

python3 -m pip list

Test TensorFlow using the command:

```
python3 -c "import tensorflow as tf;print(\"Num GPUs Available: \",
len(tf.config.experimental.list physical devices('GPU')))"
```

This test returns the number of compatible GPUs available for PAI (zero is an acceptable result if you do not have a compatible NVIDIA GPU).

2.2.2 R Installation

Please download and install the most recent R version for MacOS from <u>https://cran.r-project.org/</u> (note that our testing to date has used version 4.0.3).

There is no need to manually install additional R packages. PMOD will automatically download and install the necessary packages when the PMOD R Console is started for the first time. If no R functionality besides PAI is used in a particular PMOD installation, the installation can be restricted to a minimal package set as described in <u>Minimal R Configuration</u>^D¹¹ below.

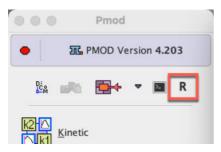
2.2.2.1 Default R Configuration

Following R installation, start PMOD and open the **Configuration** facility from the main ToolBox.

🔉 USERS 👫 DICOM 🛃 DATABA		figuration and User Se			
User1 🔻 🔄 🕨 T Edit user name	🛊 Add new user 🗢	\times <u>R</u> emove user			
	are saved when switchin	-		and Kananana I	
SETTINGS PXMOD Models PKIN Mode			S COLOR TA	ABLES MODULES	
REPORT DATABASES FTP Nodes	APPEARANCE STATI	STICS PRESETS			
Hottest Pixels Analysis Number of pixels Peak VOI volume SUV Scan Date / Time	1.0 [ccm] ● Series ○ Acquisition VOI Classification mode: ✔ Save Patient Info in VO ? Port 5999 2 [►] ● Start local R Required packages from		ing from file sys		5 (0-1)
	[🗐 🎝 🖸 🖸 Server				_
	麺 0 0 0	0 4 Set Local Ho	t 👘 🙌	R Configuration test	
Address	rserve.pmod.com		Save	Server Starting Script	
Login				(Empty =	automatic login)
Password				(Empty =	automatic login)
Python					0
▶ OI 🕅 ?		Qk		Cance	el .

On the **STATISTICS** tab select **Start local R** to ensure local execution. Select **Install to Pmod folder** to avoid permission problems when installing the R packages.

Restart PMOD and wait for the R icon on the main ToolBox to become active.



Then click on the **R** icon to open the **PMOD Console**. The required packages are downloaded and installed, followed by an execution test and printing of the R version information:

] ?					C	t t	N.	?		
m MR . R	elaxometry	• ?	? General	ANOVA	~	?	×		~	•	>
Be ×			Output					8	×		=
	Loading de Execution to	fault set est Pa			Out' Mac OS X						

The Settings button indicated above opens the dialog window below.

		R console	esettings			
	ional packages > 5 load on start)	tseries				
		التق Package manage /Library/Frameworks/Python.fram				
	Tools location	ТОР		•	4	•
٦	Task tabs location	LEFT		•	4	Þ
🗌 Initial	Workspace Data	Workspace: Image: Description Image: Description Save workspace on exit to the	selected R Data file	4 I		•
	Initial script	NONE Use initial script after each wor Editing: Parentheses autocomplete Text output:	kspace is loaded	~	4	
	Font	Fixed		•	4	
	columns in table x lines in printout					
		<u>O</u> k	<u>C</u> ancel			

Please verify the **Path to Python** and open the **Package Manager**. All packages should have status **OK**.

CRAN CRAN CRAN CRAN CRAN	OK OK OK	4.6.9 2.1.3	4.6.9 2.1.3
CRAN			
	OK	1 7 6	
CRAN		1.7.6	1.7-6
	OK	2.0.6	2.0-6
CRAN	OK	3.4	3.4
CRAN	OK	0.10.48	0.10-48
CRAN	OK	0.60.10	0.60-10
CRAN	OK	2.8.3	2.8-3
CRAN	OK	0.8.80	0.8-81
CRAN	OK	4.5.0	4.5-0
CRAN	OK	3.0.10	3.0-10
CRAN	OK	0.2.1	0.2-1
CRAN	OK	0.2.6	0.2-6
CRAN	OK	0.8.8	0.8.8
CRAN	OK	1.1.9	1.1-10
CRAN	OK	1.5.12.2	1.5-12.2
CRAN	OK	1.17.0.1	1.17.0.1
CRAN	OK	3.2.7	3.2-10
CRAN	OK	4.1.1	4.1-1
CRAN	OK	1.4.0	1.4.0
CRAN	OK	1.2.1	1.2.1
CRAN	OK	1.0.3	1.0.3
CRAN	OK	1.18	1.18
CRAN	OK	2.4.0	2.4.0
CRAN	OK	1.7.2	1.7.2
CRAN	OK	1.7.10	1.7.10
CRAN	OK	1.1.9	1.1-10
CRAN	OK	4.1.0	4.1-0
Local	OK	4.201.1	-
Local	OK	4.203.1	-
	CRAN CRAN CRAN CRAN CRAN CRAN CRAN CRAN	CRANOK	CRAN OK 0.60.10 CRAN OK 2.8.3 CRAN OK 0.8.80 CRAN OK 4.5.0 CRAN OK 3.0.10 CRAN OK 0.2.1 CRAN OK 0.2.6 CRAN OK 0.2.6 CRAN OK 1.19 CRAN OK 1.5.12.2 CRAN OK 1.5.12.2 CRAN OK 1.17.0.1 CRAN OK 1.2.7 CRAN OK 1.2.1 CRAN OK 1.4.0 CRAN OK 1.2.1 CRAN OK 1.2.1 CRAN OK 1.0.3 CRAN OK 1.2.1 CRAN OK 1.2.1

Note: If package installation fails, please check your firewall settings or contact your IT service.

2.2.2.2 Minimal R Configuration

For instances of PMOD that will only be used for PAI it is possible to install a reduced set of R packages. To achieve this, perform the following configuration and installation procedure.

Following R installation, start PMOD and open the **Configuration** facility from the main ToolBox.

	A DICOM	
	<u> </u>	
Login enabled	[+] (1) User settings MOD Models PKIN Model	are saved when switching the user. els READ / WRITE Formats LOADING TOOLS COLOR TABLES MODULES
	TABASES FTP Nodes	APPEARANCE STATISTICS PRESETS
Hottest Pixel		
		(🖼) O Server
	Address	Image: Configuration configuration Image: Configuration configuraticon configuration configuration configuratico configuration
	Login Password	(Empty = automatic login) (Empty = automatic login)
	Python	

On the **STATISTICS** tab select **Start local R** to ensure local execution and verify that the path to the local R installation is correct. Select **Install to Pmod folder** to install the base required packages on PMOD restart.

Restart PMOD and wait for the **R** icon on the main ToolBox to become active.

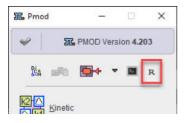


Return to the **Configuration** facility from the main ToolBox and change the R package installation selection to Don't install:

Susers 👷 dicom 🖬 dat	
User1 🔻 🖣 🕨 T Edit user name	
Login enabled [+] (User sett ETTINGS PXMOD Models PKIN M	Ings are saved when switching the user. Indels READ / WRITE Formats LOADING TOOLS COLOR TABLES MODULES
REPORT DATABASES FTP Nodes	
SUV Scan Date / T	[] Start local R Required packages from repository on start Don't install
Addr	Image: Server Image: Server
Lo Passw	igin (Empty = automatic login) ord (Empty = automatic login)
Pyti	non 🔤

On the **STATISTICS** tab select **Start local R** to ensure local execution and verify that the path to the local R installation is correct. Select **Don't install** for the R packages as illustrated above.

Restart PMOD and wait for the R icon on the main ToolBox to become active.



Then click on the **R** icon to open the **PMOD Console**. The internal packages **pm.base** and **pm.ai** were installed automatically whereas the remaining packages are skipped and **not loaded** messages listed:

Connecting to the server localhost Connected. Loading default settings Loaded. Package doBy not loaded. Package psych not loaded. Package e1071 not loaded. Package lawstat not loaded. Package not loaded. Package not loaded. Package openair not loaded. Package openair not loaded. Package pila not loaded. Package car not loaded. Package car not loaded. Package reshape not loaded. Package compare not loaded. Package greshape not loaded. Package Gorro not loaded. Package Gairo not loaded. Package greshape not loaded. Package pROC not loaded. Package gimnet not loaded. Package gimnet not loaded. Package greshout loaded. Package stringr not loaded. Package ison ison tloaded. Package ison ison ison ison ison ison ison ison	Output Image: Connecting to the server localhost Connected. Loading default settings Loaded. Package doBy not loaded. Package doBy not loaded. Package grych not loaded. Package psych not loaded. Package series not loaded. Package part not loaded. Package terries not loaded. Package prime not loaded. Package terries not loaded. Package car not loaded. Package car not loaded. Package car not loaded. Package compare not loaded. Package car not loaded. Package car not loaded. Package strings not loaded. Package car not loaded. Package strings not loaded. Package strings not loaded. Package strings not loaded. Package for not loaded. Package for not loaded. Package for not loaded. Package strings not loaded. Package for not loaded. Package strings not loaded. Package strings	?										a			?
Connecting to the server localhost Connected. Loading default settings Loaded. Package doBy not loaded. Package psych not loaded. Package e1071 not loaded. Package e1071 not loaded. Package any not loaded. Package np not loaded. Package np not loaded. Package openair not loaded. Package phia not loaded. Package phia not loaded. Package car not loaded. Package prism not loaded. Package prism not loaded. Package reshape not loaded. Package compare not loaded. Package compare not loaded. Package compare not loaded. Package cairo not loaded. Package cairo not loaded. Package first not loaded. Package gimen tot loaded. Package gimen tot loaded. Package stringr not loaded. Package ison it loaded. Package stringr not loaded. Package ison it loaded. Package stringr not loaded. Package ison it lo	Connecting to the server localhost Connected. Loading default settings Loaded. Package doBy not loaded. Package gox/ch not loaded. Package psych not loaded. Package series not loaded. Package teries not loaded. Package penair not loaded. Package openair not loaded. Package openair not loaded. Package car not loaded. Package car not loaded. Package compare not loaded. Package compare not loaded. Package compare not loaded. Package compare not loaded. Package sershape not loaded. Package sershape not loaded. Package sershape not loaded. Package sershape not loaded. Package sersing not loaded. Package glimet not loaded. Package sersion not loaded. Package isonlite not loaded. Package isonlite not loaded. Package sersins not loaded. Package ser	IR . Relaxor	etry 🔻	?	General		ANOVA	ŭ.			•	?	×		
Loading default settings Loaded. Package doBy not loaded. Package psych not loaded. Package psych not loaded. Package 1071 not loaded. Package lawstat not loaded. Package np not loaded. Package openair not loaded. Package openair not loaded. Package phia not loaded. Package car not loaded. Package compare not loaded. Package reshape not loaded. Package reshape not loaded. Package sfismisc not loaded. Package glimet not loaded. Package grimet not loaded. Package grimet not loaded. Package glimet not loaded. Package glimet not loaded. Package rot loaded. Package rot loaded. Package rot loaded. Package session not loaded. Package reticulate not loaded. Package reticulate not loaded. Package isonlite not loaded. Package isonlite not loaded. Package sismisc not loaded. Package sismisc not loaded. Package session not loaded. Package sessinite not loaded. Package sessine not loaded. Pa	Loading default settings Loaded. Package doBy not loaded. Package psych not loaded. Package UsingR not loaded. Package UsingR not loaded. Package tseries not loaded. Package np not loaded. Package openair not loaded. Package phia not loaded. Package car not loaded. Package compare not loaded. Package rompare not loaded. Package rompare not loaded. Package sfsmisc not loaded. Package mr not loaded. Package stringr not loaded. Package stringr not loaded. Package session not loaded. Package session not loaded. Package stringr not loaded. Package iubridate not loaded. Package iubridate not loaded. Package stringr not loaded. Package stringr not loaded. Package stringr not loaded. Package stringr not loaded. Package iubridate not loaded. Package stringr not loade				•									8	×
Package psych not loaded. Package e1071 not loaded. Package UsingR not loaded. Package lawstat not loaded. Package iseries not loaded. Package openair not loaded. Package openair not loaded. Package phia not loaded. Package car not loaded. Package compare not loaded. Package prot loaded. Package reshape not loaded. Package afsmisc not loaded. Package afsmisc not loaded. Package afsmisc not loaded. Package glimet not loaded. Package session not loaded. Package reticulate not loaded. Package reticulate not loaded. Package isonlite not	Package psych not loaded. Package e1071 not loaded. Package e1071 not loaded. Package lawstat not loaded. Package np not loaded. Package openair not loaded. Package openair not loaded. Package car not loaded. Package compare not loaded. Package compare not loaded. Package reshape not loaded. Package sfsmisc not loaded. Package glmnet not loaded. Package glmnet not loaded. Package glmnet not loaded. Package stringr not loaded. Package stringr not loaded. Package session not loaded. Package isonlite not loaded. Package stringr not loaded. Package isonlite not	Loadi	ng default	setting	gs Load		onnecte	d.							
Package UsingR not loaded. Package lawstat not loaded. Package prot loaded. Package openair not loaded. Package openair not loaded. Package dmisc not loaded. Package car not loaded. Package compare not loaded. Package compare not loaded. Package compare not loaded. Package reshape not loaded. Package sfsmisc not loaded. Package glmont not loaded. Package glmet not loaded. Package glmet not loaded. Package glmet not loaded. Package stringr not loaded. Package mcr not loaded. Package mcr not loaded. Package reticulate not loaded. Package keras not loaded. Package keras not loaded. Package sison not loaded. Package stringr not loaded. Package isonlite not loaded. Package isonlite not loaded. Package stringr not loaded. Package tseries not loaded. Package tseries not loaded.	Package UsingR not loaded. Package lawstat not loaded. Package openair not loaded. Package openair not loaded. Package Hmisc not loaded. Package car not loaded. Package compare not loaded. Package compare not loaded. Package compare not loaded. Package cairo not loaded. Package Cairo not loaded. Package glmnet not loaded. Package glmnet not loaded. Package stringr not loaded. Package stringr not loaded. Package session not loaded. Package isonlite not loaded. Package isonlite not loaded. Package session not loaded.	Packa	ge psych r	not loa	ded.										_
Package tseries not loaded. Package np not loaded. Package openair not loaded. Package Hmisc not loaded. Package car not loaded. Package compare not loaded. Package compare not loaded. Package reshape not loaded. Package sfsmisc not loaded. Package for not loaded. Package pROC not loaded. Package glumet not loaded. Package stringr not loaded. Package stringr not loaded. Package session not loaded. Package reticulate not loaded. Package keras not loaded. Package session not loaded. Package keras not loaded. Package keras not loaded. Package keras not loaded. Package keras not loaded. Package session not loaded. Package tseries not loaded. Package tseries not loaded.	Package tseries not loaded. Package np not loaded. Package openair not loaded. Package car not loaded. Package compare not loaded. Package reshape not loaded. Package reshape not loaded. Package fairs not loaded. Package fairs not loaded. Package glmnet not loaded. Package glmnet not loaded. Package stringr not loaded. Package sersion not loaded. Package reticulate not loaded. Package reticulate not loaded. Package reticulate not loaded. Package sersion not loaded. Package isonlite not loaded. Package sersion not loaded. Package isonlite not loaded. Package sersion not loaded. Package memuse not loaded. Package memus	Packa	ge UsingR	not lo	aded.										-,
Package openair not loaded. Package Hmisc not loaded. Package car not loaded. Package car not loaded. Package reshape not loaded. Package reshape not loaded. Package sfsmisc not loaded. Package Gairo not loaded. Package pROC not loaded. Package glmnet not loaded. Package stringr not loaded. Package session not loaded. Package reticulate not loaded. Package reticulate not loaded. Package keras not loaded. Package session not loaded. Package keras not loaded. Package keras not loaded. Package session not loaded	Package openair not loaded. Package Hmisc not loaded. Package car not loaded. Package compare not loaded. Package reshape not loaded. Package sfsmisc not loaded. Package gap ROC not loaded. Package glmnet not loaded. Package glmnet not loaded. Package stringr not loaded. Package mcr not loaded. Package reticulate not loaded. Package reticulate not loaded. Package reticulate not loaded. Package sisonine not loaded. Package serison not loaded. Package isonlite not loaded. Package serison not loaded. Package isonlite not loaded.	Packa	ge tseries	not loa	aded.										
Package car not loaded.Package phia not loaded.Package compare not loaded.Package reshape not loaded.Package fsmisc not loaded.Package Cairo not loaded.Package pROC not loaded.Package glmnet not loaded.Package stringr not loaded.Package stringr not loaded.Package stringr not loaded.Package session not loaded.Package session not loaded.Package reticulate not loaded.Package keras not loaded.Package keras not loaded.Package ibonlite not loaded.Package ibonlite not loaded.Package ibonlite not loaded.Package sersin not loaded.Package ibonlite not loaded.Package stringr not loaded.Package ibonlite not loaded.Package stringr not loaded.Package tseries	Package car not loaded. Package phia not loaded. Package compare not loaded. Package reshape not loaded. Package Sismisc not loaded. Package pROC not loaded. Package glmnet not loaded. Package stringr not loaded. Package mcr not loaded. Package reticulate not loaded. Package reticulate not loaded. Package keras not loaded. Package jsonlite not loaded. Package keras not loaded. Package sismic not loaded. Package sismic not loaded. Package sismic not loaded. Package sismic not loaded. Package terises not loaded. Package sismic not loaded. Package sismic not loaded. Package sismic not loaded. Package tseries not loaded. Package tseries not loaded. Package tseries not loaded.	Packa	ge openaii	r not lo	baded.										
Package compare not loaded.Package reshape not loaded.Package sfsmisc not loaded.Package Cairo not loaded.Package pROC not loaded.Package glmnet not loaded.Package stringr not loaded.Package stringr not loaded.Package session not loaded.Package reticulate not loaded.Package keras not loaded.Package keras not loaded.Package iborlite not loaded.Package iborlite not loaded.Package stringr not loaded.Package keras not loaded.Package keras not loaded.Package iborlite not loaded.Package iborlite not loaded.Package strings not loaded.Package tseries not loaded.	Package compare not loaded. Package reshape not loaded. Package sfsmisc not loaded. Package pROC not loaded. Package glmnet not loaded. Package mcr not loaded. Package mcr not loaded. Package reticulate not loaded. Package reticulate not loaded. Package keras not loaded. Package jsonlite not loaded. Package jsonlite not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package memuse not loaded. Package tseries not loaded.	Packa	ge car not	loade	d.										
Package sfsmisc not loaded.Package Cairo not loaded.Package pROC not loaded.Package glmnet not loaded.Package stringr not loaded.Package mcr not loaded.Package reticulate not loaded.Package keras not loaded.Package keras not loaded.Package isonlite not loaded.Package isonlite not loaded.Package sersion not loaded.Package keras not loaded.Package keras not loaded.Package isonlite not loaded.Package isonlite not loaded.Package sist not loaded.Package stringt not loaded.Package tseries not	Package sfsmisc not loaded. Package Cairo not loaded. Package pROC not loaded. Package glmnet not loaded. Package mcr not loaded. Package reticulate not loaded. Package reticulate not loaded. Package keras not loaded. Package jsonlite not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package memuse not loaded. Package tseries not loaded.	Packa	ge compai	re not	loaded.										
Package pROC not loaded. Package glmnet not loaded. Package stringr not loaded. Package mcr not loaded. Package session not loaded. Package reticulate not loaded. Package keras not loaded. Package jsonlite not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package memuse not loaded. Package tseries not loaded. Execution test Passed.	Package pROC not loaded. Package glmnet not loaded. Package stringr not loaded. Package mcr not loaded. Package reticulate not loaded. Package keras not loaded. Package isonlite not loaded. Package lubridate not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Package tseries not loaded. Package tseries not loaded. Package tseries not loaded.														
Package glmnet not loaded. Package stringr not loaded. Package mcr not loaded. Package session not loaded. Package reticulate not loaded. Package keras not loaded. Package isonlite not loaded. Package sismisc not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Execution test Passed.	Package glmnet not loaded. Package stringr not loaded. Package mcr not loaded. Package session not loaded. Package reticulate not loaded. Package keras not loaded. Package lubridate not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Package tseries not loaded. Package tseries not loaded. Package tseries not loaded.		-												
Package mcr not loaded. Package session not loaded. Package reticulate not loaded. Package keras not loaded. Package jsonlite not loaded. Package lubridate not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Execution test Passed.	Package mcr not loaded. Package session not loaded. Package reticulate not loaded. Package keras not loaded. Package jsonlite not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Package tseries not loaded. Package tseries not loaded. Package tseries not loaded.	Packa	ge glmnet	not lo	aded.										
Package reticulate not loaded. Package keras not loaded. Package jsonlite not loaded. Package lubridate not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Execution test Passed.	Package reticulate not loaded. Package keras not loaded. Package jsonlite not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Package tseries not loaded. Execution test Passed.	Packa	ge mcr no	t loade	ed.										
Package jsonlite not loaded. Package lubridate not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Execution test Passed.	Package jsonlite not loaded. Package lubridate not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Execution test Passed.		-												
Package lubridate not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Execution test Passed.	Package lubridate not loaded. Package sfsmisc not loaded. Package memuse not loaded. Package tseries not loaded. Execution test Passed.	Packa	ge keras n	ot loa	ded.										
Package memuse not loaded. Package tseries not loaded. Execution test Passed.	Package memuse not loaded. Package tseries not loaded. Execution test Passed.	Packa	ge lubrida	te not	loaded.										
Package tseries not loaded. Execution test Passed.	Package tseries not loaded.		-												
		A REAL PROPERTY AND A REAL PROPERTY.													
R version 4.0.3 (2020-10-10) 'Bunny-Wunnies Freak Out' Mac OS Y	R version 4.0.3 (2020–10–10) 'Bunny-Wunnies Freak Out' Mac OS X														
R VEISION T.O.S (2020-10-10) Builly-Wullines Heak Out Mac OS X		R ver	sion 4.0.3	(2020	-10-10)'	Bunny	-Wunnie	es Freal	c Out' M	lac OS	х				

The Settings button indicated above opens the dialog window below.

	R console	esettings			
Additional packages > (To load on start)	tseries				
Path to Python:	L	tan ang kanalan ang kanala	5		
Tools location	ТОР		-	4	Þ
Task tabs location	LEFT		•	4	Þ
Initial Workspace Data	Workspace: Save workspace on exit to the	selected R Data file] 4 1	•	•
Initial script	NONE		~	4	
	Use initial script after each wor Editing: Parentheses autocomplete Text output:	kspace is loaded			
Font	Fixed		•	4	•
Max columns in table Max lines in printout					
	<u>O</u> k	<u>C</u> ancel			

Please verify the **Path to Python** and open the **Package Manager**. Most packages will have **Requires installation** in the **Status** column

psych C e1071 C UsingR C lawstat C tseries C openair C foreign C Hmisc C car C	RAN RAN RAN RAN RAN RAN RAN RAN RAN	Requires ins Requires ins Requires ins Requires ins Requires ins Requires ins Requires ins		4.6.9 2.1.3 1.7-6 2.0-6 3.4 0.10-48
psych C e1071 C UsingR C lawstat C tseries C openair C foreign C Hmisc C car C	RAN RAN RAN RAN RAN RAN RAN	Requires ins Requires ins Requires ins Requires ins Requires ins Requires ins		1.7-6 2.0-6 3.4
UsingR C lawstat C tseries C np C openair C foreign C Hmisc C car C	RAN RAN RAN RAN RAN RAN	Requires ins Requires ins Requires ins Requires ins Requires ins		2.0-6 3.4
lawstat CC tseries CC np CC openair CC foreign CC Hmisc CC car CC	RAN RAN RAN RAN RAN	Requires ins Requires ins Requires ins		3.4
tseries C np C openair C foreign C Hmisc C car C	RAN RAN RAN RAN	Requires ins Requires ins Requires ins		
np C openair C foreign C Hmisc C car C	RAN RAN RAN	Requires ins		0.10-48
openair C foreign C Hmisc C car C	RAN RAN			
foreign C Hmisc C car C	RAN	Requires ins		0.60-10
Hmisc C car C				2.8-3
car C	PAN	OK	0.8.80	0.8-81
	IN/AIN	Requires ins		4.5-0
phia C	RAN	Requires ins		3.0-10
	RAN	Requires ins		0.2-1
compare C	RAN	Requires ins		0.2-6
reshape C	RAN	Requires ins		0.8.8
sfsmisc C	RAN	Requires ins		1.1-10
Cairo C	RAN	Requires ins		1.5-12.2
pROC C	RAN	Requires ins		1.17.0.1
survival C	RAN	OK	3.2.7	3.2-10
glmnet C	RAN	Requires ins		4.1-1
stringr C	RAN	Requires ins		1.4.0
mcr C	RAN	Requires ins		1.2.1
session C	RAN	Requires ins		1.0.3
reticulate C	RAN	Requires ins		1.18
keras C	RAN	Requires ins		2.4.0
jsonlite C	RAN	Requires ins		1.7.2
lubridate C	RAN	Requires ins		1.7.10
sfsmisc C	RAN	Requires ins		1.1-10
memuse C	RAN	Requires ins		4.1-0
pm.base Lo	ocal	OK	4.201.1	-
pm.ai Lo	ocal	OK	4.203.1	-

To install only the packages necessary for PAI, please select **Install PAI only** and then **Install/Update**

Package	Type	Status	Installed version	CRAN version
doBy	CRAN	Requires ins		4.6.9
psych	CRAN	Requires ins		2.1.3
e1071	CRAN	Requires ins		1.7-6
UsingR	CRAN	Requires ins		2.0-6
lawstat	CRAN	Requires ins		3.4
tseries	CRAN	Requires ins		0.10-48
np	CRAN	Requires ins		0.60-10
openair	CRAN	Requires ins		2.8-3
foreign	CDAN	0V	0 8 80	0 9 91
Hmisc		C	onfirmation	
car				
phia				
compare		The following nac	kages will be installed:	
reshape		The following paci	Rages will be installed.	
sfsmisc		stringr		
Cairo		session		
pROC		 reticulate 		
survival		keras		
glmnet		 jsonlite 		
stringr	?	 lubridate 		
mcr		 sfsmisc 		
session		memuse		
reticulate		• pm.ai		
keras		This operation is a	ima concuming and	a't he stepped
jsonlite			time consuming and car	it be stopped.
lubridate		Do you want to co	nunue?	
sfsmisc				
memuse		(
pm.base		✓ <u>Y</u> es		X <u>N</u> o
pm.ai	- Balance			
		Install	all packages Install F	Al only 🖡 Install / Upda

Following installation the **Status** entries will be updated:

Package	Type	Status	Installed version	CRAN version
doBy	CRAN	Requires ins		4.6.9
osych	CRAN	Requires ins		2.1.3
1071	CRAN	OK	1.7.6	1.7-6
JsingR	CRAN	Requires ins		2.0-6
awstat	CRAN	Requires ins		3.4
series	CRAN	Requires ins		0.10-48
ar	CRAN	Requires ins		0.60-10
penair	CRAN	Requires ins		2.8-3
oreign	CRAN	OK	0.8.80	0.8-81
Imisc	CRAN	Requires ins		4.5-0
ar	CRAN	Requires ins		3.0-10
ohia	CRAN	Requires ins		0.2-1
ompare	CRAN	Requires ins		0.2-6
eshape	CRAN	Requires ins		0.8.8
fsmisc	CRAN	OK	1.1.9	1.1-10
Cairo	CRAN	Requires ins		1.5-12.2
ROC	CRAN	Requires ins		1.17.0.1
survival	CRAN	OK	3.2.7	3.2-10
almnet	CRAN	Requires ins		4.1-1
stringr	CRAN	OK	1.4.0	1.4.0
ncr	CRAN	Requires ins		1.2.1
session	CRAN	OK	1.0.3	1.0.3
reticulate	CRAN	OK	1.18	1.18
ceras	CRAN	OK	2.4.0	2.4.0
sonlite	CRAN	OK	1.7.2	1.7.2
ubridate	CRAN	OK	1.7.10	1.7.10
fsmisc	CRAN	OK	1.1.9	1.1-10
nemuse	CRAN	OK	4.1.0	4.1-0
om.base	Local	OK	4.201.1	_
om.ai	Local	OK	4.203.1	-
		Install	all packages Install P	2AI only 🖡 Install / Updat

Closing the window with **Ok** completes the installation.

Note: When a prediction will be launched in PSEG at a later timepoint, the R Console will report the packages that were not installed, but the **Execution test** will still pass as illustrated below.

										C		12 12	?	
			?											
>	App	olication	MR . Relaxometry	-	?	General	ANOVA		•	?	×		•	\
×			C	utput)					×	
		Package U Package ts Package n Package n Package n Package c Package c Package p Package n Package n Package n Package n Package n Package ts	sych not loaded. IsingR not loaded. awstat not loaded. p not loaded. p not loaded. penair not loaded. Imisc not loaded. Imisc not loaded. ar not loaded. ompare not loaded. actiro not loaded. ROC not loaded. Immet not loaded. ROC not loaded. series not loaded. test Passed. 4.0.3 (2020-10-10)	'Bunn	y-W	unnies Freal	« Out' Mac OS X	¢						*** 22 *

2.2.3 Selection of Python installation

Multiple installations and versions of Python may cause the PAI infrastructure test to fail.

In this situation you should define the path to Python 3.8 in the **Configuration** facility from the main ToolBox:

Sers 👫 dicom 🛃 datae	ASE 🛛 @ FTP Nodes 🛛 🖸 On Start	
User1 💌 📢 🕨 T Edit user name		
	are saved when switching the user.	
SETTINGS PXMOD Models PKIN Mod		MODULES
REPORT DATABASES FTP Nodes	APPEARANCE STATISTICS PRESETS	
Hottest Pixels Analysis Number of pixel Peak VOI volum SUV Scan Date / Time V R Statistics Console		v 4 ►
	[Server	
Addres	Contraction of the set Local Host R Co	nfiguration test
Addres	rserve.pmod.com	r Starting Script
Logi		(Empty = automatic login)
Password		(Empty = automatic login)
Pythor		
	3. 	

Restart PMOD after setting the path to Python 3.8.

2.3 Linux Platforms

2.3.1 R Installation

PAI requires R version 4.0.3 or higher. Please perform the following installation steps (Ubuntu 18.04):

Install R:

```
sudo apt-key adv --keyserver keyserver.ubuntu.com --recv-keys
E298A3A825C0D65DFD57CBB651716619E084DAB9
sudo add-apt-repository 'deb https://cloud.r-
project.org/bin/linux/ubuntu bionic-cran40/' sudo apt update
```

sudo apt install r-recommended

Install the required libraries:

```
sudo apt install libcurl4-openssl-dev
sudo apt install libcairo2-dev
sudo apt install xorg-dev
sudo apt install libssl-dev
sudo add-apt-repository ppa:c2d4u.team/c2d4u4.0+
```

```
sudo apt-get update
sudo apt-get install r-cran-lme4
sudo apt-get install r-cran-snow
sudo apt-get install r-cran-vgam
```

Start R at the command line as administrator ("sudo R") and install the required packages:

```
install.packages("doBy")
install.packages("psych")
install.packages("e1071")
install.packages("UsingR")
install.packages("lawstat")
install.packages("tseries")
install.packages("np")
install.packages("openair")
install.packages("foreign")
install.packages("Hmisc")
install.packages("car")
install.packages("phia")
install.packages("compare")
install.packages("reshape")
install.packages("sfsmisc")
install.packages("Cairo")
install.packages("pROC")
install.packages("survival")
install.packages("glmnet")
install.packages("mcr")
install.packages("stringr")
install.packages("reticulate")
install.packages("jsonlite")
install.packages("session")
install.packages("keras")
```

install.packages("Rserve",,"http://rforge.net")

Rserve Configuration

Create the configuration file "/etc/Rserv.conf".

Create the following content in the configuration file (enables TCP communication with R using port 5999):

```
remote enable port 5999
fileio disable
encoding utf8
```

Ensure that the port specified in the configuration file is not used by other applications and is enabled in the firewall. Alternatively a configuration file with user authentication can be used as follows:

```
remote enable
port 5999
fileio disable
encoding utf8
pwdfile /etc/Rserv.pwd
auth required
plaintext disable
```

The password file Rserv.pwd contains the defined users and passwords. It is a plain text file with tab-separated values:

```
myUser1 myPassword1
myUser2 myPassword2
```

Load and start Rserve from R:

```
library("Rserve");
Rserve();
```

Note: depending on how R is being run, it may require additional parameters. In that case the parameter should be passed in the args argument such as:

```
Rserve(args='--no-save');
```

2.3.2 Python and TensorFlow Installation

Python version 3.8 is required. Install Python and TensorFlow as follows:

```
sudo apt update sudo apt upgrade
sudo apt install build-essential
```

sudo apt install python3
sudo apt install python3-pip
pip3 install --upgrade pip
pip3 install tensorflow

Note: TensorFlow can alternatively be installed in Python's virtual environment.

3 Preparation of Training Data and Neural Network

3.1 Data Preparation

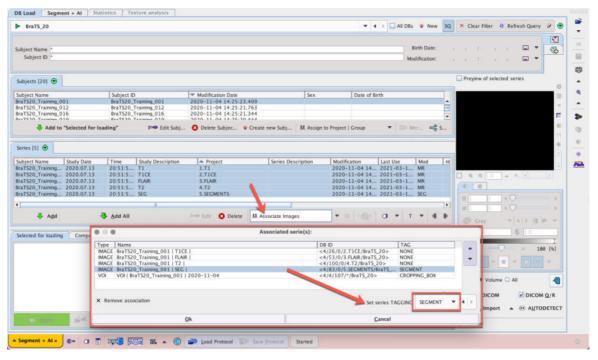
Image Import

The use of a database is a prerequisite for developing an ML model in PAI. Please refer to the *PMOD Basic Functionality User Guide* for instructions how to create and use databases. In the example below a database called **BraTS** was created and the data from the MICCAI BraTS Challenge imported.

Image Association

A training sample consists of one or several image series, and the segmentation reference result from which the neural network should learn. All of these images need to be associated in the database so that when a single image is referenced all related images are identified.

To associate the images, select a subject in the **Subjects** list and then all series to be associated in the **Series** list. From the option menu indicated below select **Associate Images**, which brings up a dialog window confirming association of the selected series.



To identify which image series is the reference segment map, select it in the list, then the **TAG** column, and in the menu that appears



select the **SEGMENT** entry. If more than one input image is required for the segmentation, it is important that they always appear in the same order in the association list. Please use the arrow buttons to the right of the list for shifting the position of a selected element.

Existing associations can be checked by selecting one of the image series and activating the button indicated below:

Subject Name	Study Date	Time	Study Description	A Pro	ject	Series Descriptio	n Modifica	tion	Last Us	ie	Mod	
BraTS20_Training		20:51:5		1.T1			2020-11	-04 14	2021-0	03-1	MR	
BraTS20_Training	2020.07.13	20:51:5	T1CE	2.T1C	ΈE		2020-11	-04 14	2021-0	03-1	MR	
BraTS20_Training	2020.07.13	20:51:5	FLAIR	3.FLA	IR		2020-11	-04 14	2021-0	03-1	MR.	
BraTS20_Training	2020.07.13	20:51:5	T2	4.T2			2020-11	-04 14	2021-0	03-1	MR	
BraTS20_Training	2020.07.13	20:51:5	SEG	5.SEG	MENTS		2020-11	-04 14	2021-0	03-1	SEG	
1			11									
🐥 A <u>d</u> d	4	🕨 <u>A</u> dd All		I= Edit	🙁 Delete	具 Associate Images	▼ #	D@M	а,	• т	•	•
Selected for loadi					Associa	ted serie(s):						
	Type Name					DB ID		TAG	6			
	IMAGE BraTS20	_Training_001	T1CE			<4/26/0/	2.T1CE/BraTS_20:	NON	E			-
	IMAGE BraTS20						3.FLAIR/BraTS_20:					
	IMAGE BraTS20						/4.T2/BraT5_20>	NON				
		Training 001					5.SEGMENTS/BraT					
	IMAGE BraTS20						/*/BraTS 20>		PPING BO	DX		
	IMAGE BraTS20		g_001)2020-11-04			<4/4/10/	/ /61415_202	CRO				
	IMAGE BraTS20		g_001)2020-11-04			<4/4/10/	//8/415_202	citor				
	IMAGE BraTS20	TS20_Training	g_001)2020-11-04			<4/4/10/	-	TAGGING		E	-	

Adding a Descriptive Variable for Training (Project Description)

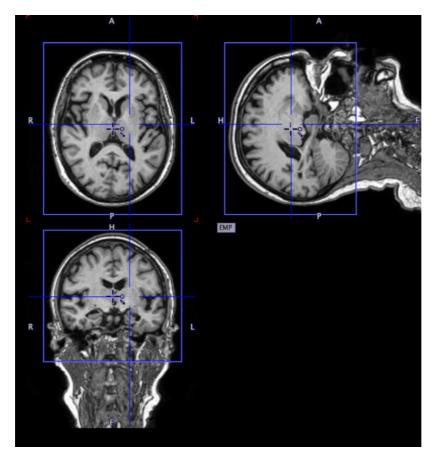
We strongly recommend adding a descriptive label to the series used for training by defining the Project using **Assign to Project | Group**. This description will be used to check that new data used for Prediction has the same content as that used for Training.

If a difference in the Project description (or number of studies) in Training/Prediction is detected, warning messages based on the following structure will be returned:

	Message
1	Segmentation cancelled: Images in the input sample (associated series) have different description, than images used to generate weights. Please verify the following database fields for the input images: Field 'Project': Image 1: found: 1., expected: 1.t1 Image 2: found: 2., expected: 2.t1ce
[× <u>C</u> lose

Data Cropping

Another part of the data preparation consists of reducing the data volume to the relevant portion. In the brain segmentation example the image should be restricted to the brain. This process can be included in the training set definition by creating a VOI that will serve as the cropping box and associating it with the input data using the same tools as image association.



To achieve this, open the input image, create a suitable VOI such as a box, position it properly and save it to the database. Then select the input image in the **Series** list on the DB Load page, followed by **Associate VOI** from the same menu where the images were associated.

		🗆 Assign to Project Group
😣 Delete	봤 Associate VOI	Associate Images Associate VOI Associate Mask (SEGMENT)
		Associate Whole blood Associate Plasma Associate Parent fraction

In the dialog window which opens select the saved VOI and activate Set Selected.

Automatic Association Creation

The neural network training process requires the preparation of a large number of samples. To make this process easier a mechanism for the automatic association of the images is available. It uses the **Incoming Folder** method. A folder that is regularly checked for data to be imported into the database is defined in the **DICOM Server** configuration. It takes into account information prepared in a csv file that must also be located in the incoming folder. The structure of such a csv file is illustrated below:

	A	B	C	D	G	н	1	J	к
	FILENAME	PTID	NAME	AGE	PROTOCOL	DIAGNOSIS	PROJECT	MODALITY	STUDYDE9
2	BraTS20_Training_001_flair.nii.gz	BraTS20_Training_001	BraTS20_Training_001	60	protocol	FLAIR	3.FLAIR	MR	FLAIR
3	BraTS20_Training_001_seg.nii.gz	BraTS20_Training_001	BraTS20_Training_001	60	protocol	SEG	5.SEG [SEGMENT]	SEG	SEG
4	BraTS20_Training_001_t1.nii.gz	BraTS20_Training_001	BraTS20_Training_001	60	protocol	T1	1.T1	MR	T1
5	BraTS20_Training_001_t1ce.nii.g>	BraTS20_Training_001	BraTS20_Training_001	60	protocol	T1CE	2.T1CE	MR	T1CE
6	BraTS20_Training_001_t2.nii.gz	BraTS20_Training_001	BraTS20_Training_001	60	protocol	T2	4.T2	MR	T2
7	BraTS20 Training 002 flair.nii.gz	BraTS20_Training_002	BraTS20_Training_002	52	protocol	FLAIR	3.FLAIR	MR	FLAIR
8	BraTS20_Training_002_seg.nii.gz	BraTS20_Training_002	BraTS20_Training_002	52	protocol	SEG	5.SEG [SEGMENT]	SEG	SEG
9	BraTS20_Training_002_t1.nii.gz	BraTS20_Training_002	BraTS20_Training_002	52	protocol	T1	1.T1	MR	T1
10	BraTS20_Training_002_t1ce.nii.g>	BraTS20_Training_002	BraTS20_Training_002	52	protocol	T1CE	2.T1CE	MR	T1CE
11	BraTS20_Training_002_t2.nii.gz	BraTS20_Training_002	BraTS20_Training_002	52	protocol	T2	4.T2	MR	T2
12	BraTS20_Training_003_flair.nii.gz	BraTS20_Training_003	BraTS20_Training_003	54	protocol	FLAIR	3.FLAIR	MR	FLAIR
13	BraTS20_Training_003_seg.nii.gz	BraTS20_Training_003	BraTS20_Training_003	54	protocol	SEG	5.SEG [SEGMENT]	SEG	SEG
14	BraTS20_Training_003_t1.nii.gz	BraTS20_Training_003	BraTS20_Training_003	54	protocol	T1	1.T1	MR	T1
15	BraTS20_Training_003_t1ce.nii.g>	BraTS20_Training_003	BraTS20 Training 003	54	protocol	T1CE	2.T1CE	MR	T1CE
16	BraTS20_Training_003_t2.nii.gz	BraTS20_Training_003	BraTS20_Training_003	54	protocol	T2	4.T2	MR	T2
17	BraTS20_Training_004_flair.nii.gz	BraTS20_Training_004	BraTS20_Training_004	39	protocol	FLAIR	3.FLAIR	MR	FLAIR
18	BraTS20 Training 004 seg.nii.gz	BraTS20_Training_004	BraTS20 Training 004	39	protocol	SEG	5.SEG [SEGMENT]	SEG	SEG
19	BraTS20_Training_004_t1.nii.gz	BraTS20_Training_004	BraTS20_Training_004	39	protocol	T1	1.T1	MR	T1
20	BraTS20_Training_004_t1ce.nii.g>	BraTS20 Training_004	BraTS20 Training 004	39	protocol	T1CE	2.T1CE	MR	T1CE
21	BraTS20 Training 004 t2.nii.gz	BraTS20 Training_004	BraTS20 Training 004	39	protocol	T2	4.T2	MR	T2
22	BraTS20_Training_005_flair.nii.gz	BraTS20_Training_005	BraTS20 Training 005	68	protocol	FLAIR	3.FLAIR	MR	FLAIR
23	BraTS20 Training 005 seg.nii.gz	BraTS20_Training_005	BraTS20 Training 005	68	protocol	SEG	5.SEG [SEGMENT]	SEG	SEG
24	BraTS20 Training 005 t1.nii.gz	BraTS20 Training_005	BraTS20 Training 005	68	protocol	T1	1.T1	MR	T1
25	BraTS20_Training_005_t1ce.nii.g>	BraTS20_Training_005	BraTS20_Training_005	68	protocol	T1CE	2.T1CE	MR	T1CE
26	BraTS20 Training 005 t2.nii.gz	BraTS20 Training 005	BraTS20 Training 005	68	protocol	T2	4.T2	MR	T2
27	BraTS20 Training 006 flair.nii.gz	BraTS20 Training 006	BraTS20 Training 006	67	protocol	FLAIR	3.FLAIR	MR	FLAIR
28	BraTS20_Training_006_seg.nii.gz	BraTS20_Training_006	BraTS20_Training_006	67	protocol	SEG	5.SEG [SEGMENT]	SEG	SEG
29	BraTS20 Training 006 t1.nii.gz	BraTS20 Training 006	BraTS20 Training 006	67	protocol	T1	1.T1	MR	T1
30	BraTS20 Training 006 t1ce.nii.g>	BraTS20 Training 006	BraTS20 Training 006	67	protocol	T1CE	2.T1CE	MR	T1CE

The label defined in the **Project** column is assigned to the imported image series. Once imported, **Associate Images Automatically** can be used to generate the associations. Note that in the example, four images in each sample are used as input for the segmentation according to the requirements for the MICCAI BraTS Challenge. To establish a consistent order, numbers are used in the labels.

			Subjec	t ID		-	Modification Date	Sex			Date of E	Sirth		
BraTS20_Training_00	1		BraTS2	0_Training_0	01	202	K Associate Images Automatically	×						
						_	Projects							
🕹 Add to	"Selected for lo	vading"			1:4	Edit Sub	1.71 2.71CE		**	H Associat	e Images Auto	matically	• 30 M	irge 📫 Spl
							3.12							
Series (5) 💿							4.FLAIR							
series (of							5.SEG[SEGMENT]		-					
Subject Name	Study Date	Time	Study.	Series De	Wodification	Last Us			Y	Organ	SN	DB	User	Project
BraTS20_Training_0	2020.07.27	13:35:57	T2		2020-07-27 13		Allowed O service do to be did by a setudo.		240			Pmod	User1	3.T2
BraTS20_Training_0	2020.07.27	13:35:56	T1CE		2020-07-27 13.		At least 2 projects should be selected		240			Pmod	User1	2.T1CE
	2020.07.27	13:35:54	T1		2020-07-27 13		Association will be created in the ord	per or projects	240			Pmod	User1	1.T1
BraTS20_Training_0		13:35:53	SEG	BraTS20_T.	2020-07-27 13	2020-07	Process can be time consuming.		240			Pmod	User1	5.SEG[SEG
BraTS20_Training_0 BraTS20_Training_0	2020.07.27		FLAR		2020-07-27 13				240			Pmod	User1	4.FLAIR

3.2 Control Mechanism

Data Consistency

A prerequisite of training a neural network is that all samples are consistent. For example, the MICCAI BraTS example described above expects four input MR images, each from a particular type of MR sequence, and reference segments identifying three tissue types for segmentation. Adding a sample with only two input MR images, or reference segments with five labels provokes a failure. Likewise, prediction using the trained neural network will fail with data of a different structure.

Manifest File

To ensure consistency, PAI uses a manifest file (JSON format) to store information about the training process and history. The consistency check includes the number and type of datasets included, their descriptions, as well as the pre-processing procedures. The manifest file is based on the first valid sample ("leading sample") when the first training occurs.

Data Checks

The following checks are included;

• Proper loading of the associated images – checking whether all associated images are properly loaded.

- Number of dimensions the number of dimensions of the input images must be consistent with the number of dimensions of the images used for the original training. It must also be consistent with the number of dimensions supported by the chosen model.
- Number of associated images the number of associated input images must be the same as the number of images associated in the samples used for the original training.
- "Project" field, serving as image description the description of the associated input images stored in the "Project" database field must be the same as in the images used for the original training
- Modalities the modalities of the associated input images must be the same as for the images used for the original training.

If one of the above requirements is not met, PAI will do the following according to the workflow in use:

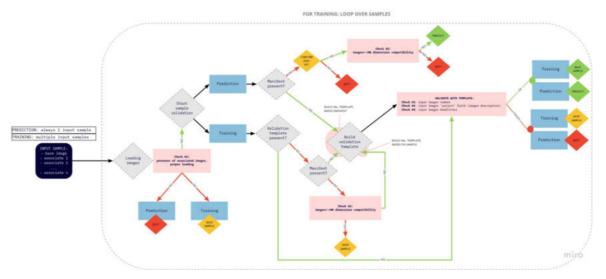
- Prediction: Cancel processing and inform the user
- Re-training: Skip the sample and print the information in the log

Model Configuration Check

The final control checks the settings in the user interface. Every time the user starts a training or saves the learning set, the content of the selected manifest file will be compared to the current settings in the user interface. This avoids using training parameters different from previous training sessions.

Control Overview

The data and model consistency checks are performed in the background during the workflows. Issues will be automatically detected and the user guided to correct them.



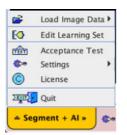
3.3 Learning Sets

In PAI, a **Learning Set** organizes all of the necessary data and parameters for training, including the data samples, the data preparation parameters and the neural network settings.

Note that any necessary <u>data preparations</u> \mathbb{D}^{34} should been done before creating or extending a **Leaning Set**.

Learning Set Dialog Window

To create a Learning Set or start a training run, select Edit Learning Set from the Segment + AI menu:



A dialog window appears listing the existing learning sets in the upper section. It allows new learning sets to be created and existing leaning sets to be extended in the lower section.

				and the second second									Preview
arning Set [1]:	SELECT DATABAS	SE Þ BraTS	20	🔻 🌒 🕨 DataBase/	".alSet]								
	Laura	Local		Les contractions of the	- Lucian Law	1.000	Lars			-			Validate Sample
mponent name	-LAI LEARNIN		t id Series descr NINC SET		Last Use Ose		P/0)	13	Group				
1-1	-JAI LEARNIN	IG SET] AT LEAN	NING SET	2021-03-31 21:3	2021-03-31 2 User	1 BraT5_2	0						
reate Learning Se	et + { Delete Ex	port Rename] e	xisting Description										
amples													
Subject Name	Study Date	Time	Study Description	Series Description	Modification	Last Use	Mod	et	nz	mx	ny	Organ	
S20_Training_0		20:51:57.8			2020-11-04 14:24		MR	1	155	240	240		
S20_Training_0	2020.07.13	20:56:38.6	T1		2020-11-04 14:25	2021-03-31 2	. MR	1	155	240	240		
S20_Training_0		21:06:49.1			2020-11-04 14:24			1	155	240	240		
\$20_Training_0		21:16:04.0			2020-11-04 14:24			1	155	240	240		
S20_Training_0		21:02:35.2			2020-11-04 14:24			1	155	240	240		
S20_Training_0		21 18:06.7			2020-11-04 14:25			1	155	240	240		
\$20_Training_0		21:05:42.1			2020-11-04 14:24			1	155	240	240		
\$20_Training_0		21:07:52.3			2020-11-04 14 25				155	240	240		C 6 6 10 a × 6 11
S20_Training_0	2020.07.13	21:15:23.5			2020-11-04 14:24				155	240	240		
520_Training_0 520_Training_0		20:56:58.1 21:15:04.4			2020-11-04 14:25 2020-11-04 14:25				155	240 240	240		6 5 6
S20_Training_0		21:08:25.3			2020-11-04 14:25				155	240	240		1 1 0 19
S20_Training_0		21:04:45.9			2020-11-04 14:24				155	240	240		
TS20_Training_0		21:06:31.7			2020-11-04 14:24.			1	155	240	240		
TS20 Training 0		21:09:50.8			2020-11-04 14:25			1	155	240	240		
TS20 Training 0		21:13:39.9			2020-11-04 14:24.			1	155	240	240		
S20_Training_0		21:04:56.0	T1		2020-11-04 14:25	2021-03-31 2	MR	1	155	240	240		
S20_Training_0	2020.07.13	20:51:18.1	T1		2020-11-04 14:24	2021-03-31 2	. MR	1	155	240	240		Carl + 4 3 12 P +
rs20_Training_0		20.53 18.7			2020-11-04 14:24			1	155	240	240		
S20_Training_0	2020.07.13	21:14:12.2	71		2020-11-04 14:24	2021-03-31 2	. MR	1	155	240	240		011 <u>P.O.</u> \$ 1.9
												•	
													8 [N]
Add samples	× Remove	/ ×											
				4									
earning paramet	sers 4. farg	et settings	5. Weights & Manifest	-									
Anonymize sam	ples					Architectu	re: Multi	channel Seg	mentation		> 7	Use GPU	Sample Mask
Crop image:	Crop to associa	and wor Box siz	e san lana san br	m) Pixel size 2.0	2.0 [mm]		tch size:						MDX (RCB Color)
Gaussian Smoot	hing 10 100	In Immi				Number of							
Scale Values to:			4 of sample.				ing rate:		d. Bealth	Lin Manifes	a bus		
	F. 2004.5		a nample.			LEATE	reng Tate: C	1000	rina U	manafes	1.1		

A text description can be appended to the Learning Set using the Description navigation button:

							Create L	earning Set				
Learning Set [1]:	SELECT DATABASE	> BraTS_	20	▼ 4	DataBase/ *	.aiSet]						
Component name	Subject name	Subject	id Series descr		Modify time	Last Use	User	Arch	Project	Group		
Docu-1	-(AI LEARNING SET]	AI LEARN	ING SET		2021-03-31 21:3	2021-03-31 2	User1	BraTS_20				
								Edit desc	ription			
					Learning Set: D	0ocu-1 <21/101/9	942/*/BraTS	_20>				
					Edit descriptio	n:						
	et + [Delete Export F			•								
2. Samples					<u>.</u>							
z. samples												
A Subject Name	Study Date Ti	me	Study Description	Serie								
BraTS20 Training 0	2020.07.13 20	51:57.8	1		1							
BraTS20_Training_0	2020.07.13 20	56:38.6	1									
BraTS20 Training 0		06:49.1 1	1									
BraTS20 Training 0		16:04.0 1	1									
	2020.07.13 21	02:35.2 1	1									
BraTS20_Training_0 BraTS20_Training_0		18:06.7										
BraTS20_Training_0 BraTS20_Training_0	2020.07.13 21		1									
BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0	2020.07.13 21 2020.07.13 21	18:06.7 1	1									
BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0	2020.07.13 21 2020.07.13 21 2020.07.13 21	18:06.7 1	1 1 1									
BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0	2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21	18:06.7 1 05:42.1 1 07:52.3 1	ri ri ri ri									
BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0	2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21	18:06.7 7 05:42.1 7 07:52.3 7 15:23.5 7				Qk				Çar	ncel	
BraTS20_Training_0	2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 20 2020.07.13 20 2020.07.13 20	18:06.7 7 05:42.1 7 07:52.3 7 15:23.5 7 56:58.1 7					A.63	-U3-31 6 MP		Çaı 1 133	ncel	240
BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0 BraTS20_Training_0	2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 20 2020.07.13 20 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21 2020.07.13 21	18:06.7 7 05:42.1 7 07:52.3 7 15:23.5 7 56:58.1 7 15:04.4 7				2020-11-04 1		-03-31 č MP				240 240

Leaning Set Creation

Create Learning Set opens a dialog window which allows an empty learning set to be created and saved to the database (as component with extension .aiSet).

The next step is to add training samples. First select the learning set in the upper **1**. Learning Set list, then select Add Samples at the bottom of the **2**. Samples list.

earning Set [1]:	SELECT DATABAS	E D Healt	s_20	🗢 4 🕨 DataBase/	".aiSet]								Validate Sample
imponent name cu-1	-LAI LEARNIN		t id Series des ININC SET		Last Use Use		₹/0)	10	Group				
	-pri constitut	a set i se a	Nerto Jul			a and a							
Create Learning Se	nt+{Delete}Exp	ort Rename] e	visting Descriptio	n 🛞									i l
Samples													-
		l.		L	1	l .	Leve	1	1	1	T.	Les 1	
Subject Name	Study Date	Time	Study Description	Series Description	Modification	Last Use	Mod	nt	nz	nx	ny	Organ	
TS20_Training_0		20:51:57.8			2020-11-04 14:24			1	155	240	240		
TS20_Training_0		20:56:38.6			2020-11-04 14:25			1	155	240	240		
TS20_Training_0		21:06:49.1			2020-11-04 14:24			1	155	240	240		
TS20_Training_0		21:16:04.0			2020-11-04 14:24			1	155	240			
TS20_Training_0		21:02:35.2			2020-11-04 14:24.				155	240	240		
TS20_Training_0		21 18:06.7			2020-11-04 14:25			1	155	240	240		
TS20_Training_0		21:05:42.1			2020-11-04 14:24				155	240	240		
TS20_Training_0		21:07:52.3			2020-11-04 14:25			1	155	240	240		
TS20_Training_0		21:15:23.5			2020-11-04 14:24			1	155	240	240		
TS20_Training_0		20:56:58.1			2020-11-04 14:25			1	155	240	240		Designed and the second s
TS20_Training_0		21:15:04.4			2020-11-04 14:25			1	155	240	240		
TS20_Training_0		21:08:25.3			2020-11-04 14:25			1	155	240	240		
TS20_Training_0		21:04:45.9			2020-11-04 14:24			1	155	240	240		
TS20_Training_0		21:06:31.7			2020-11-04 14:24			1	155	240	240		
aTS20_Training_0	2020.07.13	21:09:50.8			2020-11-04 14:25			1	155	240	240		
aTS20_Training_0		21:13:39.9			2020-11-04 14:24			1	155	240	240		
TS20_Training_0		21:04:56.0			2020-11-04 14:25			1	155	240	240		Charge + 413 (2 P)
TS20_Training_0		20:51:18.1			2020-11-04 14:24			1	155	240	240		a state way to be the second
aTS20_Training_0		20:53 18.7			2020-11-04 14:24			1	155	240	240		
TS20_Training_0	2020.07.13	21:14:12.2	71		2020-11-04 14:24	. 2021-03-31.2.	. MR	1	155	240	240		01 <u>0.0</u> \$ 1.0
	-			1. C								•	
Add samples	🗙 Remove 🧹	×											8 [N]
Learning paramet		et settings	5. Weights & Manifes										
		a second a	a a arguna a manines										Sample Mask
Anonymize sam						Architectu	ne: Multi	channel Se	gmentation		> ?	Use GPU	MIX (RC8 Color)
Gaussian Smoot		Ind VOI Box siz	* 50.0 50.0 50.0 I	mmj Pixel size 2 0 [23	2.0 Jerrel		tch size:						25 4
Caussian Smoot	multipling len	Ten (fund)				Number of	epochs:						
	Z-Score		4 of sample.				ing rate:		4 Final UR				A O A O B & A+8 =

A dialog window appears for selection of the input images. The flat database view



and advanced filtering options are useful to list the only the image series which are first in the **Associated** list. Select all appropriate series from the filtered list and **Set Selected**. The dialog window is closed and the samples added are listed in **2. Samples**. For a quick quality control, the fusion of the sample image and the corresponding reference segment can be shown in the **Validate Sample** area by activating the **Preview** box:

Subject Id Series descr. W Modify time Last Use User Arch Project Croup Al LEARNING SET 2021-03-31 21.3 2021-03-31 2 User1 BraTS 20 Rename Jexisting Description 😁	Þ 8	BraTS_3	20		A DataBase/	.aiSet]									Preview	-	
At LEARANNEG ST 2021-03-31 21.3. 2021-03-31 2.1.3. 2021-03-31 2.1.3. 2021-103-31 2.1.3. Emarts 2.0 mename 1 existing Description Series Description Modification Last Use Mod nt nt </th <th>5</th> <th>ublect 1</th> <th>d. I</th> <th>Series destr.</th> <th>T Modify time</th> <th>Last Use</th> <th>User</th> <th>Arch</th> <th>Prote</th> <th>a 1</th> <th>Crown</th> <th></th> <th></th> <th></th> <th>Validate Sample</th> <th></th> <th></th>	5	ublect 1	d. I	Series destr.	T Modify time	Last Use	User	Arch	Prote	a 1	Crown				Validate Sample		
mm Study Description Series Description Modification Last Use Mod nt nz nx nx </th <th></th> <th></th> <th></th> <th>201103 0011011</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th>27</th> <th>or or op</th> <th></th> <th></th> <th></th> <th></th> <th>A</th> <th></th>				201103 0011011						27	or or op					A	
mm Study Description Series Description Modification Last Use Mod nt nz nx nx </th <th></th>																	
mm Study Description Series Description Modification Last Use Mod nt nz nx nx </th <th></th>																	
mm Study Description Series Description Modification Last Use Mod nt nz nx nx </th <th></th> <th>10 m</th> <th></th>																10 m	
mm Study Description Series Description Modification Last Use Mod nt nz nx nx </th <th></th> <th>12</th> <th></th> <th></th>															12		
mm Study Description Series Description Modification Last Use Mod nt nz nx nx </td <td></td> <td>1</td> <td>100</td> <td>100 C</td> <td></td>														1	100	100 C	
me Surdy Description Modification Modification Nordification Modification Nordification 557.8.11 2020-11-04 1622. 2021-03-312. MR 1 155 240 240 1564.6.11 2020-11-04 1622. 2021-03-312. MR 1 155 240 240 1564.0.11 2020-11-04 1624. 2021-03-312. MR 1 155 240 240 1806.7.11 2020-11-04 1624. 2021-03-312. MR 1 155 240 240 1806.7.11 2020-11-04 1624. 2021-03-312. MR 1 155 240 240 0542.1.11 2020-11-04 1625. 2021-03-312. MR 1 155 240 240 0553.1.11 2020-11-04 1625. 2021-03-312. MR 1 155 240 240 0553.5.11 2020-11-04 1625. 2021-03-312. MR 1 155 240 240 063.7.7 2020-11-04 1625. 2021-03-312. MR 1 155 240 240 063.7.7 2020-11-04 1625. 2021-03-312. MR 1 155 240 240 063.7.7 2020-11-04 1625. 2021-03-312. MR 1 155 240 240	Renam	ne]exi	sting	Description (8											1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
251578.11 2002-11-04 1422. 2021-03-312. MR 1 155 240 240 6649.1 1 2002-11-04 1422. 2021-03-312. MR 1 155 240 240 10640.1 1 2002-11-04 1422. 2021-03-312. MR 1 155 240 240 10542.2.11 2002-11-04 1422. 2021-03-312. MR 1 155 240 240 10552.3.11 2002-11-04 1422. 2021-03-312. MR 1 155 240 240 10552.3.11 2002-11-04 1422. 2021-03-312. MR 1 155 240 240 10552.3.11 2002-11-04 1423. 2021-03-312. MR 1 155 240 240 1052.3.11 2002-11-04 1423. 2021-03-312. MR 1 155 240 240 1052.3.11 2002-11-04 1423. 2021-03-312. MR 1 155 240 240 1053.4.11 2002-11-04 1423. 2021-03-312. MR 1 155 240 240 1054.3.11 2002-11-04 1423. 2021-03-312. MR 1 155 240 240 1054.3.11 2002-11-04 1423. 2021-03-312. MR 1 155 240 240															R 60 4		L
51578.11 2002-11-04 1424.2021-03-312. MR 1 155 240 200 6649.1 1 2002-11-04 1424.2021-03-312. MR 1 155 240 240 10640.1 1 2002-11-04 1424.2021-03-312. MR 1 155 240 240 10542.2 11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 10552.3.11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 15523.5.11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 15534.11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 15634.11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 15635.11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 <tr< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>30</td><td></td></tr<>																30	
51578.11 2002-11-04 1424.2021-03-312. MR 1 155 240 200 6649.1 1 2002-11-04 1424.2021-03-312. MR 1 155 240 240 10640.1 1 2002-11-04 1424.2021-03-312. MR 1 155 240 240 10542.2 11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 10552.3.11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 15523.5.11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 1563411 2002-11-04 1424.2021-03-312. MR 1 155 240 240 15635.1.11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 15635.3.11 2002-11-04 1424.2021-03-312. MR 1 155 240 240 24												245					
59:38.6. T1. 00:49.1. T1. 2020-11-04:142%. 2021-03:31.2. MK 1 155 240 240 16:04.0. T1. 2020-11-04:142%. 2021-03:31.2. MK 1 155 240 240 2023.2. T1. 2020-11-04:142%. 2021-03:31.2. MK 1 155 240 240 00:50.2. T1. 2020-11-04:142%. 2021-03:31.2. MK 1 155 240 240 00:50.3. T1. 20	ime	.5	Study Des	cription	Series Description	Modification	Last	Use	Mod	nt	nz	mx .	ny	Organ	100	1000.000	
06 491. 11. 2020-11-04 1424. 2021-03-12. MR 1 155 240 240 20235.2. 11. 2020-11-04 1424. 2021-03-12. MR 1 155 240 240 20352.3. 11. 2020-11-04 1424. 2021-03-12. MR 1 155 240 240 5543.1. 11. 2020-11-04 1424. 2021-03-12. MR 1 155 240 240 15235.5. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 15245.5. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 15245.7. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 15245.7. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 15344. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 0445.9. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 0455.1. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 0455.3. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 0455.3. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 05.17. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 05.17. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 05.17. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 05.17. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 05.17. 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 05.18.1 11. 2020-11-04 1425. 2021-03-12. MR 1 155 240 240 00. 2248.9498 00. 2248.	51-57	7.8 T	1			2020-11-04 14:	24 2021	-03-31 2	MR	1	155	240	240		100	AND REAL PROPERTY.	
16040. 11. 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 20352. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 0542.L. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 0553.L. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 0631.7. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 0631.7. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 0631.7. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 0631.7. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 0631.7. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 0631.7. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 05508. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 05508. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 05508. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 05508. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 05508. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 05508. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 05508. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 00.0 ↓ 248.9498 11.12.2. 11. 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 00.0 ↓ 248.9498 11.12.2. 11. 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 00.0 ↓ 248.9498 00.0 ↓										1						Contract of the	
202352.11. 2020-11-04 1424.2021-05-112. MR 1 1355 240 240 5542.1. T1 2020-11-04 1424.2021-05-112. MR 1 1355 240 240 5543.1. T1 2020-11-04 1424.2021-05-112. MR 1 1355 240 240 5543.1. T1 2020-11-04 1425.2021-05-112. MR 1 1355 240 240 5643.7. T1 2020-11-04 1425.2021-05-112. MR 1 1355 240 240 5637.3. T1 2020-11-04 1425.2021-05-112. MR 1 1355 240 240 5637.7. T1 2020-11-04 1425.2021-05-112. MR 1 1355 240 240 5137.7. T1 2020-11-04 1425.2021-05-112. MR 1 1355 240 240 5137.7. T1 2020-11-04 1425.2021-05-112. MR 1 1355 240 240 5138.7. T1 2020-11-04 1424.2021-05-112. MR 1 1355 240 240 5147.7. T1 2020-11-04 1424.2021-05-112. MR 1 1355 240 240 5147.7. T1 2020-11-04 1424.2021-05-112. MR 1 1355 240 240 5147.7. T1 2020-11-04 1424.2021-05-112. MR 1 1355 240 240 5148.7. T1 2020-11-04 1424.2021-05-112										1							
13067. 11. 2020-11-04 1425. 2021-03-312. MK 1 155 240 240 0752.3. 11. 2020-11-04 1425. 2021-03-312. MK 1 155 240 240 0752.3. 11. 2020-11-04 1425. 2021-03-312. MK 1 155 240 240 0552.1. 11. 2020-11-04 1425. 2021-03-312. MK 1 155 240 240 0653.7. 11. 2020-11-04 1425. 2021-03-312. MK 1 155 240 240 0644.9. 11. 2020-11-04 1425. 2021-03-312. MK 1 155 240 240 0645.9. 11. 2020-11-04 1425. 2021-03-312. MK 1 155 240 240 0653.8. 11. 2020-11-04 1425. 2021-03-312. MK 1 155 240 240 0653.8. 11. 2020-11-04 1424. 2021-03-312. MK 1 155 240 240 0653.8. 11. 2020-11-04 1424. 2021-03-312. MK 1 155 240 240 0555.8. 11. 2020-11-04 1424. 2021-03-312. MK 1 155 240 240 1412.2. 11 2020-11-04 1424. 2021-03-312. MK 1 155 240 240										1					2	P	
05 42.1. 11. 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 15 23.5. 11. 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 15 23.5. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 06 82.5. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 06 83.7. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 06 83.7. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 06 53.7. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 09 50.8. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 09 50.8. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 09 50.8. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 09 50.8. 11. 2020-11-04 1425. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 122. 71 2020-11-04 1424. 2021-03-312. MR 1 1 155 240 240 14 12. 71 70 70 70 70 70 70 70 70 70 70 70 70 70										1					12- C		
07523.7 T1 2000-11-04 1422.2021-03-312. MK 1 155 240 240 5558.1 T1 2000-11-04 1425.2021-03-312. MK 1 155 240 240 06253.7 T1 2000-11-04 1425.2021-03-312. MK 1 155 240 240 0631.7 T1 2000-11-04 1425.2021-03-312. MK 1 155 240 240 0631.7 T1 2000-11-04 1424.2021-03-312. MK 1 155 240 240 0635.0 T1 2000-11-04 1424.2021-03-312. MK 1 155 240 240 0550.0 T1 2000-11-04 1424.2021-03-312. MK 1 155 240 240 0.0 € 244.9498 1 125 240 240 0.0 € 244.9498 0.0 € 244.9498										1							
15 22.5. 11. 15 22.5. 11. 2020-11-04 1424. 2021-03-13.2. MR 1 155 240 240 06 25.3. 11. 2020-11-04 1425. 2021-03-13.2. MR 1 155 240 240 06 45.9. 11. 2020-11-04 1424. 2021-03-13.2. MR 1 155 240 240 05 50.8. 11. 2020-11-04 1424. 2021-03-13.2. MR 1 155 240 240 05 50.8. 11. 2020-11-04 1424. 2021-03-13.2. MR 1 155 240 240 05 50.8. 11. 2020-11-04 1424. 2021-03-13.2. MR 1 155 240 240 05 50.8. 11. 2020-11-04 1424. 2021-03-13.2. MR 1 155 240 240 05 50.8. 11. 2020-11-04 1424. 2021-03-13.2. MR 1 155 240 240 05 50.8. 11. 2020-11-04 1424. 2021-03-13.2. MR 1 155 240 240 0.0 ↓ 248.9498 14122 11. 2020-11-04 1424. 2021-03-13.2. MR 1 155 240 240 0.0 ↓ 248.9498 14122 11. 2020-11-04 1424. 2021-03-13.2. MR 1 155 240 240 0.0 ↓ 248.9498 0.0 ↓ 248.										1							
55 55.1 11 2020-11-04 1425. 2021-05-312. MK 1 155 240 240 08253. T1 2020-11-04 1425. 2021-05-312. MK 1 155 240 240 06317. T1 2020-11-04 1424. 2021-05-312. MK 1 155 240 240 05508. T1 2020-11-04 1424. 2021-05-312. MK 1 155 240 240 05508. T1 2020-11-04 1424. 2021-05-312. MK 1 155 240 240 05508. T1 2020-11-04 1424. 2021-05-312. MK 1 155 240 240 5118.1. T1 2020-11-04 1424. 2021-05-312. MK 1 155 240 240 5118.1. T1 2020-11-04 1424. 2021-05-312. MK 1 155 240 240 0.0 € 248.548 14122. T1 2020-11-04 1424. 2021-03-312. MK 1 155 240 240 0.0 € 248.548 14122. T1 2020-11-04 1424. 2021-03-312. MK 1 155 240 240 0.0 € 248.548 14122. T1 2020-11-04 1424. 2021-03-312. MK 1 155 240 240 0.0 € 248.548 0.0 € 248.548										1					. 1.0	A 8 1	
15 04.4, 11 15 04.4, 11 06 25.3, 11 06 25.3, 11 06 25.3, 11 06 25.3, 11 07 05 05.8, 11 07 05 05.1, 11 07 05 01.104 142.4, 2021-03-312, MR 1 155 240 240 05 05.8, 11 07 05 01.104 142.4, 2021-03-312, MR 1 155 240 240 05 05.8, 11 07 05 01.104 142.4, 2021-03-312, MR 1 155 240 240 05 05.11 07 05 01.104 142.4, 2021-03-312, MR 1 155 240 240 05 05.11 07 05 02 01-104 142.4, 2021-03-312, MR 1 155 240 240 00 € 248.9498 14122, 11 00 € 248.9498 14122, 11 00 € 248.9498 14122, 11 00 € 248.9498 14122, 11 00 € 248.9498 1412, 11 155 240 240 10 0 € 248.9498 10 0 € [k] € [k] € 66 [k] 10 0 € [k] € 66 [k] 10 0 € 248.9498 10 0 € [k] € [k] € 66 [k] 10 0 € [k] € 66 [k] 10 0 € [k] € [k] € 66 [k] 10 0 € [k] € [1							
08253. T1 00459. T1 2020-11-04 1425. 2021-03-312. MR 1 155 240 240 06317. T1 2020-11-04 1424. 2021-03-312. MR 1 155 240 240 05508. T1 2020-11-04 1424. 2021-03-312. MR 1 155 240 240 0.0 € 240 2020-11-04 1424. 2021-03-312. MR 1 155 240 240 2020-11-04 1424. 2021-03-312. MR 1 155 240 240 2020-11-04 1424. 2021-03-312. MR 1 155 240 240 0.0 € 248.9498 0.0 € 248.9498										1						2 43	
04-45.9, 11 06-31.7, 11 02020-11-04 1424, 2021-03-31.2, MR 1 053.7, 11 02020-11-04 1425, 2021-03-31.2, MR 1 02020-11-04 1425, 2021-03-31.2, MR 1 02020-11-04 1425, 2021-03-31.2, MR 1 02020-11-04 1424, 2021-03-31.2, MR 1 0 0 0 0 0 0 0 0 0 0 0 0 0										1					• •	Q. 199	
0631.7. T1 2020-11-04 142.4. 2021-03-31 2 MR 1 135 240 240 0550.8. T1 2020-11-04 142.4. 2021-03-31 2 MR 1 155 240 240 0.0 € 248.9498 1412.2. T1 2020-11-04 142.4. 2021-03-31 2 MR 1 155 240 240 1412.2. T1 2020-11-04 142.4. 2021-03-31 2 MR 1 155 240 240 1412.2. T1 2020-11-04 142.4. 2021-03-31 2 MR 1 155 240 240 10.0 € 248.9498 0.0 € 248 0.0 € 248.9498 0.0 € 248.94										1					PT 20 11		
09508. 11 1339.9. 11 1339.9. 11 2020-11-04 1422. 2021-03-312. MR 1 155 240 240 04550.0 11 2020-11-04 1422. 2021-03-312. MR 1 155 240 240 35.18.1. 11 2020-11-04 1424. 2021-03-312. MR 1 155 240 240 14122. 11 2020-11-04 1424. 2021-03-312. MR 1 155 240 240 10.0 € 248.9498 10.0 € 248										1					78 1	4	5.3
13 39.9 T1 00 € 50.0 T1 2020-11-04 1424 2021-03-31 Z MR 51 18.1. T1 2020-11-04 1424 2021-03-31 Z MR 1 155 240 240 14 12.Z T1 2020-11-04 1424 2021-03-31 Z MR 1 155 240 240 0.0 € 248.5498 0.0 € 248.548 0.0										1					an 11 11		
04-56.0. 11 2020-11-04 14252021-03-312 MR 1 155 240 240 551.81 T1 2020-11-04 14242021-03-312 MR 1 155 240 240 14.122 T1 2020-11-04 14242021-03-312 MR 1 155 240 240 ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓										1							
51.18.1.11 2020-11-04 14/24., 2021-03-31 2 MR 1 155 240 240 14.12.2T1 2020-11-04 14/24., 2021-03-31 2 MR 1 155 240 240 ↓ 0.0 € 248.9498 ↓ 0.0 € 248.9498\\ ↓ 0.0	1:04:56	6.0 T	1							1	155	240	240		A		1
14-12.2_T1 2020-11-04-14-24_2021-03-31 2_MR 1 155 240 240 ings 5.Weights & Manifest @ X @ @ I import OVL Mask ▼ > Lt ▼										1					CUTA CLEA		100
ings 5. Weights & Manifest @ X @ C I I I I I I I I I I I I I I I I I I										1						1 140 0400	
ings 5. Weights & Manifest @ x @ b import @ x @ b import OVL Mask > Lt	14:12	Z.2 T	1			2020-11-04 14:	24 2021	-03-31 2	MR	1	155	240	240		0.0	₹ 240.9498	
ings S.Weights & Manifest @ X @ Import OVL Mask > Lt				-11												X	_
ings S.Weights & Manifest @ X @ Import OVL Mask > Lt															0 [%]	× 66	151
ings 5. Weights & Manifest Sample Mask																	
ings 5. Weights & Manifest Sample Mask															D Pro-		-
		100	Malaker												a) as	U 4	1
· ★ ■◆■ Import OVL Mask ▼ > Lt ▼	tings	<u>.</u> 5.	weights	& manifest													
⊙ X															Sample	Mask	
UTIMER VII												100		-			
													×	Import	OVL Mask	♥ > Lt ♥	
																-	

Data Preparation

In **3. Learning parameters**, the data preparation steps, architecture to be used and the training settings are configured.

omponent name	Subject name	Subjec	t id 1	Series descr.	T Modify time	Last Use	User	Arch	Project	T a	Group	1		
xu-1	-[AI LEARNING SET]		INING SET		2021-03-31 21:3			8raTS 20		15				
			1000	Description (C)	6.1									
Create Learning 5	et + [Delete Export	Rename J e	xisting	Description @	9									
										unione la				
Samples														
and the second second	In the La					Las and	- 1 ×			1	1	1	1	1.0
 Subject Name 		ime	Study De	scription	Series Description	Modification	Last U		Mod	nt	nz	nx	ny	Organ
raTS20_Training_0		0.51:57.8				2020-11-04 14				1	155	240	240	1.1
raTS20_Training_0		0:56:38.6				2020-11-04 14				1	155	240	240	
raTS20_Training_0		1:06:49.1				2020-11-04 14:				1	155	240	240	
iraTS20_Training_0		1:16:04.0				2020-11-04 14:				1	155	240	240	
raTS20_Training_0		1:02:35.2				2020-11-04 14:				1	155	240	240	
raTS20_Training_0		1:18:06.7				2020-11-04 14:				1	155	240	240	
raTS20_Training_0		1:05:42.1				2020-11-04 14				1	155	240	240	
iraTS20_Training_0		1:07:52.3				2020-11-04 14				1	155	240	240	
raTS20_Training_0		1:15:23.5				2020-11-04 14				1	155	240	240	
raTS20_Training_0		0:56:58.1				2020-11-04 14:				1	155	240	240	
raTS20_Training_0		1:15:04.4				2020-11-04 14:				1	155	240	240	
raTS20_Training_0		1:08:25.3				2020-11-04 14				1	155	240	240	
raTS20_Training_0		1:04:45.9				2020-11-04 14				1	155	240	240	
raTS20_Training_0		1:06:31.7				2020-11-04 14				1	155	240	240	
raTS20_Training_0		1:09:50.8				2020-11-04 14				1	155	240	240	
raTS20_Training_0		1:13:39.9				2020-11-04 14				1	155	240	240	
raTS20_Training_0		1:04:56.0				2020-11-04 14				1	155	240	240	
raTS20_Training_0		0:51:18.1				2020-11-04 14:				1	155	240	240	
raTS20_Training_0		0:53:18.7				2020-11-04 14:				1	155	240	240	
raTS20_Training_0	2020.07.13 2	1:14:12.2	T1			2020-11-04 14:	24 2021-0	3-31 2	MR	1	155	240	240	
1				1										•
Add samples	🗙 Remove 🧹 🗙													
. Learning parame	ters 4. Target set	tings	5. Weight	s & Manifest										
	and a second													
🖌 Anonymize sam	pies						A	chitecture	e: Multicha	innel Seg	mentation		1 ?	Use GPU
C. Construction D	Terreto and the		- 100 0 10	an line liter t	Bluel size D.O. Harr	Do I front								
Crop image:	Crop to associated Vi	Box siz	e 150,0 15	0.0 [50.0 [(mm]	Pixel size 2.0 2.0	2.0 [mm]		Bate	ch size: 5					
Conselan Smart		(mark)												
Laussian smoot	thing 8.0 8.0 8.0	funut					N	umber of e	pochs: 5					
Scale Values to	Z-Score	-	4 1	of sample				Learning	ng rate: 5.0E	-4	Final LR	in Manifes	a hat	

The available data preparation steps are:

• Anonymize Samples: Anonymizes all images selected for training or workspace export (this is particularly relevant for training on cloud-computing infrastructure).

- Crop Image: Enables cropping to the associated VOI as described in <u>Data Preparation</u>^D³⁴ or to a fixed Box size.
- **Pixel Size**: Re-sampling of the images to a certain pixel size by either interpolation or down-sampling.
- Gaussian Smoothing: Input image smoothing to reduce noise.
- Scale Values to: Normalization of the pixel value range by scaling according to a method selected.

M	Aver
	Max
	Aver above % of Max
	Aver in percentile range
	Z-Score

Note that as an alternative to such pre-processing steps, the input images could be (manually) preprocessed in other PMOD tools. In this case, however, the identical operations have to be applied to the input images before prediction.

Data preparation helps to reduces the amount of unnecessary information in the sample and standardize images which were not acquired using the same protocol.

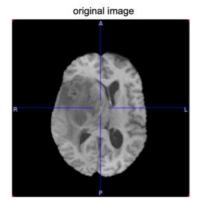
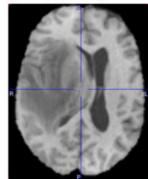


image after preprocessing in PMOD



Neural Network and Training Parameters

The neural network **Architecture** and the training parameters are selected in the area to the right.

2020-11-04 14:	4 2021-03-31 2 MR 1 155	5 240 240
ts & Manifest		
10.0 50.0 [mm] Pixel size 2.0 2.0 [mm]	Architecture: Multichannel Segmentati Batch size: 5 Number of epochs: 5	on 🔻 4 🕨 ? 🛄 Use GPU ME
of sample.		LR in Manifest: NaN
ain Net <u>w</u> ork with Workspace	0	G. Save Learning Set 🛛 Save as

The neural network architecture is selected from the drop-down menu **Architecture**. The list corresponds to the the content of the Pmod4.2/resources/pai folder, where the neural network configurations are stored in sub-directories. Note that the **Multichannel Segmentation** architecture is designed to be retrainable. It was initially tested for the 4 input series, 3 segment output MICCAI BraTS example case, and was successfully reapplied for the Rat Brain

Dopaminergic PET example case. This retraining is described as a Case Study later in this documentation.

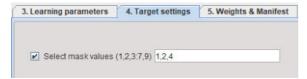
The checkbox **Use GPU** allows you to choose between training using the CPU or available/compatible GPU.

The training parameters are:

- **Batch Size**: This parameter defines the number of samples that are processed before the internal model parameters are updated.
- Number of Epochs: Defines the number of times that the learning algorithms processes the entire training data sets. The length of the vector of loss values recorded in the Manifest corresponds to the number of epochs. Hence multiple epochs are required to observe an evolution of the loss value through training.
- Learning Rate: Defines the rate of change of the Weights. (For a Learning Set that has been used for training the final learning rate reported in the Manifest is shown)

Definition of Target Segments

The reference segment image may contain more segments than actually required. The option **Select mask values** on the **4**. **Target Settings** panel allows the integer value of the required segments to be specified by entering the label values of the target segments, separated by a "comma".



Saving of Training Result

Two files result from a neural network training, **Weights** and **Manifest**. The **Weights** file contains the weighting given to each layer in the network. The **Manifest** file contains details of the **Learning Set** and the training process such as the samples used for training, samples used for validation (every fifth sample), number of epochs used, batch size, volume size, and the segments in the output.

The file locations are defined on the **5. Weights & Manifest** panel, and the files will be logically attached to the current learning set.

Veights f weights_TF.	5 <1701/2011/4642/*/B	raTS>			Ξ×	942	Import
danifest					• ×	⊜¢∎	Import
Send e			Copy to FTP ser NODE_1	- 4 1		MOD@loca	ilhost [

4 Training of Neural Network

Training of the neural network can be performed in three different ways represented by the three buttons at the bottom of the dialog window:

Train Network 🛛 🖶 Export R Workspace 🛛 🦣 Train Network with Workspace

- The Train Network button directly starts the configured training locally. Depending on the checkbox Use GPU, either your CPU or GPU will be used. Note that only the samples selected in the 3. Samples list will be used for the training. As a result, the weights and manifest files will be updated.
- 2. When activating <u>Export R workspace</u>^{□51}, the configured preprocessing operations are applied to the selected data and the resulting images are exported together with the training configuration in the form of a compact R workspace. The workspace can then be transferred to a more powerful processing environment for the actual training. This can either be another PMOD installation on a more powerful machine or in the cloud.
- 3. The **Train Network with Workspace** button opens a dialog window for loading a previously exported R workspace and starts the training locally.

Deployment

After completion of the training, the resulting **Weights** and **Manifest** files can be transferred, along with the definition of the model if necessary, to other PMOD installations for prediction.

Recommendations

On typical personal computers local training is only recommended for tests with a limited amount of data. Performance may be acceptable with data that has a small matrix size (e.g. 50 x 50 x 50 for cropped PET data) and low number of input series for multichannel segmentation (e.g. 1 or 2). The total time required for training cannot be estimated. While training is running you will see a significant load on CPU/GPU. Even for powerful workstations, training with hundreds of samples may take many hours. Training on a cloud computing infrastructure with virtual machines accessing several GPUs is likely to be more time- and cost-efficient.

It is advisable to always perform a small "infrastructure check" training before launching training with your full data set and many epochs. This can be performed using the minimum requirement for input samples (2 samples), a batch size of 1 and a low number of epochs (1 is acceptable, but 2 or 3 will reveal changes in the loss value in the Manifest). If the input data has a high matrix size (e.g. 200 x 200 x 200) and/or there are multiple input series in the sample, the data volume could be reduced by using a larger pixel size for this training test (e.g. $2 \times 2 \times 2 \times 2$ mm instead of planned 1 x 1 x 1 mm).

Training Progress and Output

For data prepared on your local system, training is started by selecting the desired samples in the **Learning Set** and clicking **Train Network**:

Component name Subject name Subject i ame Subject i Series descr. V Modif time Lati Use User Arch Project Group esample-learning set -/ALEARNING SE ALLEARNING 2021-04-02 16 2 2021-04-02 1 User1 Pmod Create Learning Set - [Delete] Export Rename] existing Description Create Learning Set - [Delete] Export Rename] existing Description Create Learning Set - [Delete] Export Rename] existing Description Component and Subject name Subject name] existing Description Create Learning Set - [Delete] Export Rename] existing Description Component and Subject name Subject name] existing Description Component and Subject name] existing Description] exercise subject name] existing and examples and examples and examples [Comp IIII _ 2021-04-021. PT 1 400] [IIIII _	earning Set [1]: S	ELECT DATABASE	⊳ Prnod	•	DataBase/	*.aiSet]						Validate Sample
Create Learning Set + [Delete Export Rename] existing Description (a) finite is a description. 2. Samples * Subject Name * Subject Name * Subject Name * Add samples * Add samples </th <th></th> <th></th> <th></th> <th>Series descr</th> <th></th> <th></th> <th></th> <th></th> <th>Project</th> <th>Gro</th> <th>up</th> <th>Fandate Sumple</th>				Series descr					Project	Gro	up	Fandate Sumple
Create Learning Set + [Delete Export Rename] existing Description Descri	ample-learning-set	-(AI LEARNING SE.	ALLEARNING		2021-04-02 16:2	. 2021-04-02 1	User1	Pmod				
2. Samples	-				1							
Study Liste Imme Study Liste EARLY 2021-01-07 17.3. 2021-04-02 1. PT 1 40 15:05:25 RAC EARLY 2021-01-07 17.3. 2021-04-02 1. PT 1 40 08:34:45 DTBZ EARLY 2021-01-07 17.4. 2021-01-07 17.5. 2021-04-02 1. PT 1 40 09:32:0 MP EARLY 2021-01-07 17.4. 2021-04-02 1. PT 1 40 09:32:0 MP EARLY 2021-01-07 17.4. 2021-04-02 1. PT 1 40 10:41:0 MP EARLY 2021-01-07 17.4. 2021-04-02 1. PT 1 40 09:32:0 MP EARLY 2021-01-07 17.4. 2021-04-02 1. PT 1 0		+ [Delete Export R	ename] existing	Description 😁	this is a descriptio	n	192392272277					- 1 56
104110 RAC EARLY 2021-01-07 17.3												1
085725 RAC EARLY 2021-01-07 17.1. 2021-01-07 15.5. 2021-01-07 15.5. 15:0025 DTBZ EARLY 2021-01-07 15.5. 2021-01-07 15.5. 2021-01-07 15.5. 09:44.45 DTBZ EARLY 2021-01-07 15.5. 2021-01-02 1.PT 1 40 09:13:20 MP EARLY 2021-01-07 15.5. 2021-01-02 1.PT 1 40 09:13:20 MP EARLY 2021-01-07 15.5. 2021-01-02 1.PT 1 40 09:13:20 MP EARLY 2021-01-02 1.PT 1 40 10:13:20 MP EARLY 2021-01-02 1.PT 1 40 10:13:20 MP EARLY 2021-01-02 1.PT 1 40 11:10:10:10:10:10:10:10:10:10:10:10:10:1	Subject Name									1		
03.4445 DTBZ EARLY 2021-01-07 17.0. 2021-04-021. PT 1 40 09.13.20 MP EARLY 2021-01-07 17.4. 2021-04-021. PT 1 40 09.13.20 MP EARLY 2021-01-07 17.4. 2021-04-021. PT 1 40 Add samples X Remove X Image: Composition of the state in the st										1		
09:13:20 MP EARLY 2021-01-07 17.5		15:0		EAF	RLY.	2021-01-07 16	5 2021	I-04-02 1 F	T	1	40	() S ()
09:12:0 MP EXELY 2021:01:07:17.4 2021:04:02:1 PT 1 40 09:12:20 MP EARLY 2021:01:07:17.4 2021:04:02:1 PT 1 40 4.1 arget settings 5. Weights & Manifest • </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>1</td> <td></td> <td></td>										1		
Add samples × Remove ✓ X Add samples × Remove ✓ X A Learning parameters A Target settings 5. Weights & Manifest Anonymice samples Crop in. Crop to associat. Box s. 0000000 [mm]. Pixel:::::[] Ratch size: [] Number of epoc5										1. 3		
Add samples × Remove × X 3. Learning parameters 4. Target settings 5. Weights & Manifest Anonymize samples Crop Im. Crop to associat. Box s. 200 200 [mm. Pixel : [m. Bitch size: 1 Number of epoc 5 Number of epoc 5		09:1	3:20 MP	EAP	(L¥	2021-01-07 17	:4 2021	1-04-02 1 P	46	া ি	40	
Add samples × Remove ✓ X 3. Learning parameters 4. Target settings 5. Weights & Manifest Anonymize samples Crop Im. Crop to associat. Box s.: 200 ::00 ::00 ::00 ::00 ::00 ::00 ::0						-						
3. Learning parameters 4. Target settings 5. Weights & Manifest Anonymize samples Architect. Multichannel Segm. • • • • • • • • • • • • •											•	
A. Learning parameters A. Larget settings S. Learning parameters A. Larget settings A nonymize samples Architect Multichannel Segm V () S. Learning Crop Im Crop Im Crop Im Pixel Tm Batch size: 1 Number of epoc S	🕈 Add samples 🔹	Remove 🧹 🗙										0 [8] × 100 [
Crop Im. Crop to associat. Box s 500 500 500 [mm	I. Learning paramete	rs 4. Target setti	ngs 5. Weig	its & Manifest								
Crop Im. Crop to associat. Box s 500 500 200 [mm Pixel 5 [m Batch size: 1	Anonymize sampl	les				Architect	Multichar	nel Seam	• (1)	2 0	Ise	Sample Mask
Gaussian Smoothing 20 00 [mm] Number of epoc5	Crop im	on to associat Box	s 500 500 5	Imm Pixel	t t Im.					1.1		MIX = (RGB Color)
Gaussian Smoothing 10 89 00 [mm] Number of epoc. 5			and the second s		- It form							
Scale Values to: Z-Score • 4 > of sample. Learning rate: 5.0E-4 4 Final LR in Manif_ out	Gaussian Smooth	hing 80 80 9.0	[mm]			Number of	epoc 5					
	Scale Values to:	Z-Score		of sample.		Learnin	ng rate: 5.0	DE-4 F	Final LR in	Manif		→ O A O B ® A+B =

The **RConsole** opens and the Execution test and PAI diagnostics test are performed. If the tests are passed the selected samples (all input series and associated Segments) are loaded:

🖁 Roonsole	× [?		(0%)			
Data 🕶 Matrix 👻 Measure 👻 Workspace 👻 🎫	Scripts > Application	MR . Relaxometry	• ?	General	ANOVA	-	?	× 🗖	*
Commands [<ctrl+enter>-> execute, <ctrl+b>-> execute block, <ctrl+up down=""></ctrl+up></ctrl+b></ctrl+enter>	12 .2	na × 1		Output				6	×
		Ex R 1 Pn Lo Lo Lis Lo Lo Lo Lo Lo	ecution tes version 4.0 nod PAI dia ading ima ading ima at creation ading ima ading ima ading ima ading ima	agnostics test (l ge data: 1/2 inp ge data: 2/2 inp Created. ge data: 1/1 ma Created. ge data: 1/2 inp ge data: 2/2 inp Created.) 'Bunny-Wunnies	aded. aded. aded. aded. aded.	JW5		

During training a high CPU/GPU load can be observed in the system monitor (Windows 10 Task Manager shown):

rocesses	Performance App history	Startup Users	Details Services			
[mm]	CPU 30% 3.52 GHz	CPU % Utilization	Intel(R) Core(TM) i7-2600K CP		5Hz
	Memory 7.3/24.0 GB (30%)	· · · · · · · · · · · · · · · · · · ·		my		
	Disk 0 (D:) 0%					
٨	Disk 1 (C:) 0%				L	~
	Ethernet Local Area Conne	60 seconds Utilization	ipeed	Base speed:	3.40 GHz	C
	S: 0 R: 0 Kbps		3.52 GHz	Sockets:	1	
				Cores:	4	
		Processes T	hreads Handles	Logical processors:	8	
		228 2	2618 94886	Virtualization:	Disabled	
		Uptime		Hyper-V support:	Yes	
			10	L1 cache:	256 KB	
		14:17:17:	10	L2 cache: L3 cache:	1.0 MB 8.0 MB	
				L3 cache:	a.u MB	

Once training is complete a dialog appears to save the **Weights**. They can be saved to the database or file system (the same database as the **Learning Set** is recommended):

Save as AI LEARI	NING WEIGHTS										×
	Pmod	🗢 📢 🕨 [DataBase/*.t	15]			× c	lear Fill	ter	8 Refresh Query	ø	•
Enter name exam	nple-training						×	1	Attach to Subject (s) ×
Subject Name Subject ID		Birth Date:	1	3	1	Q.		•			
Component name	*	Modification:			1	•		•	Prj * Grp *	_	▼
Components 🕤	1							-			
√ Sejectall X		Export Rename		 				L	Save to Eile S	ystem	
	🚽 Save						Cancel	2			

A confirmation dialog in the RConsole confirms that learning was completed and the components saved. The RConsole can be closed:

nomon/maskim	agene Wil e pante (ma	ekima'i essa		
names(maskim	ages6)[i] <- paste("ma	isking,i,sep=	· <i>h</i>	^
) maaldmaaaa < lint/	a secolar di mana bilana a		- maaldaa aa a 2 a	amala 2-r
	sample1=maskimag	es i,sampiez-	-maskimagesz,s	ampie3=i
rm(i);				
rm(masklmages1);				
gc(verbose=FALSE)				
rm(masklmages2);				
gc(verbose=FALSE)	,			
rm(maskimages3);				
gc(verbose=FALSE)	;			
rm(maskimages4);				
gc(verbose=FALSE)	;			
rm(maskimages5);				
gc(verbose=FALSE)	1			
rm(maskimag				
gc(verbose=F Conf	irmation		>	×
> pm.show(C	100012104000			
> failed <- FAL	Learning has			
if(TRUE && (Weights file ha			nages]
print('Inval			as been saved.	
failed <- T	Do you want to	close Rcons	ole?	
}else {				
output <-	✓ Yes		× No	
3	• 103			
				_
	finished.'			_
> result <- 'Learning	result <- 1 earning fai	led.7		1
> result <- 'Learning > if(failed==TRUE){				
	, count a counting for			
> if(failed==TRUE)	, south a south			

The Weights and Manifest are now attached to the Learning Set:

omponent name	Subject nan	ne Sut	jectid Series des	cr. 🔽 Modify time	LastUse U	Iser Arch	Proje	id.	Group	Validate Sample
ample-learning-se		NG SE AI LI		2021-04-02 16.2		ser1 Pmod	11.151		Group	
				1					-	•
Create Learning	Set + [Delete] Ex	port Rename	e]existing Description	in 🛞 this is a descriptio	n					
. Samples										
Subject Name	Study Date	Time	Study Description	Series Description	Modification	LastUse	Mod	nt	nz	
16RAC^ROI2	2017.10.06	10:41:10	RAC	EARLY	2021-01-07 17:3.			1	40	
19RACAROI2	2017.10.09	08:57:25	RAC	EARLY	2021-01-07 17:1.			1	40	
36DTBZ*ROI2	2017.10.11	15:09:26	DTBZ	EARLY	2021-01-07 16:5.			1	40	() () () () () () () () () ()
39DTBZ*ROI2	2017.10.12	08:44:45	DTBZ	EARLY	2021-01-07 17:0.	2021-04-02 1	PT	1	40	
47MP*ROI1	2017.10.17	09:13:20	MP	EARLY	2021-01-07 17:5.			1	40	
47MP*ROI2	2017.10.17	09:13:20	MP	EARLY	2021-01-07 17:4.	2021-04-02 1	PT	1	40	
										Gray
0										m 0.0 \$ 1.0
Add samples	× Remove	v x								0 [8] - 0 100 [
3. Learning param	otors A Tarn	et settings	5. Weights & Manifest							
A counting param	eters 4. rary	er serings	5. Weights & mannes	91L						
Weightsexample	a haisiga x0/20/5	0.7/Denode					e x	CRAS	Import	Sample Mask
										MIX (RGB Color)
Manifestexample	e-training.json <8	/20/51/*/Pmod	Þ				Θ×	846	Import	
	de			1000	FTP NODE 1		1			

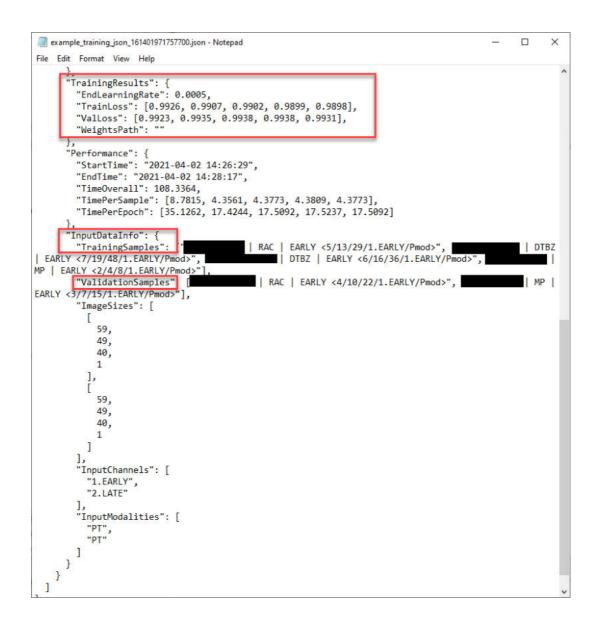
Details of the training are recorded in the Manifest. It can be exported and read using a text editor:

								×	
DATABASE Pmod		V I DataB	ase/*json]		× c	lear Fitter	9 Refresh C	luery 🤗 🕤	sw [
Subject Name * Subject ID * Component name *	rrent Series		Modification					•	te Sample
AI LEARNING MANIFEST	(1) 🖲								
Component name example-training json	Subject name -(AI LEARNING SE		Series descr.	₩ Modify Imme 2021-04-02 16 2	Last Use	File size	Sex	Birth dati	0 4 1 1 0 4 4 1 1 1 4 0 5 1 1 4 0 5 5 1 4 0 5 5 Gray + + 5 5 5 00 \$ 10 0 5 10
 ✓ Seject all X 8 	Delete	Export Rename	8			e	Load from	File System	
aining json <8/20/51/*/Pr	Retrieve		Copy to FTP			- × 6	€ € CD(B)localhes		ample Mask (RGB Color)
	Subject Name Subject ID Component name Cu Current name Current name Current name Current name Current name example-training json	Subject Name Subject D Component name Courrent Series AL LEARNING MANIFEST [1] Component name example-training json ULEARNING SE	Subject Name Subject II Component name Current Series ALEARNING MANFEST [1] © Component name Subject and Subject id Subject id Su	Subject Name Subject ID Sirth Date Modification Component name Subject name Last Use At LEARNING MANIFEST [1] Concerning Subject id Series descr. Component name Subject name Subject id Series descr. Component name Dubject name Subject id Series descr. Component name Subject name Subject name Subject id Series descr. Component name Subject name Subject name Subject id Series descr. Component name Subject name Subject name Subject id Series descr. Component name Subject name	Subject Name Subject I Birth Date: Modification: Subject I Current Series Last Use: La	Subject Name Subject II Series Birth Date: Birth Date: Modification: Modification: Automatic Series Subject II Series descr. Modify time Last Use 2021-04-02 16:2, 2021-04-02 10; 2021-04-02	Subject Name Subject I Sub	Subject Name Subject Name Subject Name Subject Name Current Series ALEARNING MANFEST [1] Component name Subject name Subject id Series descr. Modify time Last Use File size Sex Sex Sex Sex Sex Sex Sex Sex Sex Se	Subject Name Birth Date:

The content of the Manifest file is as follows. The evolution of the training loss value with each epoch can be observed, and those samples used for training and for validation can be identified:

```
axample_training_json_161401971757700.json - Notepad
                                                                                                                                    _
                                                                                                                                            File Edit Format View Help
{
  "TrainingSessions": [
    {
"Info": {
           "ReportTime": "2021-04-02 16:28:17",
           "SoftwareConfig": {
    "PMODVersion": "4.203"
             "PythonVersion": "3.8.6",
             "TFVersion": "2.4.0",
"RVersion": "4.0.3"
           },
           "HardwareConfig": {
    "ComputingUnit": "CPU",
              "RAMgb": 23.9709
           }
       },
"LearningParameters": {
    false.
           "Cropping": false,
"BoxSize": [
              50,
              50,
              50
           ],
"PixelSize": [
              1,
              1,
              1
           1,
           "VOICropping": false,
"Model": "Multichannel Segmentation",
"NormalizationType": 4,
           "BatchSize": 1,
"NumberOfEpochs": 5,
"StepsPerEpoch": 4,
"LearningRate": 0.0005,
           "UseGPU": false
        },
"TargetSettings": {
    "UsedMaskNr": [
              1,
              2,
              3
           ]
        },
"TrainingResults": {
```

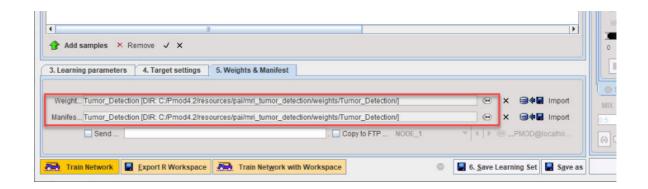
×



Additive Training

The best results are achieved by training in a single session with the maximum amount of data available. However, in a situation where the initial number of samples is limited and new samples will become available on a regular basis it is possible to try additive training. For example, where 50 samples are available at the start of a project and 10 new samples will be preprocessed every two weeks.

Additive training is achieved by adding the new samples to your existing Learning Set, selecting a subset of the total Learning Set (a combination of existing samples and new samples is recommended, e.g. select the 10 new samples and 10 existing samples), then launching Train Network based on the existing Weight and Manifest (identified on 5. Weights & Manifest).



4.1 Exporting an R workspace

Sample Selection

When exporting an R workspace for external training the selection in the **2. Samples** list is relevant. Only the selected samples will be exported and used for the training. An error message will be shown if only a single sample is selected during the export. Otherwise, a dialog window is shown listing the selected samples and providing an approximate RAM size needed for the training.

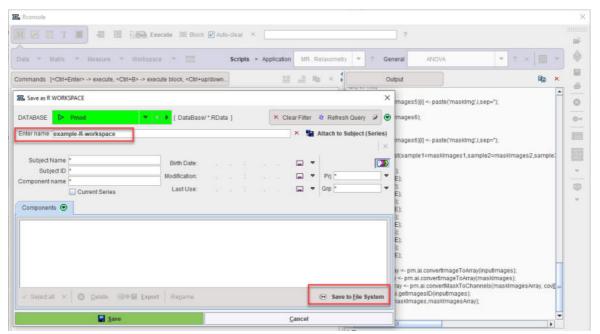
ponent name	Subject nar	ne Sut NG SE Al LI		es déscr	Modify time 2021-04-02 16:2	Last Use 2021-04-02 1	User1	Arch Pmod	Project	G	roup	Validate Sam	pie	
					1							1		
reate Learning Se	et + [Delete Ex	port Renam	e]existing De	scription 😁	this is a descriptio	n						1		
amples					******		1919-19-19-19-19-19-19-19-19-19-19-19-19					110 - 11 - 11 - 11 - 11 - 11 - 11 - 11		
ubject Name	Study Date	Time 10:41:10	Study Descripti	on Serie EARL	s Description	Modification	Last	Use 4	Mod n	t I	nz 40	Deel	0 + × 4	D
		08:57:25	RAC	EARL		2021-01-07 17				1	40			
		15:09:26	DTBZ	EARL		2021-01-07 16				1	40	0 5	\$ (0	
		08:44:45 09:13:20	DTBZ MP	EARL		2021-01-07 17 2021-01-07 17				1	40 40	an Te	1 1+0	
		09:13:20	MP	EARL		2021-01-07 17				1	40		i o	
												Gray		12
													\$ 1.0	
Add samples	A											0 [8]		100 [1
	Confirmatio	n				×						0 [0]		ron fe
earning paramet												D St	* = * C	
		Do you want	t to export R works	pace containing	[6] normalized sar	mple(s)?								
ights. example-t	?	100	transmission and the					1.6	- × =		mont			
Autors association		~	EXPORT		× <u>N</u> o							MDX	* (RGB Color)	
nifest. example-t									- x =		moort	0.5		

Note that the **Anonymize samples** option is useful when exporting an R workspace, ensuring that no subject information will be transferred to another workstation or cloud-computing infrastructure:

moonent name Subject Name Subject Name Subject Name Subject Name Study Date Totation </th <th>earning Set [1]:</th> <th>SELECT DATABASE</th> <th>▷ Pmod</th> <th></th> <th>I DataBase/</th> <th>*.aiSet]</th> <th></th> <th></th> <th></th> <th></th> <th>Preglew Validate Sample</th>	earning Set [1]:	SELECT DATABASE	▷ Pmod		I DataBase/	*.aiSet]					Preglew Validate Sample
Image: Study Date Im	omponent name								Project	Group	
Create Learning Set + [Delete Export Rename] existing Description Image: Set + [Delete Export Rename] existing Description Modification Last Use Mod nt nz Samples Subject Name Study Date Time Study Description Series Description Modification Last Use Mod nt nz 08:5725 RAC EARLY 2021-01-07 17.3. 2021-04-02 1 PT 1 40 08:5725 RAC EARLY 2021-01-07 17.3. 2021-04-02 1 PT 1 40 08:5725 RAC EARLY 2021-01-07 17.3. 2021-04-02 1 PT 1 40 09:13:20 MIP EARLY 2021-01-07 17.4. 2021-04-02 1 PT 1 40 09:13:20 MIP EARLY 2021-01-07 17.4. 2021-04-02 1 PT 1 40 09:13:20 MIP EARLY 2021-04-02 1 PT 1 40 09:13:20 MIP EARLY 2021-04-02 1 PT 1 40 Crop im Crop to associat Box s 20 20 MIM Rich size: 1 Number of eopcc5 Number of eopcc5	ample-learning-se	I -[AI LEARNING SE	AI LEARNIN	.	2021-04-02 16:2	2021-04-02 1	User1	Pmod			
Samples Subject Name Study Date Time Study Description Series Description Modification Last Use Mod nt 08:5725 RAC EARLY 2021-01-07 17.3. 2021-00-02 1 PT 1 40 08:5725 RAC EARLY 2021-01-07 17.3. 2021-00-02 1 PT 1 40 08:5725 RAC EARLY 2021-01-07 17.3. 2021-00-02 1 PT 1 40 09:13:20 DTBZ EARLY 2021-01-07 17.4. 2021-00-02 1 PT 1 40 09:13:20 MP EARLY 2021-01-07 17.4. 2021-00-02 1 PT 1 40 09:13:20 MP EARLY 2021-01-07 17.4. 2021-00-02 1 PT 1 40 Image: Source X Earning parameters 4. Target settings 5. Weights & Manifest Sample Itak Milk (RGB Color) Sample Itak Milk (RGB Color) Sample Itak Milk (RGB Color) Sample Itak Milk Sample </td <td></td> <td></td> <td></td> <td></td> <td>1</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>b</td>					1						b
Subject Name Study Date Time Study Description Series Description Modification Last Use Mod nt nt 08/5725 RAC EARLY 2021-01-07 17.3. 2021-04-02 1. PT 1 40 15/9225 DTBZ EARLY 2021-01-07 17.3. 2021-04-02 1. PT 1 40 08/5725 RAC EARLY 2021-01-07 17.3. 2021-04-02 1. PT 1 40 09/13/20 MP EARLY 2021-01-07 17.4. 2021-04-02 1. PT 1 40 09/13/20 MP EARLY 2021-01-07 17.4. 2021-04-02 1. PT 1 40 09/13/20 MP EARLY 2021-01-07 17.4. 2021-04-02 1. PT 1 40 09/13/20 MP EARLY 2021-04-02 1. PT 1 40 Crop in. Crop bit associat Samples Samples Imm Krolitical. Multichannel Segm. ? Use Sample Mix (RO	Create Learning !	Set + [Delete Export]	Rename] existi	g Description	this is a description	n					
10.4110 RAC EARLY 2021-01-01717.3. 2021-04-02.1. PT 1 40 06.57.25 RAC EARLY 2021-01-0715.5. 2021-04-02.1. PT 1 40 06.57.25 DTBZ EARLY 2021-01-0716.5. 2021-04-02.1. PT 1 40 08.4445 DTBZ EARLY 2021-01-0717.5. 2021-04-02.1. PT 1 40 09.13.20 MP EARLY 2021-01-0717.4. 2021-04-02.1. PT 1 40 Cray * X 2021-04-07.17.4. 2021-04-02.1. PT 1 40 Cray * X X 2021-04-02.1. PT 1 40 Crop in Crop in associal Box s	Samples										
08:57/25 RAC EARLY 2221-01-07 17.1. 2021-01-02 1 PT 1 40 15:02:25 DTBZ EARLY 2021-01-07 17.5. 2021-01-02 1 PT 1 40 09:44:45 DTBZ EARLY 2021-01-07 17.5. 2021-01-02 1 PT 1 40 09:13:20 MP EARLY 2021-01-07 17.5. 2021-01-02 1 PT 1 40 09:13:20 MP EARLY 2021-01-07 17.5. 2021-01-02 1 PT 1 40 09:13:20 MP EARLY 2021-01-07 17.5. 2021-01-02 1 PT 1 40 09:13:20 MP EARLY 2021-01-07 17.4. 2021-01-02 1 PT 1 40 09:13:20 MP EARLY 2021-01-07 17.4. 2021-01-02 1 PT 1 40 1 Add samples K Target settings 5. Weights & Manifest	Subject Name			Description	Series Description	Modification			nt bol		
15.092.9 DTBZ EARLY 2021-01-07 15.5. 2021-00-02 1. PT 1 40 08:43.445 DTBZ EARLY 2021-01-07 17.0. 2021-00-02 1. PT 1 40 09:13.20 MP EARLY 2021-01-07 17.4. 2021-01-02 1. PT 1 40 09:13.20 MP EARLY 2021-01-07 17.4. 2021-01-02 1. PT 1 40 Add samples × Remove × X X Earning parameters 4. Target settings 5. Weights & Manifest Anonymize samples Crop Im Crop Im Pixel (mm.) Mitchannel Segm * * ? Use_ Gaussian Smoothing 5.07 [mm.] Imm. Pixel Imm. Mitchannel Segm * * ? Use_											
08.44.45 DTBZ EARLY 2021-01-07 17.0. 2021-01-02 1 PT 1 40 09.13.20 MP EARLY 2021-01-07 17.4. 2021-01-02 1 PT 1 40 09.13.20 MP EARLY 2021-01-07 17.4. 2021-04-02 1 PT 1 40 09.13.20 MP EARLY 2021-01-07 17.4. 2021-04-02 1 PT 1 40 Add samples X Remove X											Carta Paral
09.13.20 MP EARLY 2021-01-07 17.5 2021-04-02 1 PT 1 40 09.13.20 MP EARLY 2021-01-07 17.4 2021-04-02 1 PT 1 40 Add samples × Remove × X Image: Samples Image: Samples<											P B & P
09:13:20 MP EARLY 2021-01-07 17.4 2021-04-02 1 PT 1 40 Image: Solution of the state of the stat											
Add samples × Remove × X Learning parameters 4. Target settings 5. Weights & Manifest Anonymize samples Crop to associat Box s50 20 20 (mm Pixel (m (m Pixel (m (m.											
Add samples × Remove ✓ X Learning parameters A. Target settings 5. Weights & Manifest Anonymize samples Crop to associat Box s. 300 300 30 [mm. Pixel] [m. Batch size: 1 Number of spoc5 Number of spoc5											
Learning parameters 4. Target settings 5. Weights & Manifest Anonymize samples Crop to associat Box s. 200 200 [mm. Pixel 1 [m. Batch size: 1 Number of epoc5]			1			1				,	m 0.0 \$ 1.0
Archited. Multichannel Segm. V (RGB Color)	Add samples	🗙 Remove 🧹 🗙									0 [0] × 100 [0
Archited. Multichannel Segm. • • • • • • • • • • • • • • • • • • •	. Learning parame	eters 4. Target set	tings 5. We	ghts & Manifest							
Gaussian Smoothing 10 10 20 [mm] Number of epoc5	🗌 Anonymize sar	nples				Architect	Multichanne	I Segm	▼ < > 3	Use_	
Gaussian Smoothing 20 00 [mm] Number of epoc5	Crop im	Crop to associat. Bo	x s 50.0 50.0	50.0 [mm. Pixel	1 1 1 [m						MIX (RGB Color)
Gaussian Smoothing 8.0 8.0 8.0 [mm] Number of epoc5					the second second			_			
To block a start of the start o	🗌 Gaussian Smo	othing 3.0 4.0	[mm] 0			Number of	epoc5				
	Scale Values to	. Z-Score	v 4	of sample.		Learnin	rate: 5.0E-	4 (F	inal LR in Mar	if_ Pints	OAOB A+B =

R Workspace Export

The **EXPORT** button opens the PMOD R Console, executes the preparations including data preprocessing, and opens a dialog window for saving the workspace. Typically **Save to File System** will be used to make it easily available for transfer to a different training environment:

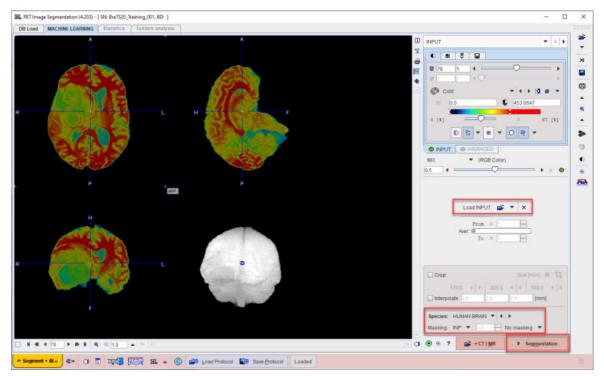


5 Use of Trained Neural Network for Prediction

Trained networks can be used in PSEG for the segmentation of input images with the same characteristics as the training images. Please apply the same <u>preparations</u> 13^{4} including associations and cropping VOI definition as for the training samples.

Image Loading

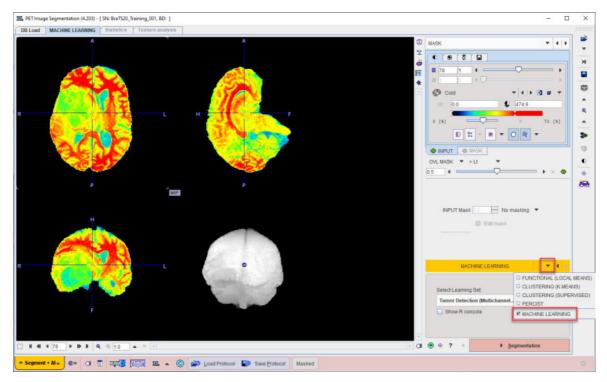
Start PSEG, and on the **INPUT** page use the **Load INPUT** button for loading the image to be segmented. In case of a segmentation requiring multiple input images, use the one which appears first in the association list.



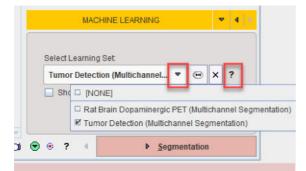
Do NOT apply cropping or interpolation in the lower right (this will be done by the model if needed), set **Masking** to **No Masking**, and continue using the **Segmentation** button.

Learning Set Configuration

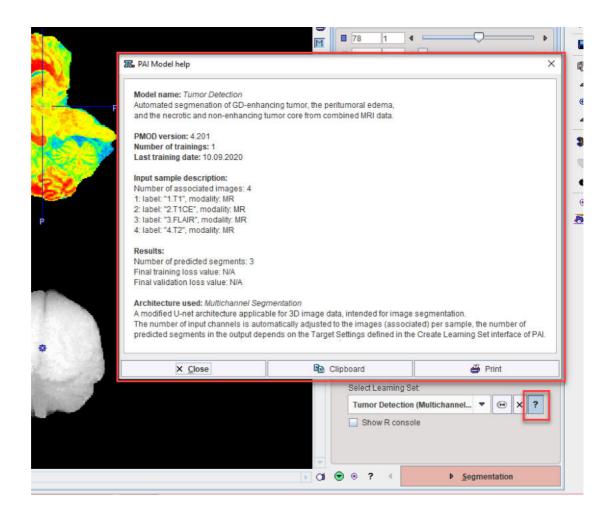
On the MASK page set the segmentation method to MACHINE LEARNING.



Then choose the appropriate model for the segmentation using the menu Select Learning Set.

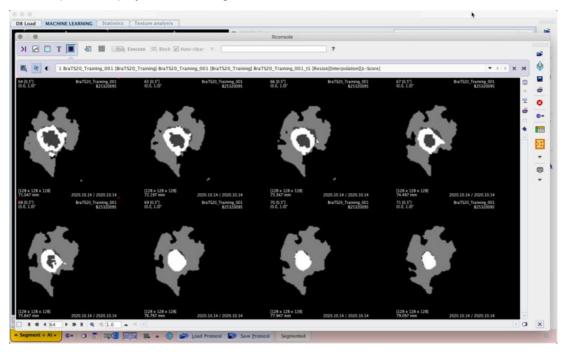


Note that a description of the model can be retrieved using the PAI Model Help button:



Segmentation

Use the **Segmentation** workflow button to start prediction. The input data is transferred to the R Console and processed using the selected model. If **Show R console** was enabled, the resulting label maps are displayed on the image tab of the R Console:



ire]] DB Load MACHINE LEARNING B • [10 - [36 - **4**- [30 SEGMENTS - 4 D . . * **5**4 M B + 0 O 1 1 4. A * 1 [9] ID 9: 0 -0 AVER
 SEGMENTS MIP ø OVL SEGMENTS 🗢 > Lt • 4 = > 30 h. 115 8 🖛 -2 Ċ e range: STUDY Marker . ent 080 PVC ۲ × S. II T 2 * New YOI p Template N 48 4 54 P IP N 4 0 1.0 A 2 · · · · · · a 🗢 Segment + Al * 🔹 🔿 📆 🎞 🕮 🖾 🕱 📽 🔺 💿 💕 Load Protocol 💽 Save Protocol Segmented

The result of the segmentation is a label map which is overlaid on the input series on the **SEGMENTS** page (once the R Console has been closed).

The labels can be converted into a VOI by right-clicking a segment in the image. This opens a dialog window which allows a VOI name to be selected from a list, or simply entered, and then applies iso-contouring to generate the VOI. The label map itself can be saved using the save button in the taskbar to the right.

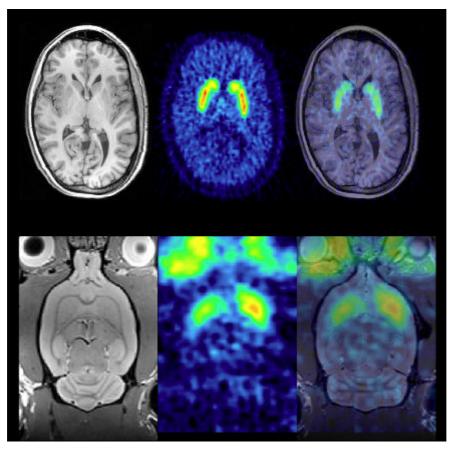
Please refer to the PSEG User Guide for details of the general segmentation functionality.

6 Case Study - Rat Brain Dopaminergic PET Model

The **Multichannel Segmentation** architecture is designed to be used in new applications. It was initially tested for the 4 input series, 3 segment output MICCAI BraTS example case, and was successfully reapplied for segmentation of striatum and cerebellum in rat brain dopaminergic PET. The process of preparing the data to reapply the architecture, the training, and the evaluation of the outcome is described in this case study.

6.1 Sample Preparation

PET imaging of the dopaminergic system results in images with high tracer uptake in the basal ganglia:



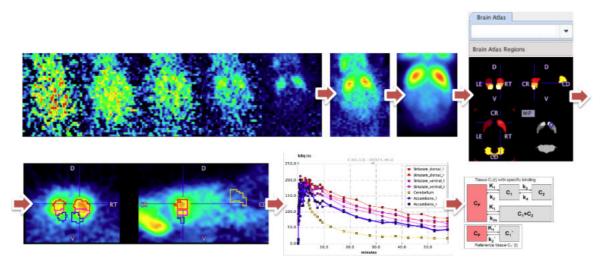
Fully quantitative analysis of PET with tracers for targets in the dopaminergic system typically uses time-activity curves from the striatum (in small animals; caudate and putamen in humans) and cerebellum (reference regions devoid of dopaminergic neurons/synapses). Dynamic PET studies typically cover a time range from 0-60 minutes after intravenous tracer injection.

In both small animals and humans, brain VOI atlases and tracer-specific templates such as those available in PMOD have long been used to achieve reproducible analysis and facilitate batch processing. The application of VOI atlases and templates used depend on the availability of anatomical imaging series to complement the PET data. In small animal dopaminergic PET studies it is common to have only the dynamic PET data. Matching to a PET template normally requires averaging in a time range that reveals specific binding and reduces image noise. Due to the limited tracer distribution researchers sometimes struggle to achieve a satisfactory result.

PMOD's **Rodent Brain analysis tool (PNROD)** provides a streamlined workflow for such analysis and with careful creation of a template image and selection of the averaging range works well for batch processing of rodent brain PET data. It was used to process 382 rat brain dynamic PET image series. The data comprised PET at a range of ages and with the tracers [¹¹C]-raclopride,

[¹¹C]-methylphenidate and [¹¹C]-DTBZ. A template image specific to this study data was created from a subset of the data using standard functionality in **View** and **Fusion** tools.

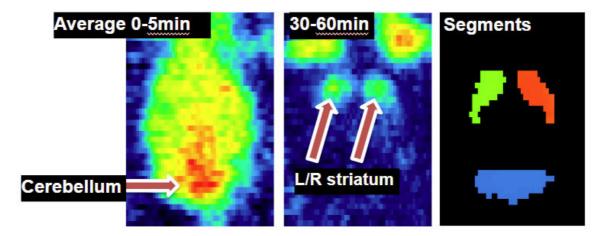
The traditional analysis workflow for this data is summarized below:



The dynamic PET data was averaged. This average was normalized to the template, allowing atlas VOIs for striatal regions and cerebellum to be created in the original PET image space. These VOIs were used to extract time-activity curves that were used for kinetic modeling. The Simplified Reference Tissue Model was used to calculate BP_{nd}.

PMOD's AI framework (PAI) offers an alternative approach to segmentation of such data. 382 input samples represents a reasonable number for training of an ML model, and the VOIs generated by PNROD represent gold-standard method reference segments.

The **Multichannel Segmentation** architecture presented a potential advantage over the traditional workflow in that multiple averages can be provided as input. The average used for PNROD processing was selected to provide a specific-binding signal in the striatum but also some remaining blood pool signal to represent a more general brain outline. The cerebellum is not well defined in this average. Therefore an early average image created from the first 5 minutes after tracer injection and a late average of 30-60 minutes after tracer injection were generated using **Pipeline Processing** and organized in a **Database**:



The VOI results from PNROD were converted into reference Segments using the **Mask By VOI Number** functionality available in the **View** tool and added to the **Database**.

The LATE and SEGMENT images were **Associated** with the EARLY image for each subject in the **Database**. The **Project** labels 1.Early and 2.Late were assigned to the EARLY and LATE images.

The **Database** was used to create a **Learning Set** for training with the **Multichannel Segmentation** architecture.

6.2 Training and Validation

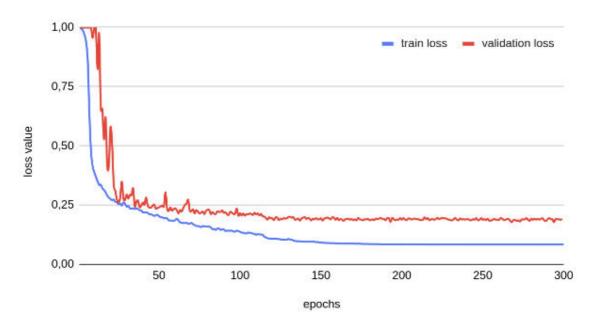
The **Learning Set** was exported as an R workspace and transferred to cloud computing infrastructure for training. PMOD can be installed on the virtual machine provided by the cloud computing provider and training launched using the R workspace:

Learning Set [1]:	SELECT DATABASE	-	Prinod			DataBase/	alber J					2	Validate Sample
Component name cample-learning-set	Subject name t -[AI LEARNING :		bject id EARNING	Series desc		Modify time 2021-04-02 16 2	Last Use 2021-04-02 1	User	Arch	Proje	d	Group	
aniha inanihi ya	a state a state of	Change and the				EVE I OT VE IV.E.	EVEL OF VE 1	(Grant)	1.1100				
						11						1	•
Create Learning S	Set + [Delete Export	Renam	e]existing	Description		his is a description	n						
Samples				in a second second		in the second				*****			
	1		1		1		1	11			1	-	
Subject Name		Time 10:41:10	Study De RAC	scription	EARLY	Description	Modification 2021-01-07 17		st Use	Mod	nt	10 nz	
		8:57:25	RAC		EARLY		2021-01-07 1			PT	1	40	
		5:09:26	DTBZ		EARLY		2021-01-07 16				1	40	0 5 6
	0	8:44:45	DTBZ		EARLY	(2021-01-07 17	1:0 20	21-04-02 1	PT	1	40	
	0	9:13:20	MP		EARLY	6	2021-01-07 17	1:5 20.	21-04-02 1	PT	1	40	
	0	9:13:20	MP		EARLY	(2021-01-07 11	1:4 20	21-04-02 1	PT	1	40	
													💮 Gray 🗢 🗧 🖻
													m 0.0 10 1.0
			1									•	
Add samples	× Remove 🧹 🕽	<											0 [8] - X 100 [9
Learning parame	eters 4. Target s	ettings	5. Weight	s & Manifest	1								D 31 - = - C E -
Anonymize san	mples						Architect	Multich	annel Segm.		2	Use	Sample Mask
Crop im	Crop to associat	lor e	o en o so	Imm Pin	et 1	t t m.							MIX (RGB Color)
						T. L. Brenn	Bat	ch size:					
Gaussian Smo	othing 80 6.0	1 0.6	mm]				Number o	epoc	5				
	o: Z-Score			of sample.			1	ng rate:	07.4	Final LR i			OAOB®A+B =

The parameters used were:

- 4 GPU V100, memory 488 GB
- 382 samples (305 training, 77 validation)
- pixel size 0.5 x 0.5 x 0.5 mm
- batch size 16
- Learning rate 0.05
- epochs 300

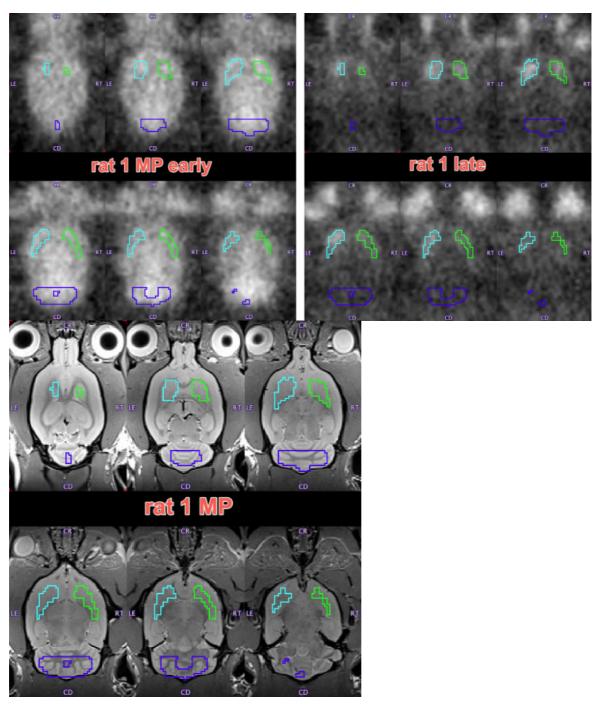
Training took 3 hours 8 minutes at 0.123 seconds/sample. The loss values for training and validation were extracted from the **Manifest** and plotted:



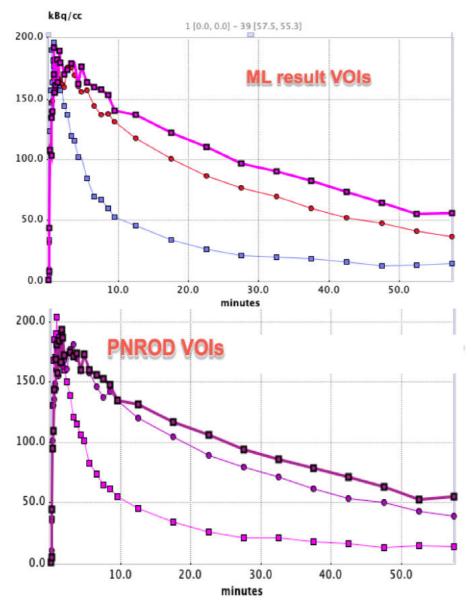
The plot illustrates how the loss value reduces with each epoch until a plateau is reached.

The Learning Set, Weights and Manifest were exported from the virtual machine and used to create a new model folder **Rat Brain Dopaminergic PET** in the weights subfolder of the **Multichannel Segmentation** folder in *Pmod4.2/resources/pai*. After this **Deployment** it was possible to test the model performance of comparable rat brain [¹¹C]-methylphenidate data for which an anatomical MR image was available.

The resulting VOIs are shown below on the EARLY, LATE and anatomical reference MR images:



Time-activity curves were extracted from the dynamic PET series using both these VOIs and reference VOIs from PNROD. The two sets of TACs are shown below with matched axes:



The curve with faster washout in each case is the cerebellum.

7 PMOD Copyright Notice

Copyright © 1996-2021 PMOD Technologies LLC. All rights reserved.

The PMOD software contains proprietary information of PMOD Technologies LLC; it is provided under a license agreement containing restrictions on use and disclosure and is also protected by copyright law. Reverse engineering of the software is prohibited.

Due to continued product development the program may change and no longer exactly correspond to this document. The information and intellectual property contained herein is confidential between PMOD Technologies LLC and the client and remains the exclusive property of PMOD Technologies LLC. If you find any problems in the document, please report them to us in writing. PMOD Technologies LLC does not warrant that this document is error-free.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without the prior written permission of PMOD Technologies LLC.



PMOD Technologies LLC Sumatrastrasse 25 8006 Zürich Switzerland +41 (44) 350 46 00 support@pmod.com http://www.pmod.com

- P -

PMOD Copyright Notice 63