

Dynamic Analysis Environment for Nuclear Forensic Analyses

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NFUSP Culmination Seminar

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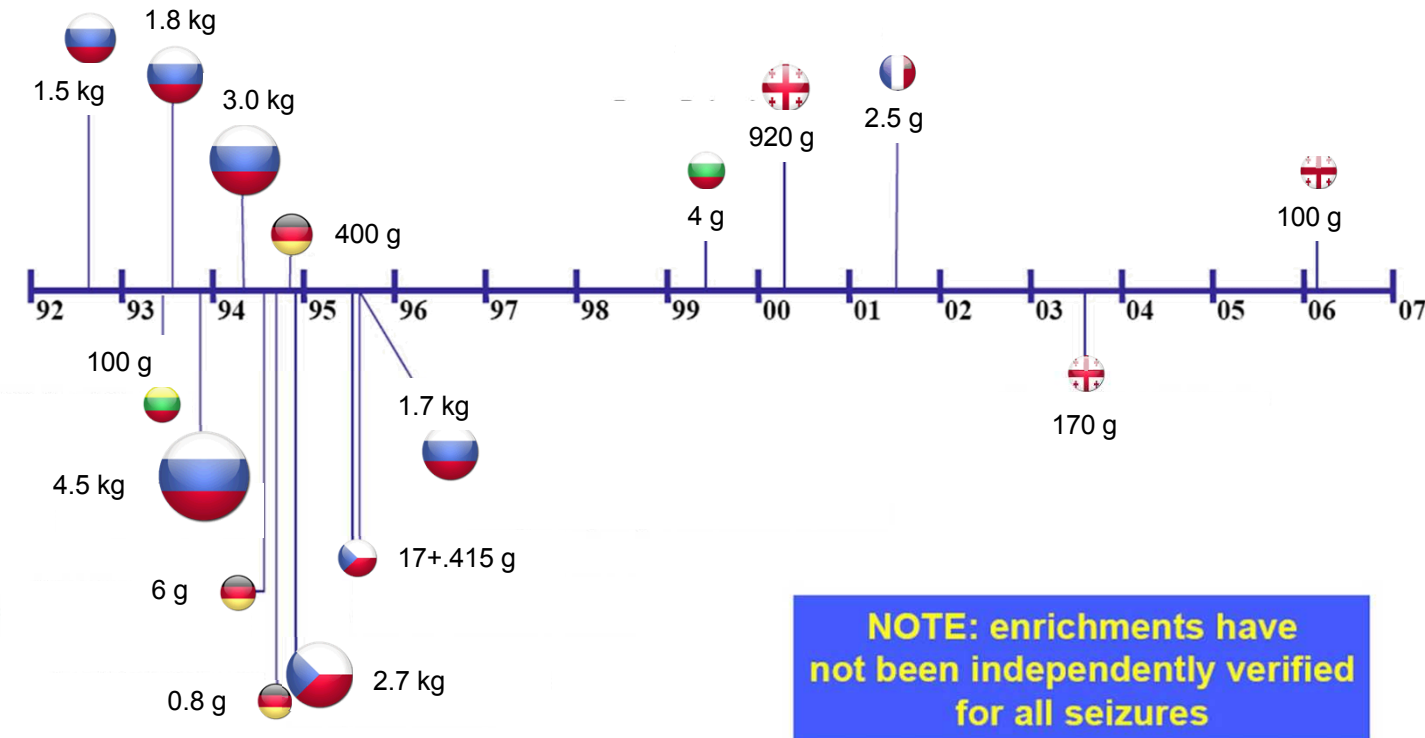
What is Nuclear Forensics?

Nuclear forensics refers to the characterization of intercepted nuclear materials to identify evidence of their source and intended use.

Current work in two areas

- The creation of national nuclear forensics libraries (NNFLs) of known nuclear materials
- The development of multivariate group inclusion/exclusion algorithms

Reported Weapons-Usable Nuclear Materials Seizures



Source: Los Alamos National Laboratory, Tom Bielefeld

Nuclear Forensics Data — SFCOMPO

Reactor	Country	Type
Calvert Cliffs No. 1	USA	PWR
Cooper	USA	BWR
Fukushima-Daiichi-3	Japan	BWR
Fukushima-Daini-2	Japan	BWR
Genkai-1	Japan	PWR
Gundremmingen	Germany	BWR
H.B. Robinson Unit 2	USA	PWR
JDPR-1	Japan	BWR
Mihama-3	Japan	PWR
Monticello	USA	BWR
Obrigheim	Germany	PWR
Takahama-3	Japan	PWR
Trino Vercellese	Italy	PWR
Tsuruga-1	Japan	BWR

Isotopic ratios used:

- $^{235}\text{U}/^{238}\text{U}$
- $^{236}\text{U}/^{238}\text{U}$
- $^{240}\text{Pu}/^{239}\text{Pu}$
- $^{241}\text{Pu}/^{239}\text{Pu}$
- $^{242}\text{Pu}/^{239}\text{Pu}$



SFCOMPO – Spent Fuel Isotopic Composition Database (2015). URL <http://www.oecd-neo.org/sfcompo/>

Nuclear Forensics Data — SFCOMPO

Reactor	Country	Type	Unknown Samples
Calvert Cliffs No. 1	USA	PWR	
Cooper	USA	BWR	
Fukushima-Daiichi-3	Japan	BWR	
Fukushima-Daini-2	Japan	BWR	13-20
Genkai-1	Japan	PWR	
Gundremmingen	Germany	BWR	
H.B. Robinson Unit 2	USA	PWR	1-4
JDPR-1	Japan	BWR	
Mihama-3	Japan	PWR	
Monticello	USA	BWR	
Obrigheim	Germany	PWR	
Takahama-3	Japan	PWR	
Trino Vercellese	Italy	PWR	5-12
Tsuruga-1	Japan	BWR	

Isotopic ratios used:

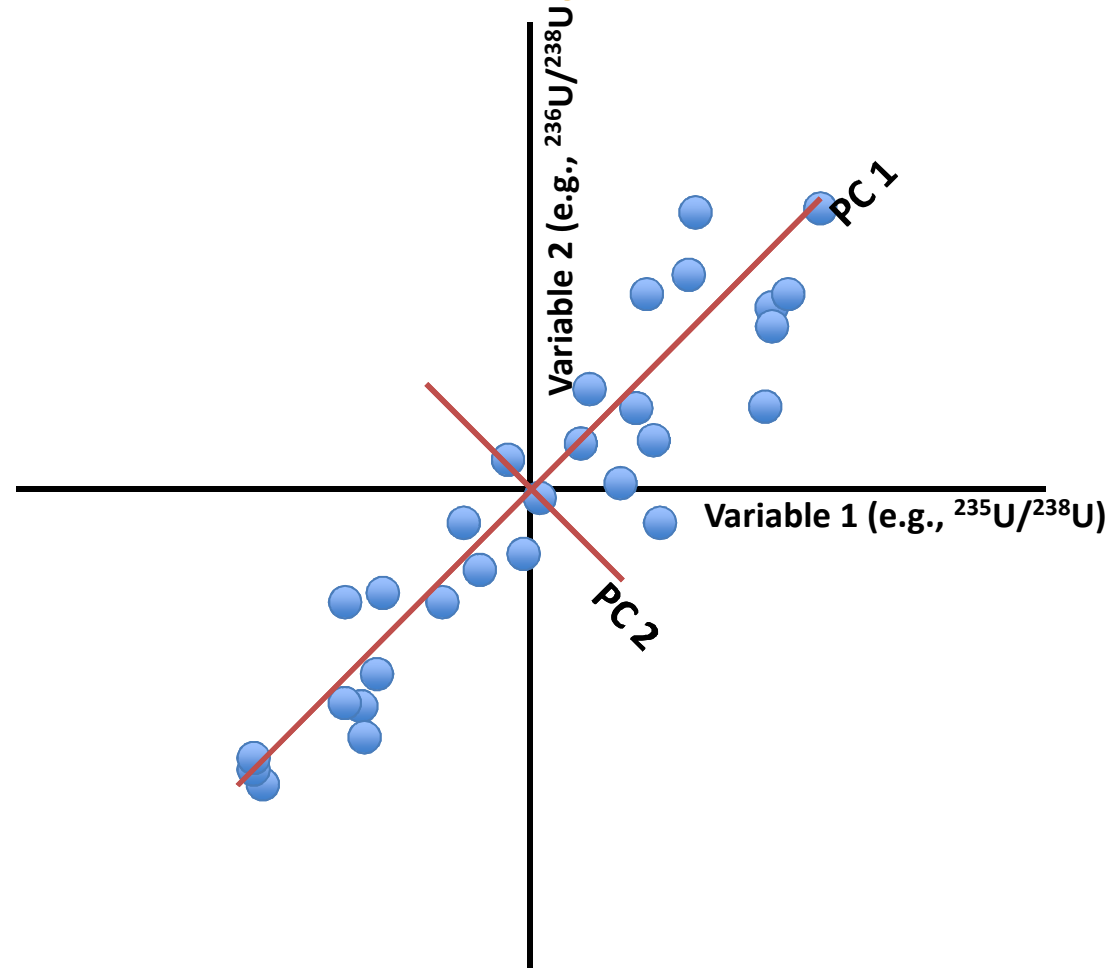
- $^{235}\text{U}/^{238}\text{U}$
- $^{236}\text{U}/^{238}\text{U}$
- $^{240}\text{Pu}/^{239}\text{Pu}$
- $^{241}\text{Pu}/^{239}\text{Pu}$
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SFCOMPO – Spent Fuel Isotopic Composition Database (2015). URL <http://www.oecd-nea.org/sfcompo/>

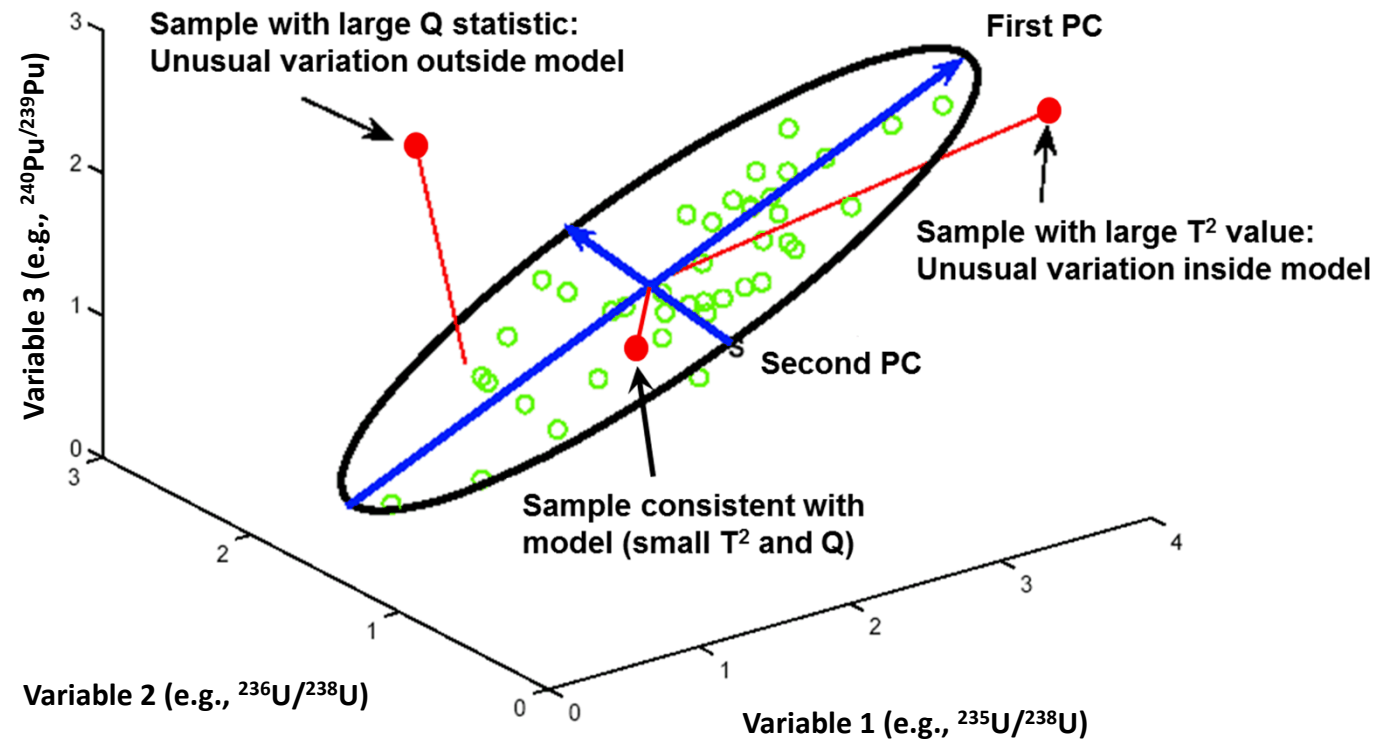
Principal Component Analysis (PCA)

The objective of PCA is to transform the coordinates of a data matrix to a new set of axes, called principal components, which optimally describe the data variance.



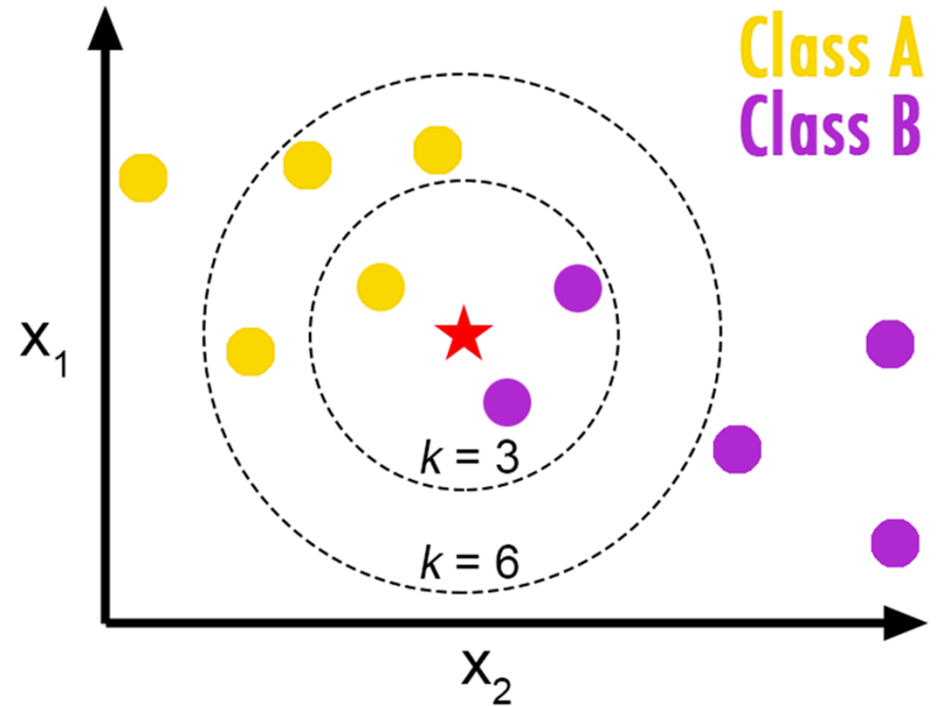
Principal Component Analysis (PCA)

Low Q , T^2 , and T_H^2 indicate sample is correlated with the model data.



K-Nearest Neighbors (KNN)

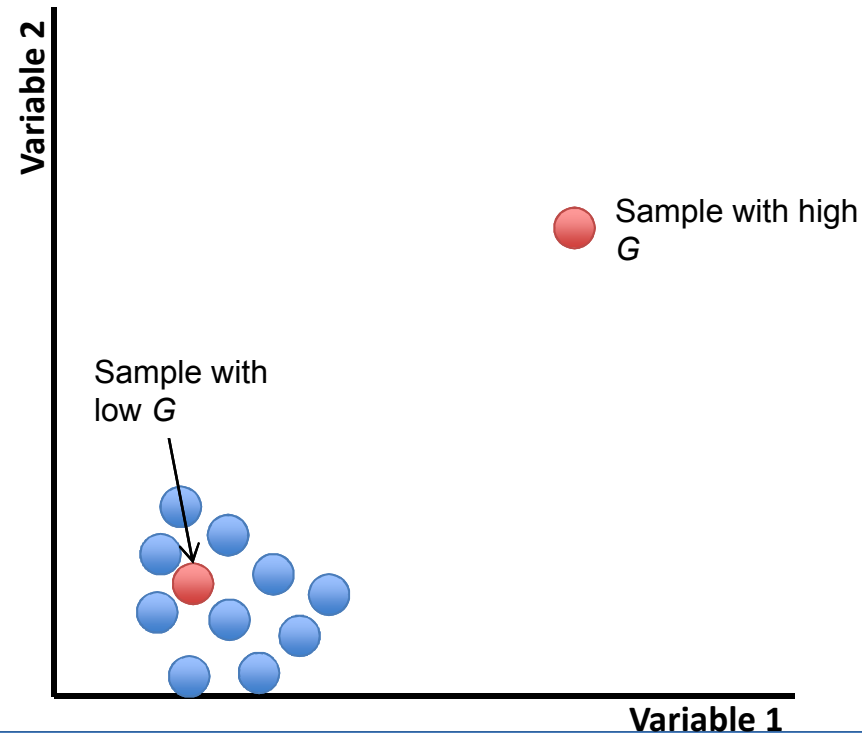
The KNN algorithm predicts the class of an unknown sample based on the majority vote of the k known sample(s) nearest to it.



KNN - Goodness Values

$$G = \frac{d_{unk} - \overline{d_B}}{sd(d_B)}$$

If G for an unknown sample exceeds the *goodness value threshold* of the class to which it is assigned, that assignment is removed.



PCA in DAE

LOAD

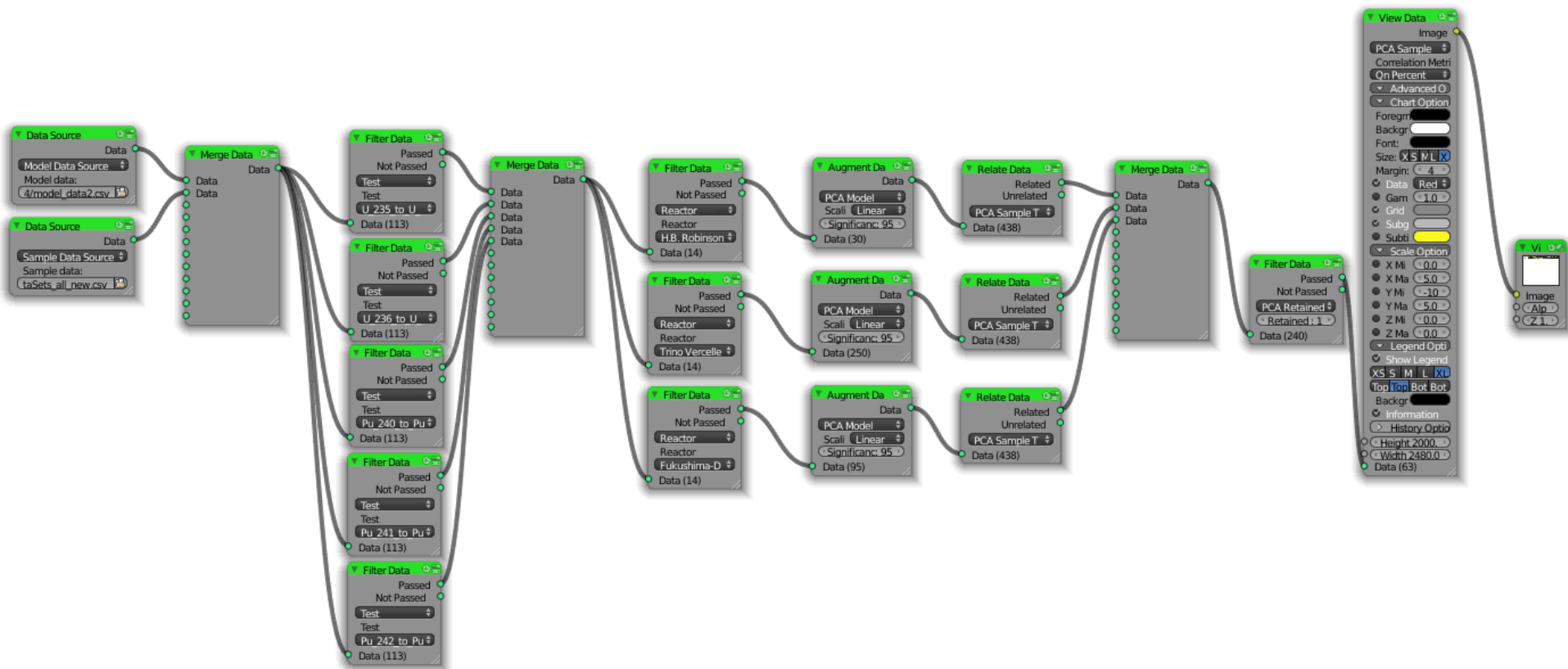
FILTER

FILTER

PCA
MODEL

COMPARE
UNKNOWN
SAMPLES

OUTPUT



Results — PCA — Q Percentage

[illegible]

Results — PCA — T^2 Percentage

Reactor	Retained Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Calvert Cliffs No. 1	2	0.09	0.71	0.88	0.35	0.23	0.05	0.28	0.13	0.01	0.01	0.09	0.13	0.01	0.02	0.13	0.08	0.14	0.01	0.03	0.09
Calvert Cliffs No. 1/H.B. Robinson Unit 2	2	0.14	0.91	0.90	0.55	0.07	0.05	0.15	0.13	0.01	0.00	0.10	0.15	0.00	0.00	0.05	0.02	0.06	0.00	0.00	0.02
Cooper	1	0.25	1.00	0.60	0.60	0.86	0.10	0.50	0.21	0.05	0.04	0.16	0.20	0.12	0.25	0.28	0.79	0.33	0.29	0.82	0.73
Fukushima -Daiichi-3	1	0.02	0.09	0.22	0.05	0.03	0.01	0.02	0.01	0.00	0.00	0.01	0.01	0.30	0.13	0.01	0.04	0.01	0.08	0.01	0.05
Fukushima -Daini-2	1	0.24	0.88	0.70	0.54	0.66	0.10	0.42	0.20	0.06	0.04	0.16	0.20	0.17	0.38	0.28	0.94	0.33	0.50	0.66	0.88
Genkai-1/Mihama-3	1	0.58	0.66	0.37	0.99	0.87	0.28	0.81	0.47	0.17	0.12	0.39	0.47	0.09	0.19	0.59	0.56	0.66	0.25	0.91	0.52
Gundrem-mingen	1	0.14	0.37	0.07	0.88	0.68	0.01	0.54	0.07	0.00	0.00	0.04	0.07	0.00	0.01	0.16	0.19	0.24	0.01	0.73	0.15
H.B. Robinson Unit. 2	1	0.18	0.85	0.38	0.60	0.86	0.05	0.38	0.12	0.03	0.02	0.09	0.12	0.05	0.11	0.19	0.60	0.24	0.15	0.85	0.53
JPDR-1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monticello	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01	0.00	0.00	0.00	0.01	0.00	0.00
Obrigheim	1	0.08	0.92	0.53	0.42	0.66	0.01	0.25	0.05	0.00	0.00	0.03	0.05	0.03	0.12	0.10	0.81	0.13	0.19	0.63	0.72
Takahama-3	2	0.25	0.20	0.10	0.24	0.85	0.31	0.74	0.49	0.19	0.12	0.42	0.45	0.16	0.39	0.67	0.89	0.74	0.57	0.88	0.84
Trino Vercellese	1	0.85	0.03	0.00	0.20	0.14	0.40	0.46	0.88	0.17	0.10	0.68	0.85	0.00	0.00	0.82	0.02	0.68	0.00	0.16	0.01
Tsuruga-1	3	0.09	0.00	0.00	0.05	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.04	0.00

Results — PCA — T_H^2 Percentage

Reactor	Retained Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Calvert Cliffs No. 1	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calvert Cliffs No. 1/H.B. Robinson Unit 2	2	0.67	0.18	0.61	0.60	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooper	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fukushima -Daiichi-3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Fukushima -Daini-2	1	0.11	0.11	0.03	0.06	0.22	0.02	0.20	0.09	0.00	0.00	0.12	0.17	0.70	0.54	0.26	0.29	0.27	0.68	0.65	0.33
Genkai-1/Mihama-3	1	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.05	0.12	0.00	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gundremmingen	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
H.B. Robinson Unit. 2	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
JPDR-1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Monticello	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Obrigheim	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Takahama-3	2	0.00	0.00	0.00	0.00	0.01	0.03	0.08	0.07	0.02	0.00	0.08	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trino Vercellese	1	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tsuruga-1	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00

KNN in DAE

LOAD

FILTER

FILTER

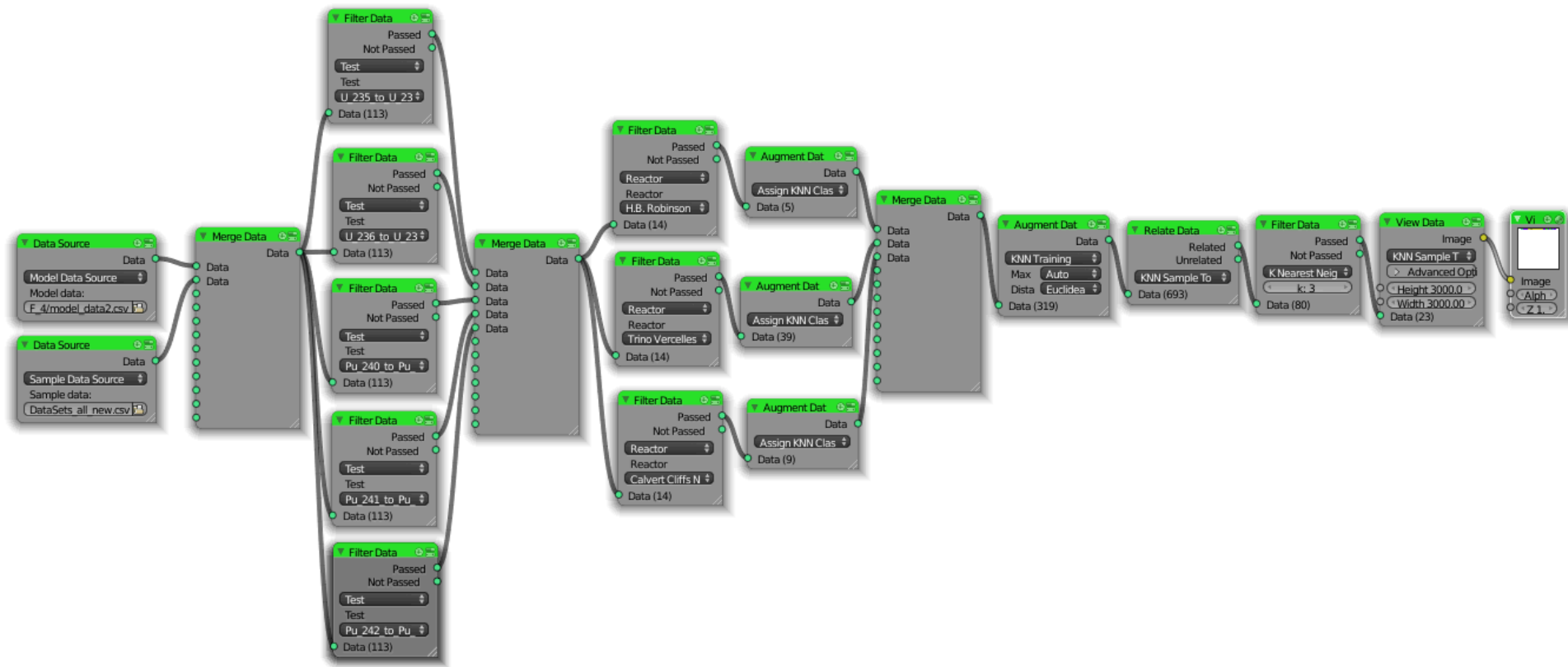
ASSIGN
CLASSES

TRAINING

KNN

FILTER

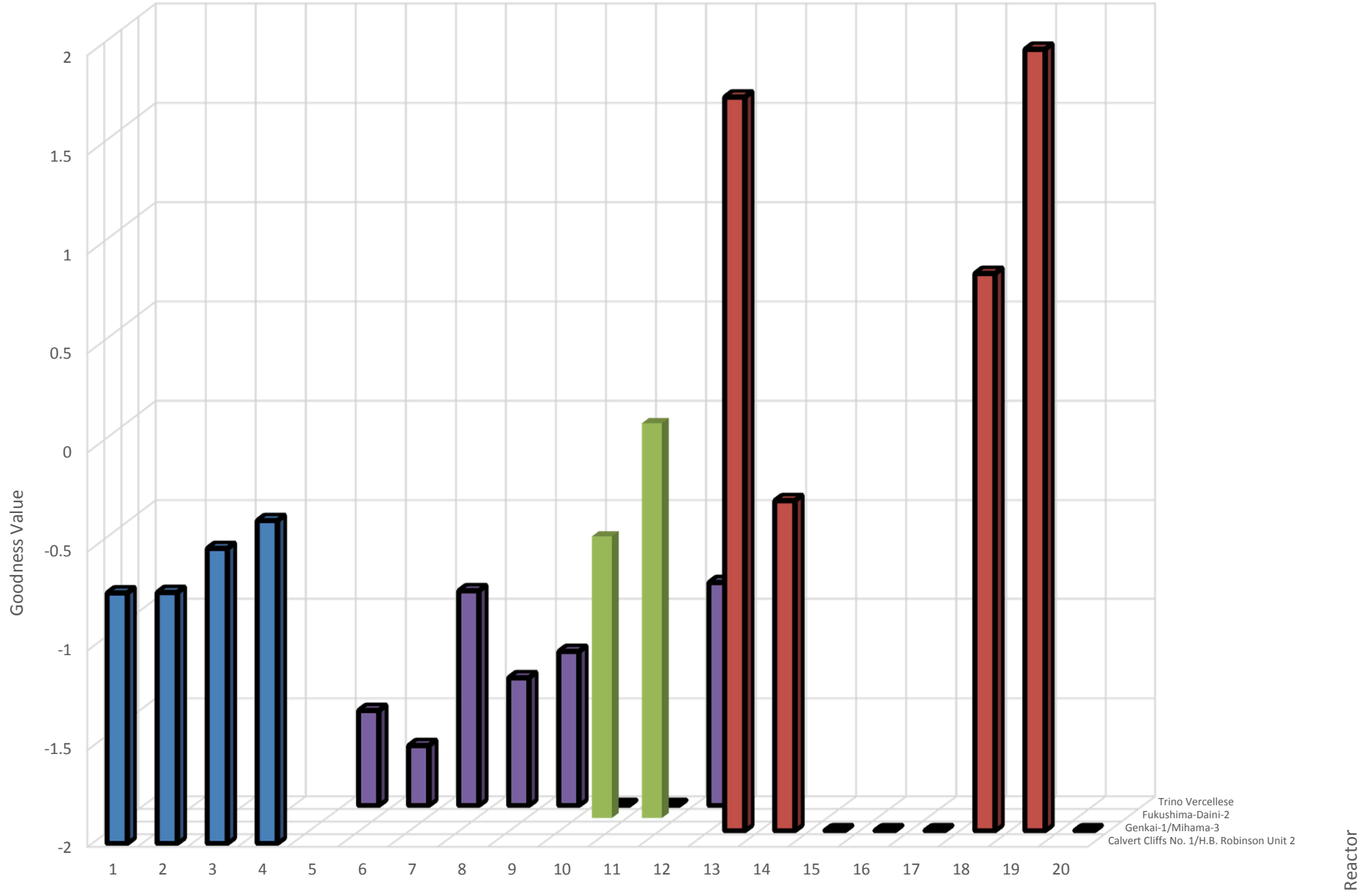
OUTPUT



Results — KNN

Unknown Sample	Assigned Reactor
1	Calvert Cliffs No. 1/H.B. Robinson Unit 2
2	Calvert Cliffs No. 1/H.B. Robinson Unit 2
3	Calvert Cliffs No. 1/H.B. Robinson Unit 2
4	Calvert Cliffs No. 1/H.B. Robinson Unit 2
5	Trino Vercellese
6	Trino Vercellese
7	Trino Vercellese
8	Trino Vercellese
9	Trino Vercellese
10	Genkai-1/Mihama-3
11	Genkai-1/Mihama-3
12	Trino Vercellese
13	Fukushima-Daini-2
14	Fukushima-Daini-2
15	
16	
17	
18	Fukushima-Daini-2
19	Fukushima-Daini-2
20	

Results — KNN



Conclusions



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UNIVERSITY OF CALIFORNIA

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