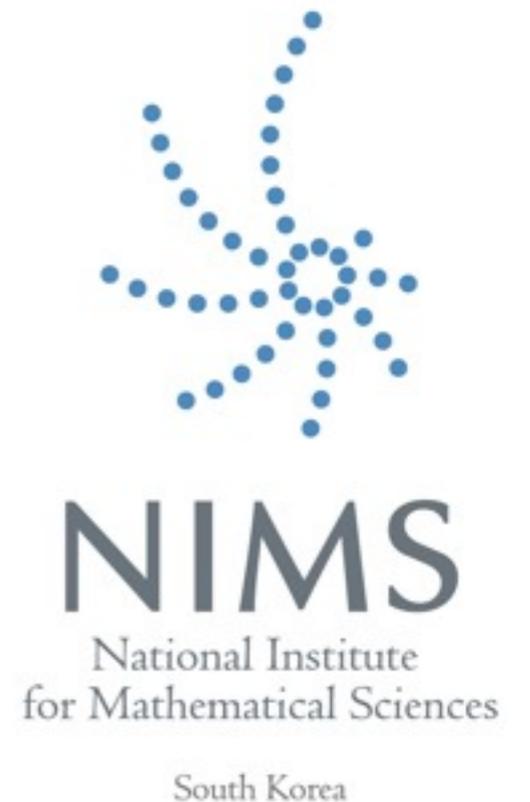




Multivariate Classification of Noise Artifacts using Auxiliary Channels - *Artificial Neural Networks*

SangHoon Oh (NIMS)
on behalf of AuxMVC Group in KGWG

Second Korea-Japan Workshop on KAGRA
May 28, 2012



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- Faculties

- Sang Hoon Oh (吳 尚勳, NIMS)
- John J. Oh (吳 廷根, NIMS)
- Chang-Hwan Lee (Pusan Nat'l Univ.)



- Research Fellow

- Edwin J. Son (孫 在圭, NIMS)

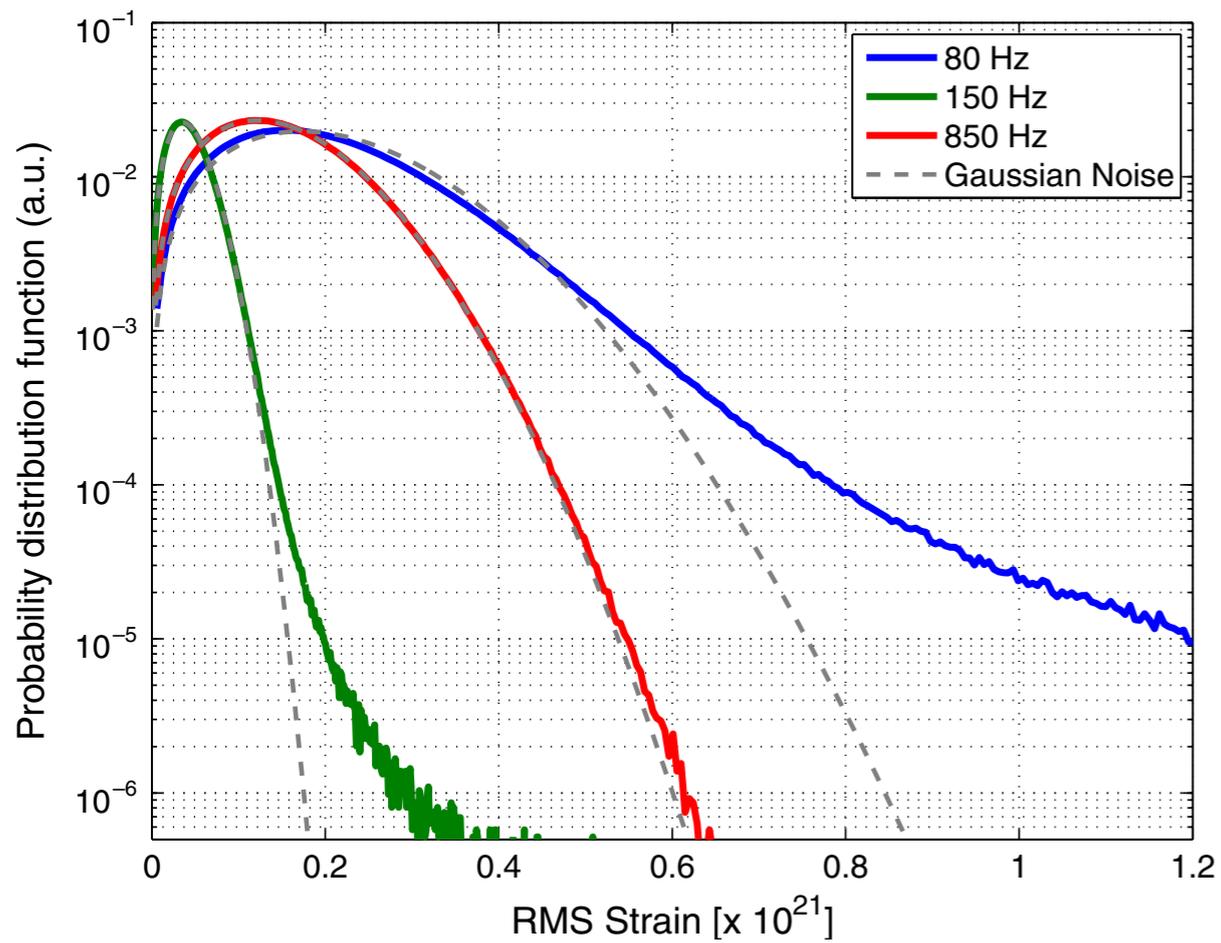


- Grad student

- Young-Min Kim (金 永敏, NIMS, Pusan Nat'l Univ.)

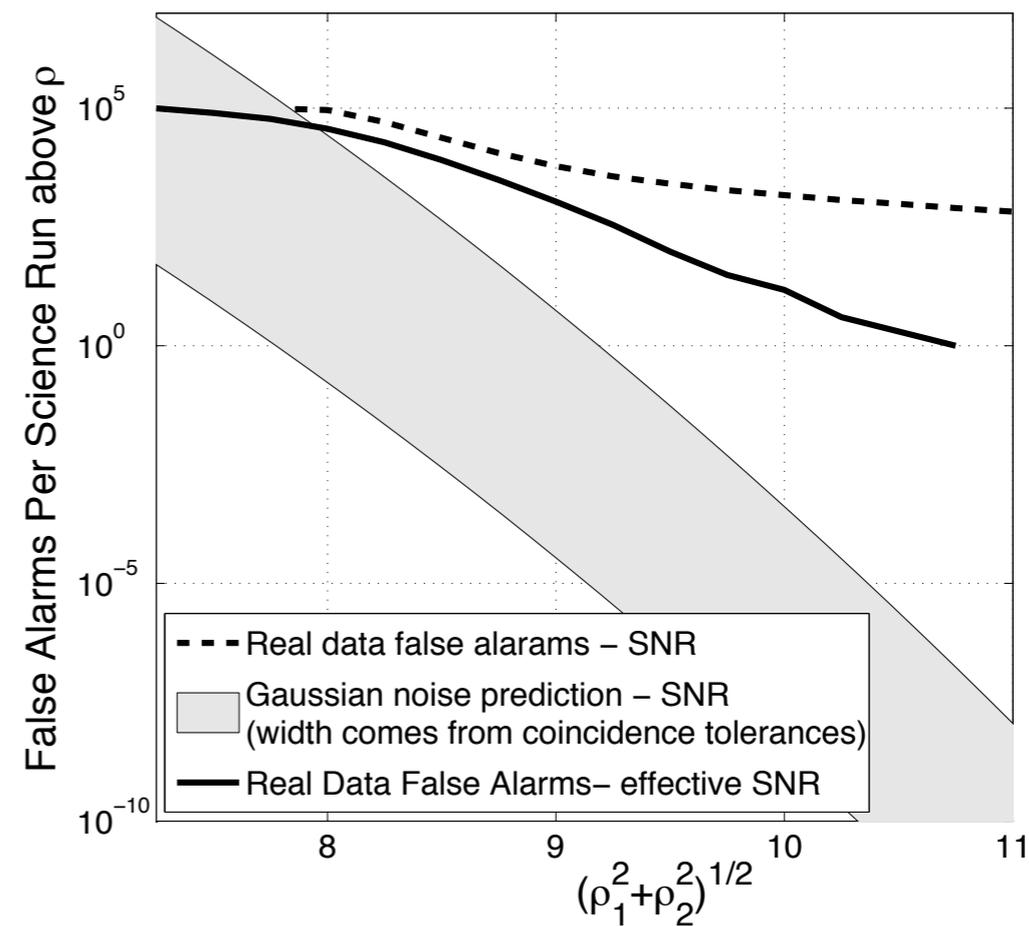
Motivation

Distribution of strain noise amplitude for H1



Abbott et al. (2009)

glitch rate

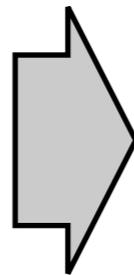
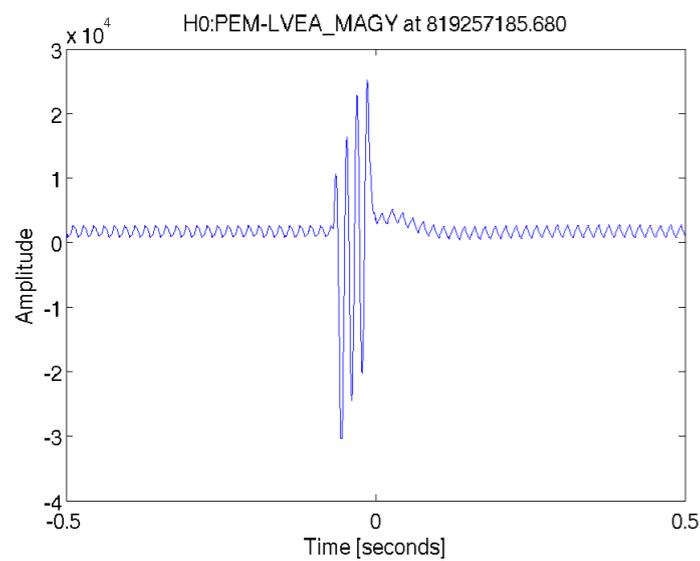


Goals

- Automate process of glitch identification
 - machine learning algorithms
 - $O(10^3)$ of auxiliary channels
- Develop monitoring tools
 - detector characterization
 - feedback to instrumental scientists
 - exploration of important channels in glitch identification

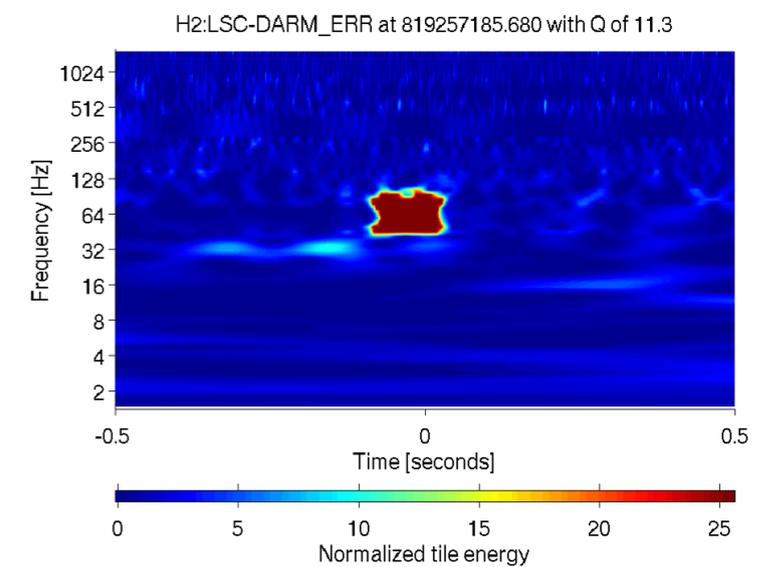
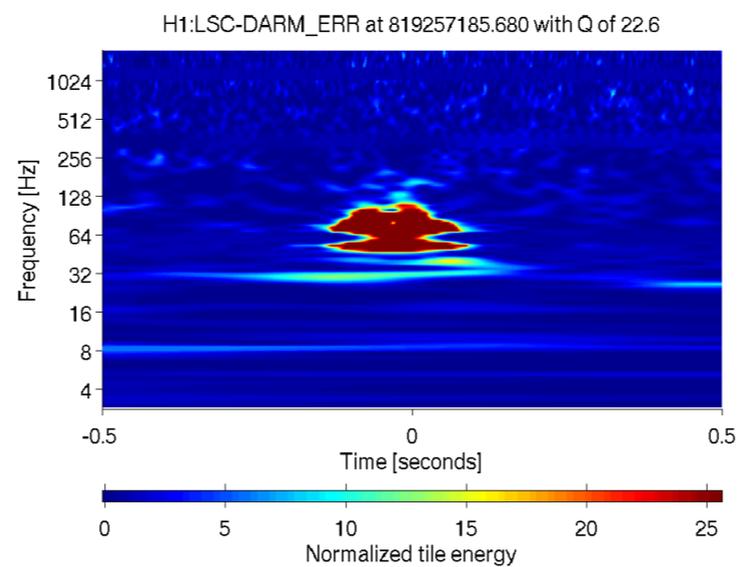
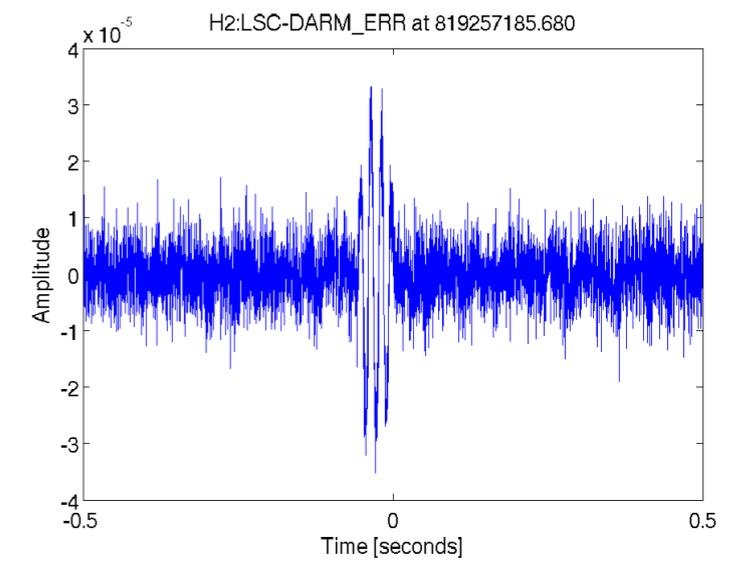
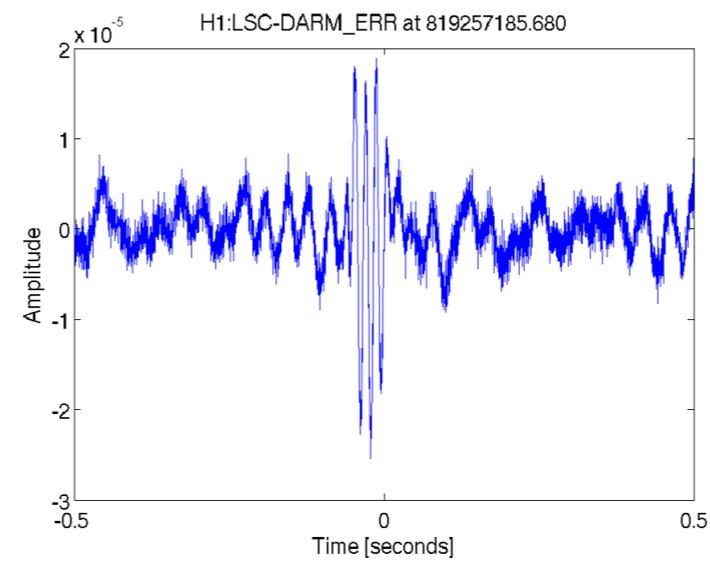
Auxiliary Channel

Power line glitch (noise transient)



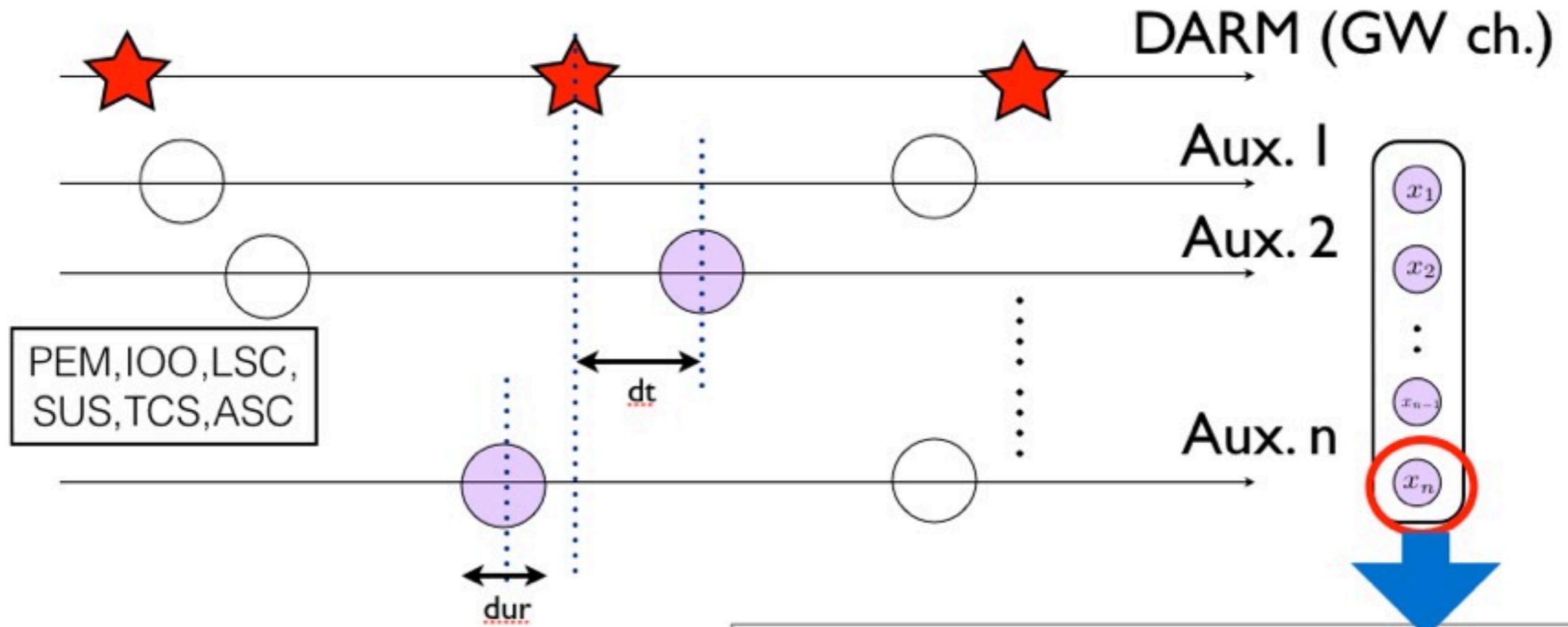
Magnetometer channel

GW channel



- initial LIGO ~1,000 aux channels
- advanced LIGO ~10,000 aux channels

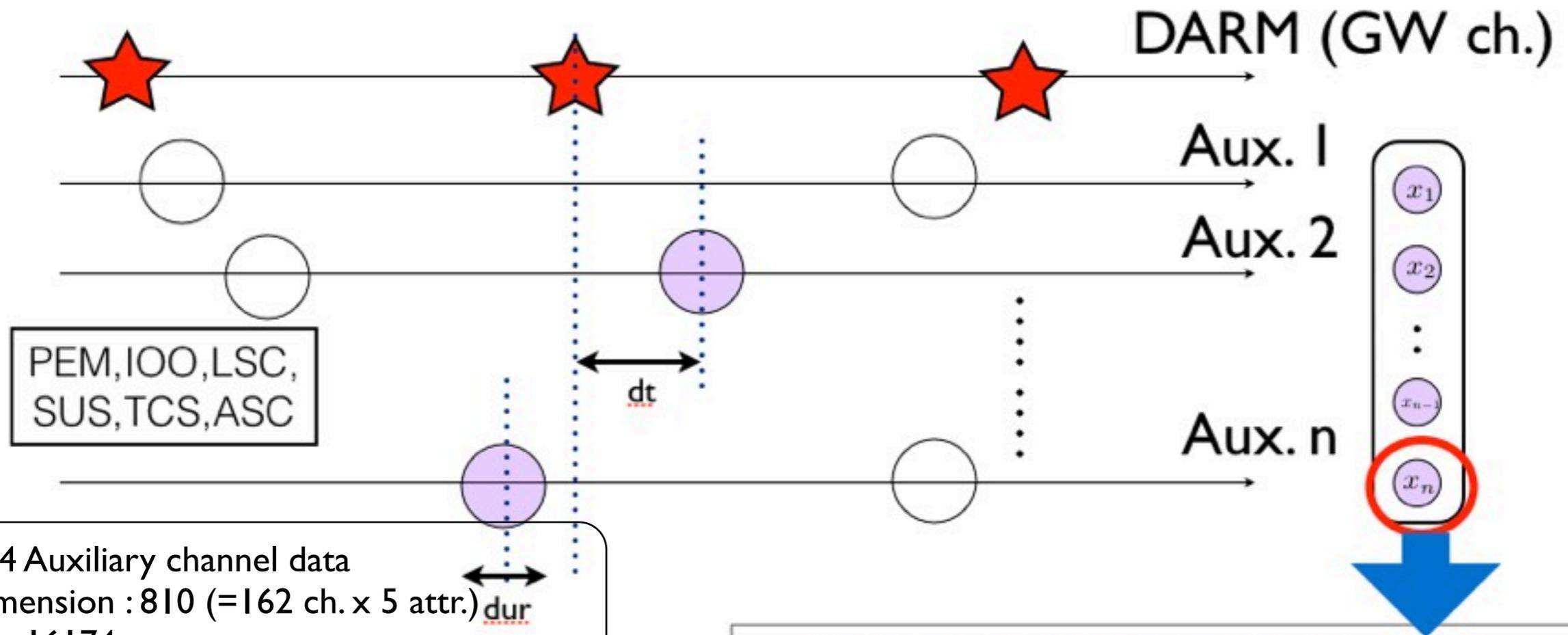
Input Variables



signal (=glitch)	clean
loud glitches	random time

- (a) **cluster significance** of loudest trigger within ± 100 ms, or significance of nearest trigger if none exists (significance is related to the SNR)
- (b) **dt** between DARM trigger and AUX trigger in (a)
- (c) **duration** of AUX trigger in (a)
- (d) **frequency** of AUX trigger in (a)
- (e) **npts** (cluster size) of AUX trigger in (a)

Input Variables



LIGO S4 Auxiliary channel data
input dimension : 810 (=162 ch. x 5 attr.)
Glitches : 16174
Clean Samples : 98147

LIGO a week data of S6
(959131741~)
input dimension : 1250
(=250 ch. x 5 attr.)
Glitches : 2826
Clean Sample : 99869

- (a) **cluster significance** of loudest trigger within +/- 100ms, or significance of nearest trigger if none exists (significance is related to the SNR)
- (b) **dt** between DARM trigger and AUX trigger in (a)
- (c) **duration** of AUX trigger in (a)
- (d) **frequency** of AUX trigger in (a)
- (e) **npts** (cluster size) of AUX trigger in (a)

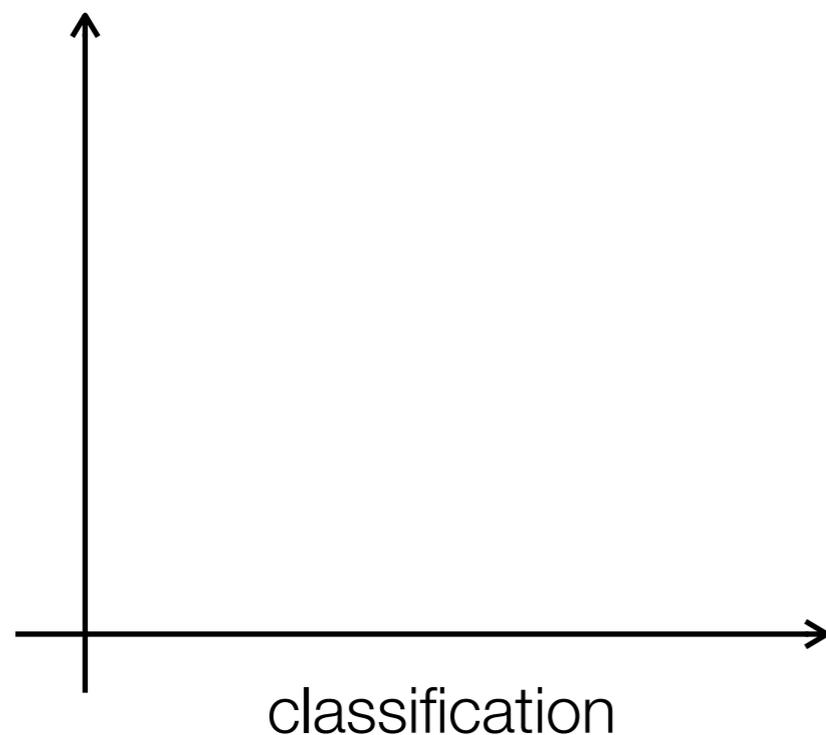
Machine Learning Algorithms

- Algorithms that allow computers to evolve behaviors based on empirical data, such as from sensor data or database.
- Automatic learning to recognize complex patterns and make intelligent decision based on data

(from wikipedia)



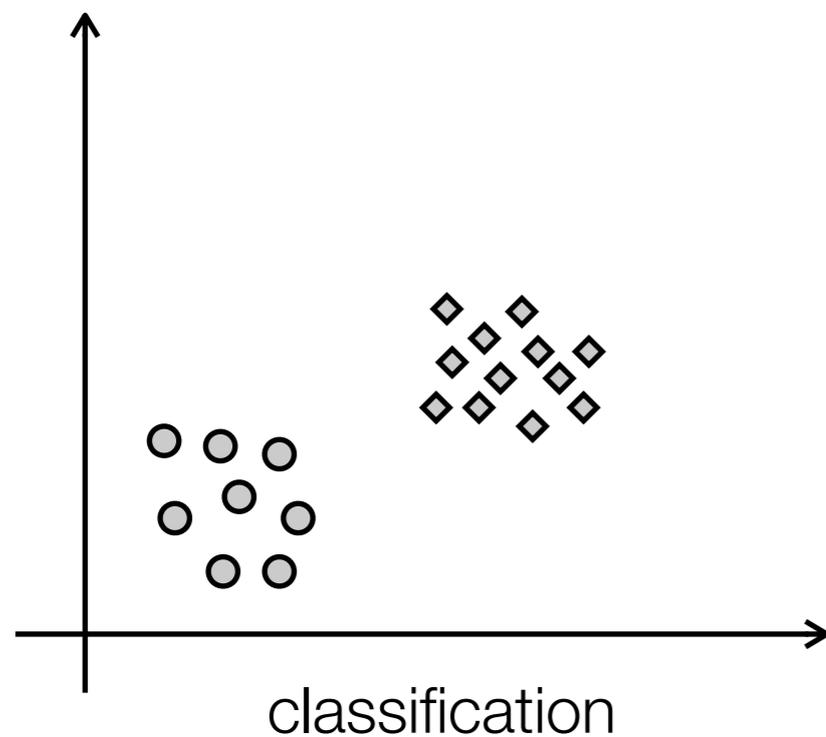
Stanford online ML Class



Machine Learning Algorithms

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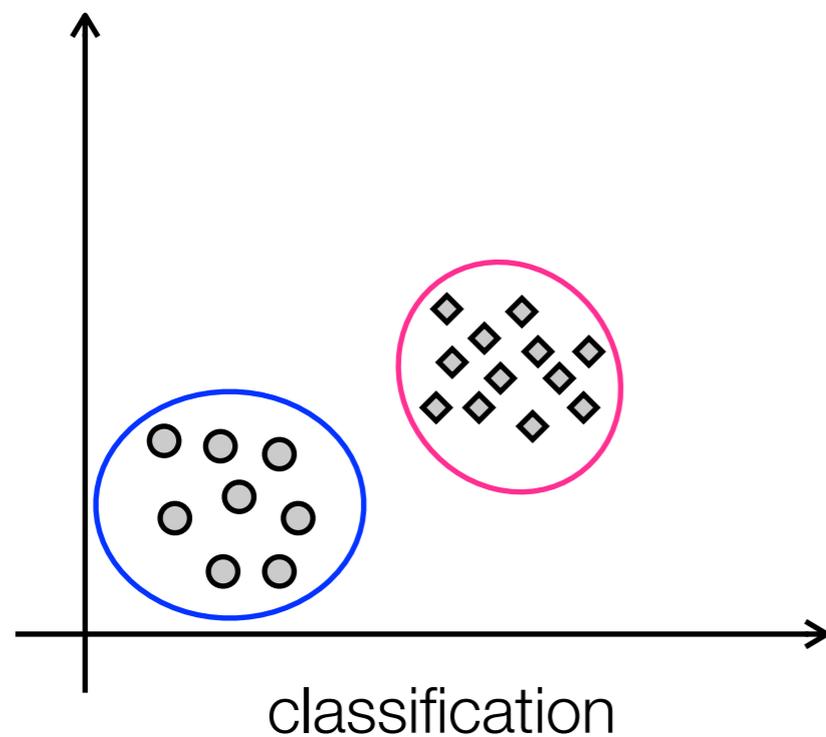
Stanford online ML Class



Machine Learning Algorithms

- Algorithms that allow computers to evolve behaviors based on empirical data, such as from sensor data or database.
- Automatic learning to recognize complex patterns and make intelligent decision based on data

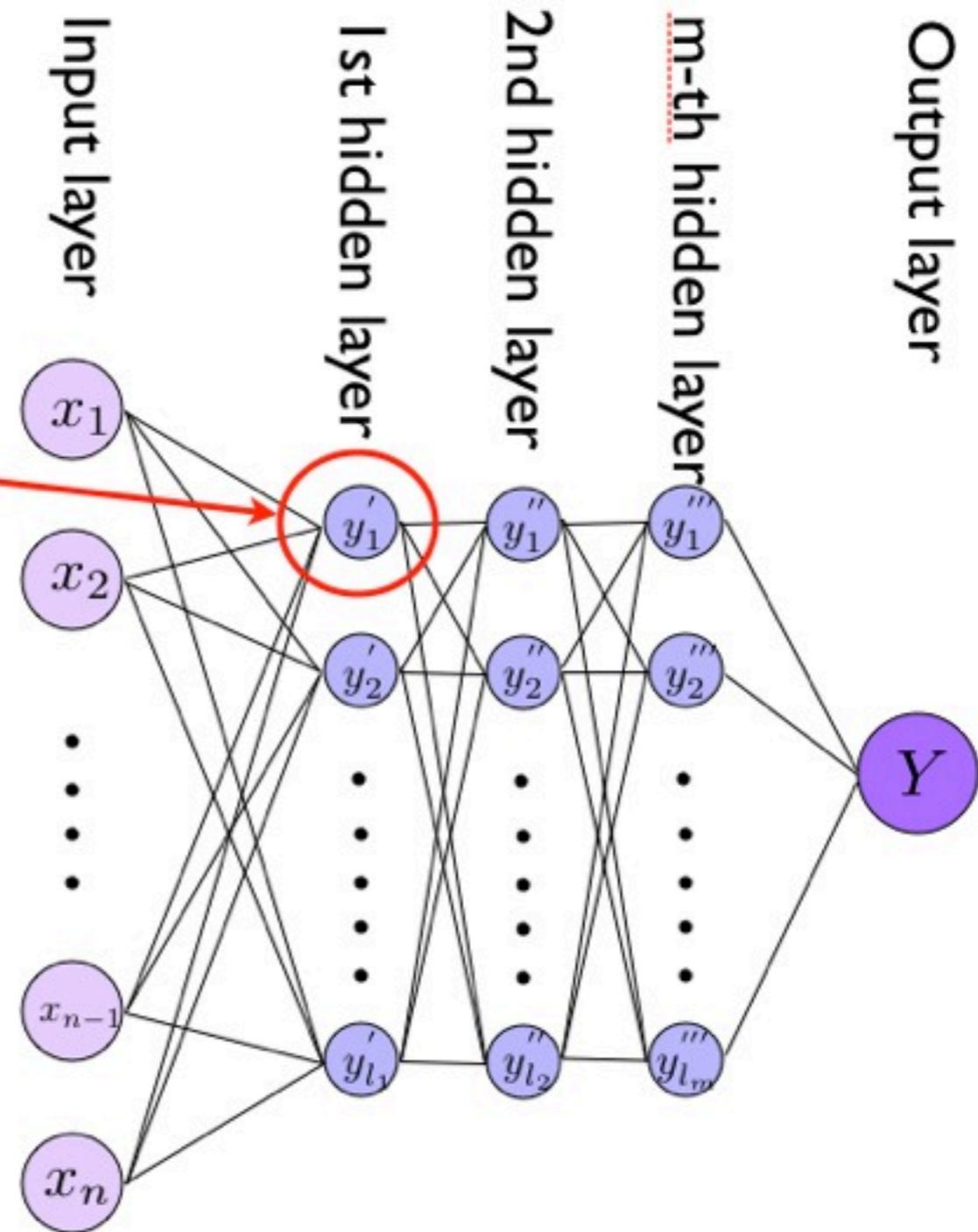
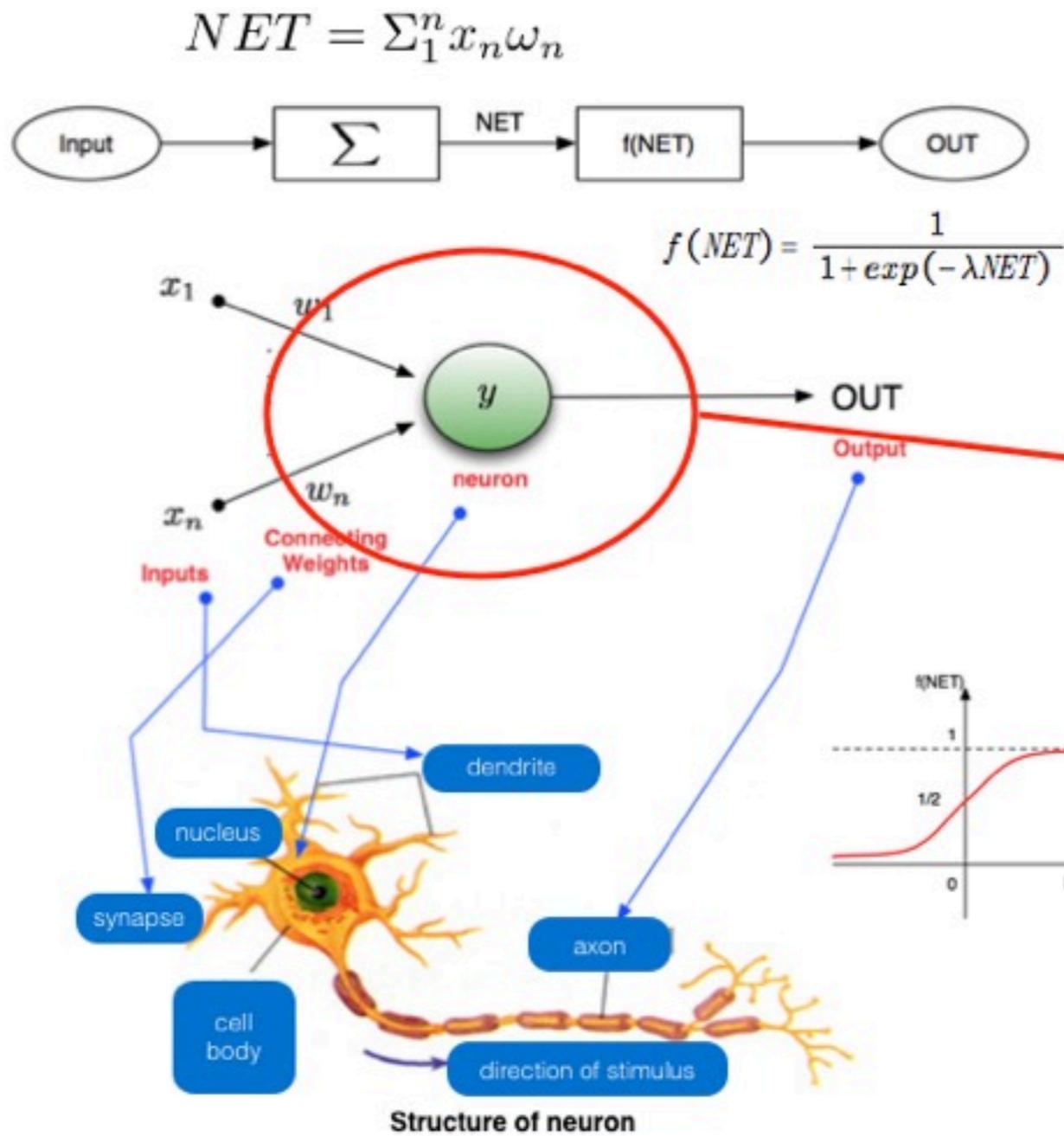
(from wikipedia)



Stanford online ML Class

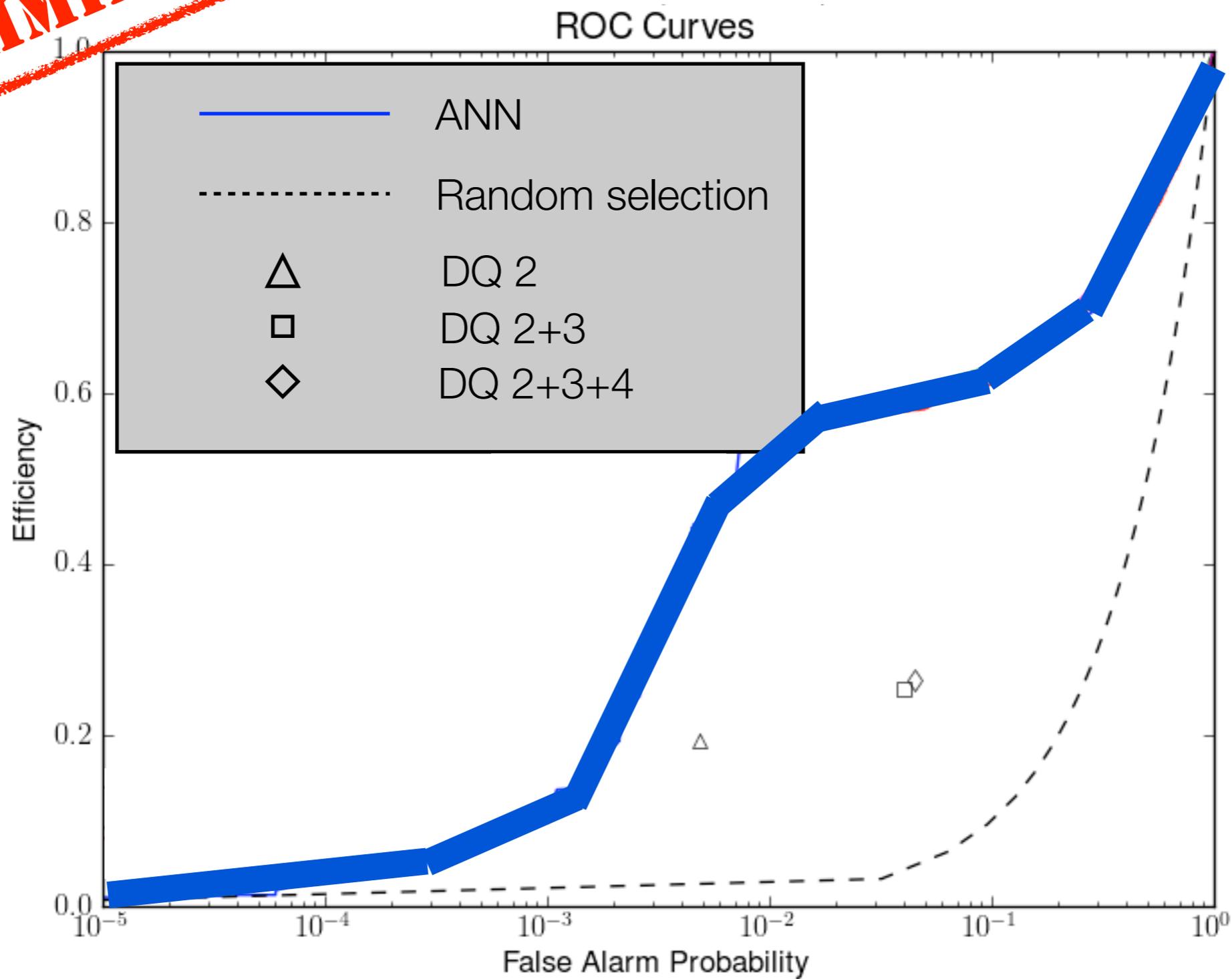


Artificial Neural Networks



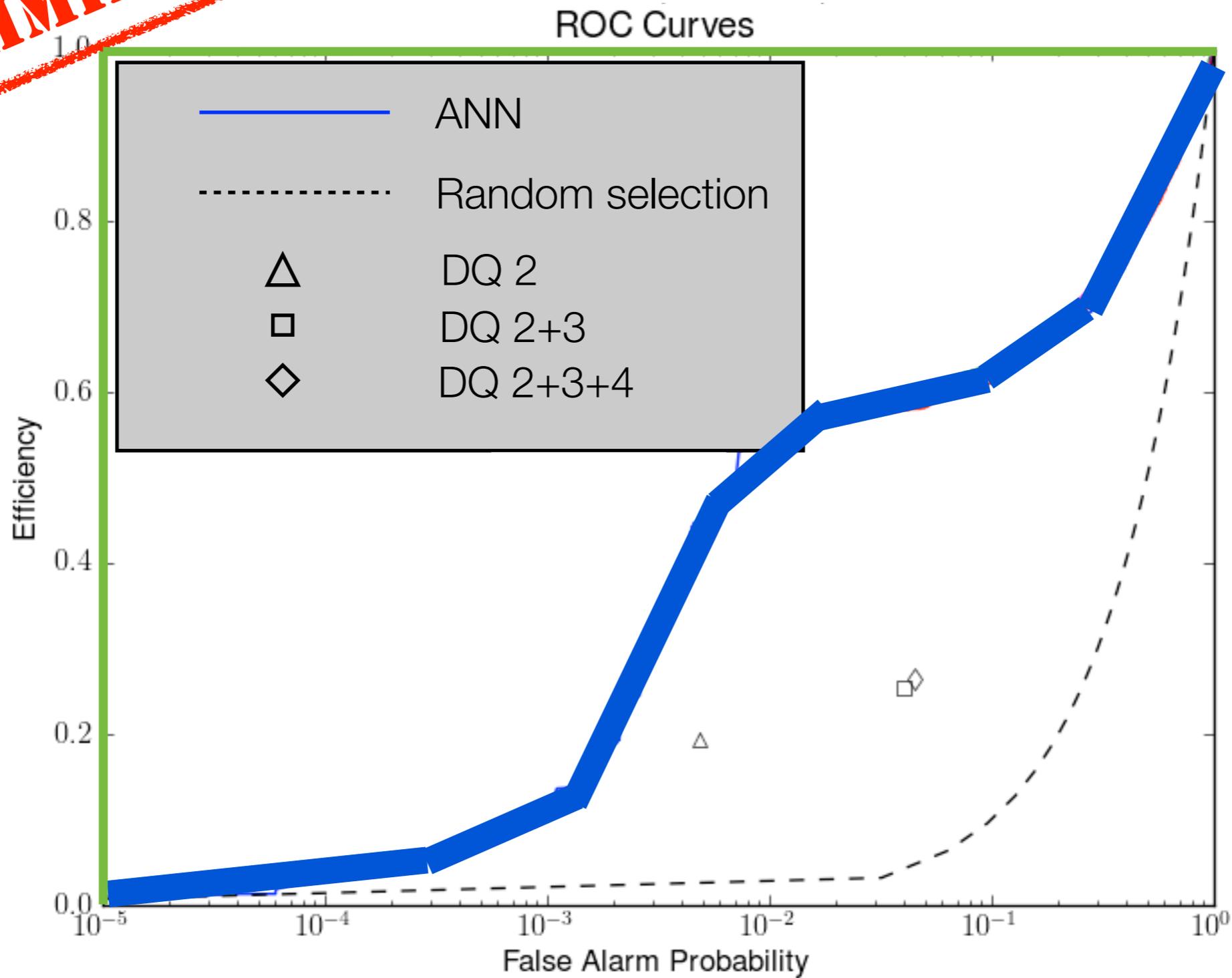
Preliminary Performance

PRELIMINARY



Preliminary Performance

PRELIMINARY



Important Channels

Significant Factor (SF)

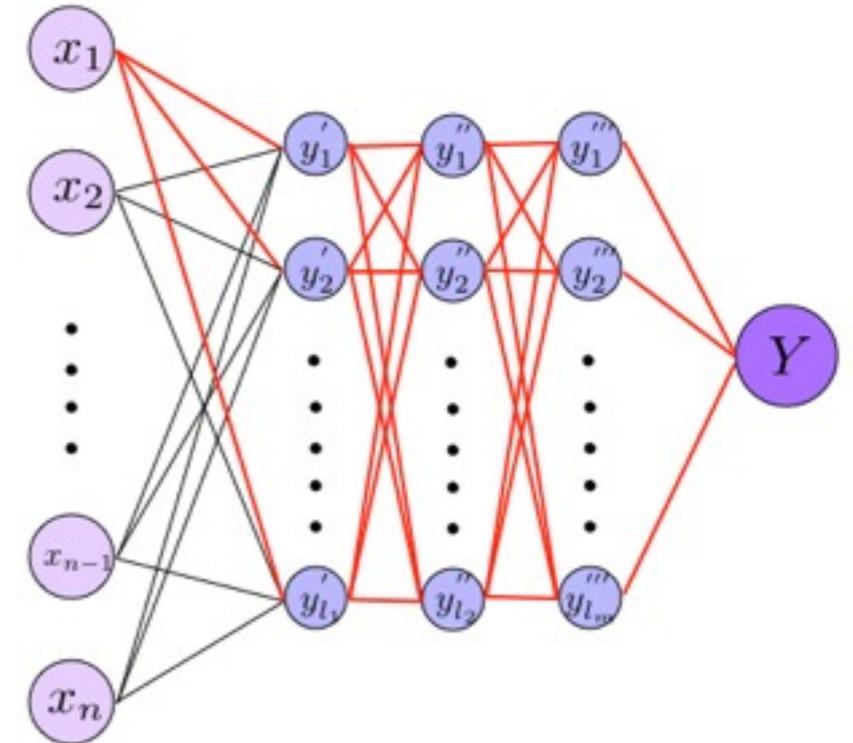
Indicate an quantitative importance of an input variable(x_i) to give an output(Y)

In ANN, total summation of all connection weights(red lines) connected to a given input variable(x_i) is considered as SF.

$$S(i) = \sum_M |(w(i, l_1)w(l_1, l_2) \dots w(l_{M-1}, l_M)w(l_M, o))|$$

$$\sum_M = \sum_{l_1=1}^{L_1} \sum_{l_2=1}^{L_2} \dots \sum_{l_{M-1}=1}^{L_{M-1}}$$

The larger SF indicates the stronger association with noise artifacts in GW channel.



Important Channels

PRELIMINARY

Test week

19 of top 35 channels in ANN are matched with the result of HVeto.

ANN

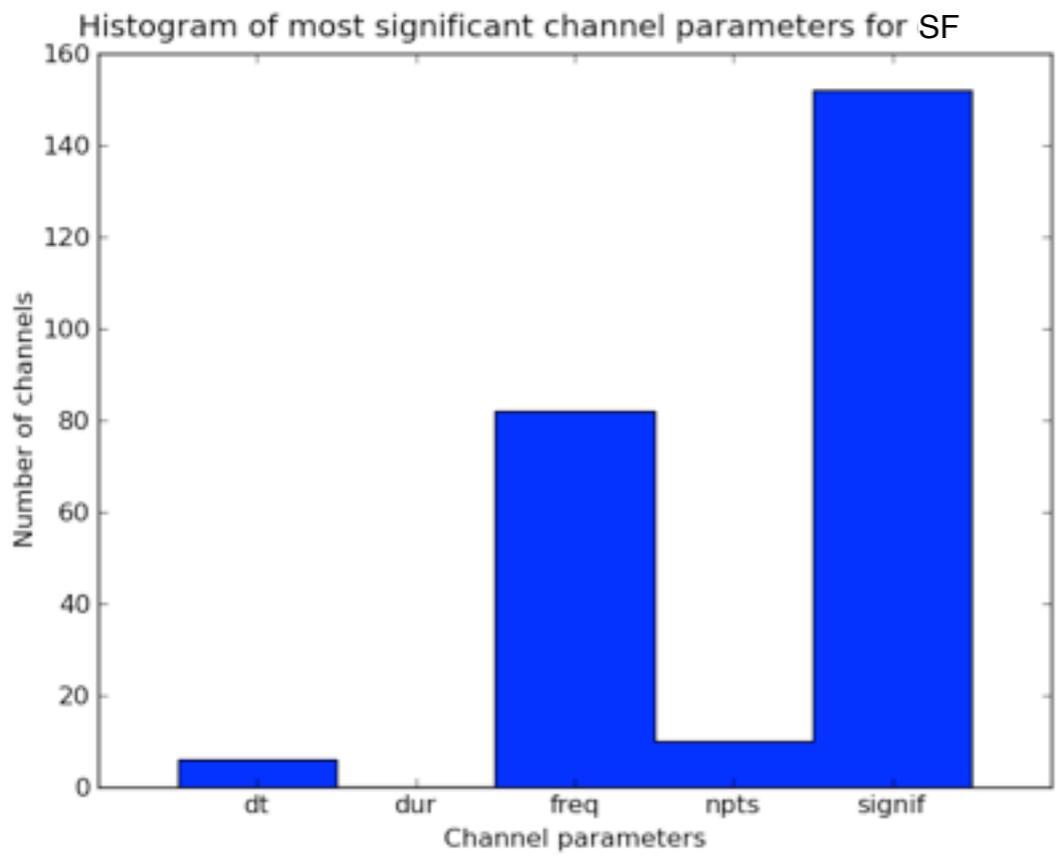
HVeto

```

L1_OPC-QPD1_F_OUT_DAO_32_3048+447289817640
L1_OPC-QPD2_Y_OUT_DAO_32_3048+440329340313
L1_OPC-QPD3_F_OUT_DAO_32_3048+448880835448
L1_OPC-PZT_LSC_OUT_DAO_8_1024+611644080158
L1_OPC-QPD3_F_OUT_DAO_8_1024+340136453594
L1_OPC-QPD1_SUM_OUT_DAO_32_3048+464437187728
L1_OPC-QPD2_SUM_OUT_DAO_32_3048+340147925119
L1_IS-OPC_CONT_RZ_INI_DAO_8_1024+021934370W99
L1_LSC-REF_Q_32_3048+281485244417
L1_OPC-QPD4_F_OUT_DAO_8_1024+247231341518
L1_OPC-QPD4_Y_OUT_DAO_8_1024+238743180353
L1_OPC-PZT_VHON_AC_OUT_DAO_32_3048+213446834119
L1_OPC-QPD3_Y_OUT_DAO_8_1024+210633289612
L1_IS-OPC_GEOFF_HI_INI_DAO_8_1024+201769173267
L1_ASC-WFS4_IP_8_254+184508980033
L1_ASC-WFS2_IP_8_254+174079131805
L1_ASC-RM_P_8_254+147316587591
L1_LSC-POB_I_1024_4096+14124858001
L1_LSC-PRC_CTRL_32_3048+140997938081
L1_LSC-POB_I_32_3048+132375465580
L1_PEM-HAMI_ACCZ_8_1024+13089399712
L1_ASC-ETHX_F_8_254+12746132814
L1_ASC-ETHY_F_8_254+114186921959
L1_IS-OPC_GEOFF_HQ_INI_DAO_8_1024+108914485549
L1_ASC-ITHY_F_8_254+108810942927
L1_PEM-EY_SEDY_8_128+108150738979
L1_IS-OPC_GEOFF_V3_INI_DAO_8_1024+965078823112
L1_ASC-ITHX_F_8_254+915804862348
L1_ASC-WFS2_QP_8_254+84060800434
L1_ASC-WFS2_IP_8_254+755299142881
L1_ASC-WFS1_QP_8_254+731351890178
L1_OPC-DUOTONE_OUT_DAO_1024_4096+696358853255
L1_SUS-ETHY_SENSOR_SIDE_8_254+495592061476
L1_ASC-QPDY_T_8_128+43463210493
L1_SE-ETHX_T_8_128+415823383791
    
```

```

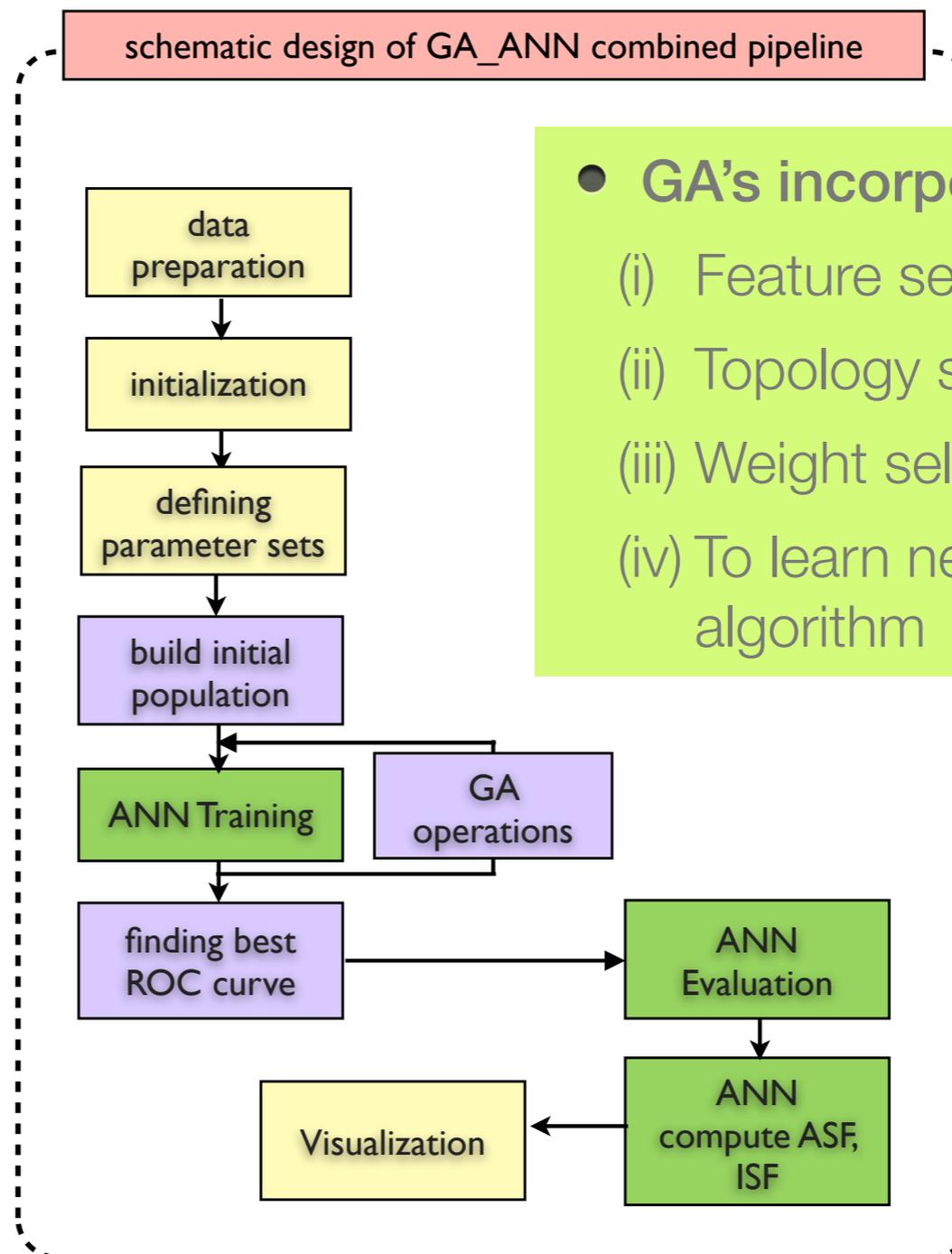
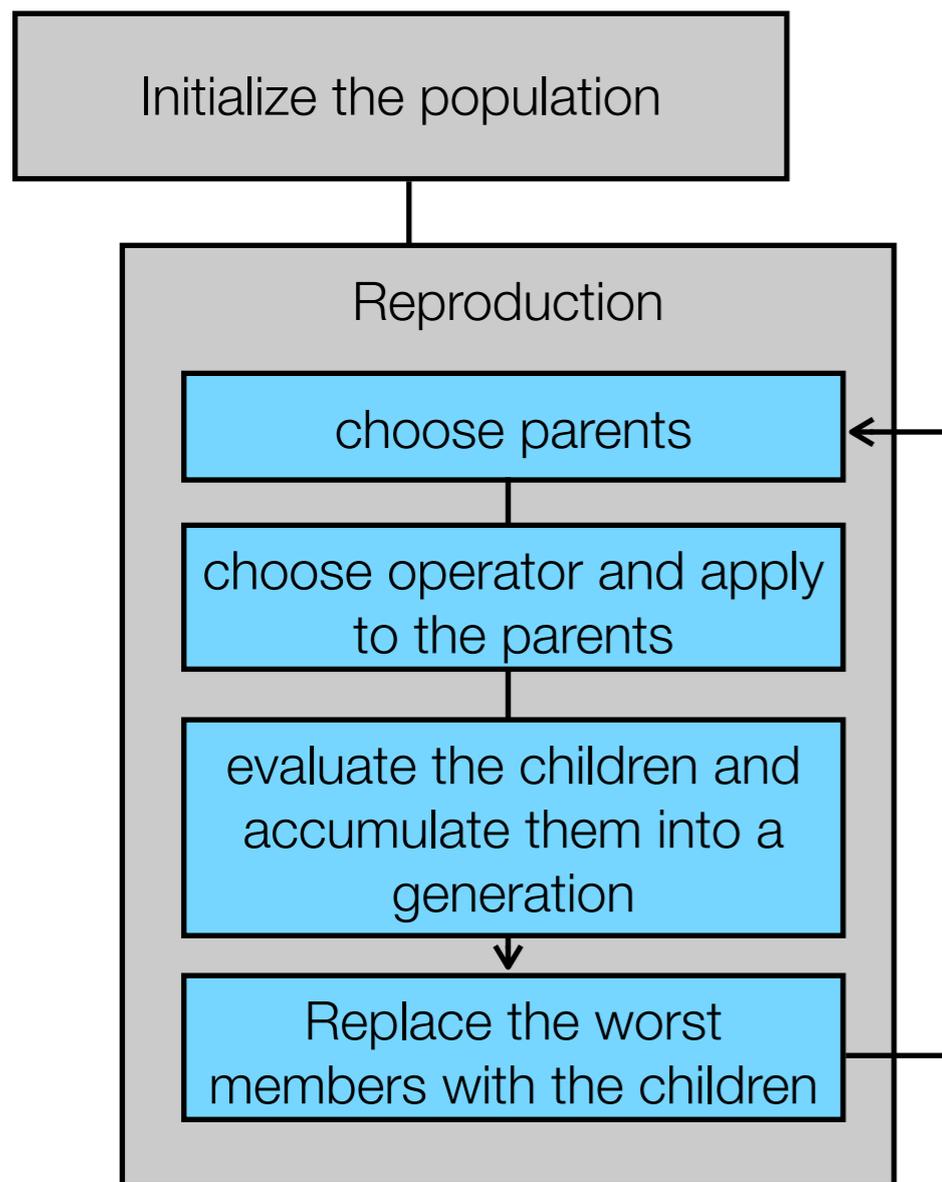
L1_LSC-POB_Q_1024_4096
L1_OPC-PZT_LSC_OUT_DAO_8_1024
L1_IS-OPC_GEOFF_HQ_INI_DAO_8_1024
L1_PEM-VISA_SEIS2_8_128
L1_IS-OPC_GEOFF_HI_INI_DAO_8_1024
L1_ASC-ITHY_F_8_254
L1_PEM-VISA_SAI9HC_8_1024
L1_ASC-BS_P_8_254
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L1_ASC-ITHX_F_8_254
L1_ASC-WFS1_QT_8_254
L1_SUS-ETHX_SENSOR_SIDE_8_254
L1_SUS-ETHY_SENSOR_SIDE_8_254
L1_PEM-EX_SEISX_8_128
L1_ASC-ITHY_Y_8_254
L1_OPC-QPD1_F_OUT_DAO_32_3048
L1_ASC-WFS2_IP_8_254
L1_ASC-ETHX_T_8_254
L1_OPC-PZT_VHON_AC_OUT_DAO_32_3048
L1_ASC-WFS2_QT_8_254
L1_SUS-RM_SUSPT_INI_8_32
L1_OPC-QPD2_Y_OUT_DAO_32_3048
L1_OPC-QPD3_SUM_OUT_DAO_32_3048
L1_OPC-QPD3_F_OUT_DAO_32_3048
L1_ASC-ITHX_Y_8_254
L1_ASC-WFS2_FT_8_254
L1_OPC-QPD1_Y_OUT_DAO_8_1024
L1_LSC-PRC_CTRL_32_3048
L1_OPC-QPD3_F_OUT_DAO_8_1024
L1_PEM-HAMI_ACCZ_8_1024
L1_ASC-WFS1_QP_8_254
L1_PEM-EY_MAGX_I_1024
L1_OPC-QPD4_F_OUT_DAO_8_1024
L1_PEM-VISA_MAGY_I_1024
    
```



Genetic Algorithm

- Optimization / Machine learning (loosely) based on biological evolution; ***natural selection of genes***

Search global optimum



- **GA's incorporation with ANN**
 - Feature selection
 - Topology selection
 - Weight selection
 - To learn neural network learning algorithm

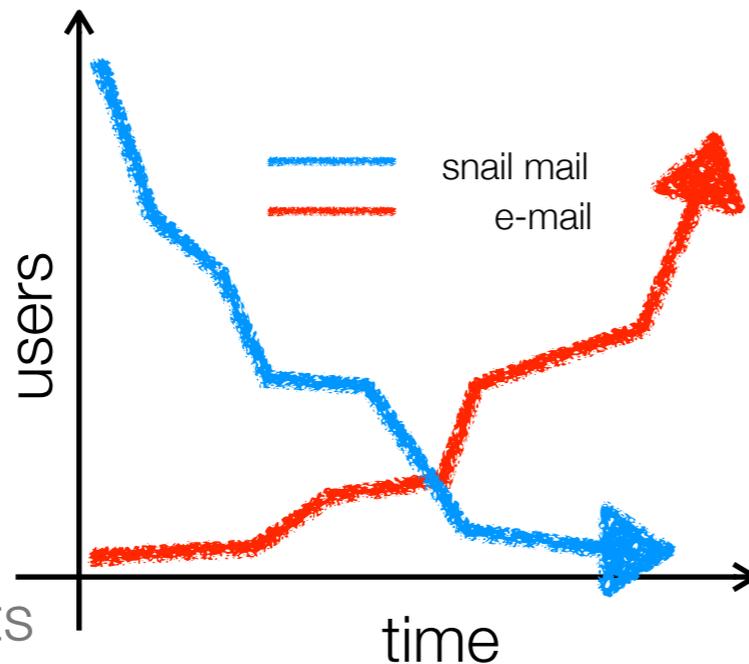
Summary

- Artificial Neural Networks (ANNs) has been applied to auxiliary channels to identify noise artifacts in the GW channel.
- Handling 810 input variables per trigger, feeding into ANN's input layer.
- Preliminary results show better performance than DQ category.
- Genetic algorithm can optimize ANN for choosing the initial guess of connection weights, input features, and values of topological parameters.
- Worth further investigation

Thank you for your attention!
ありがとうございます。

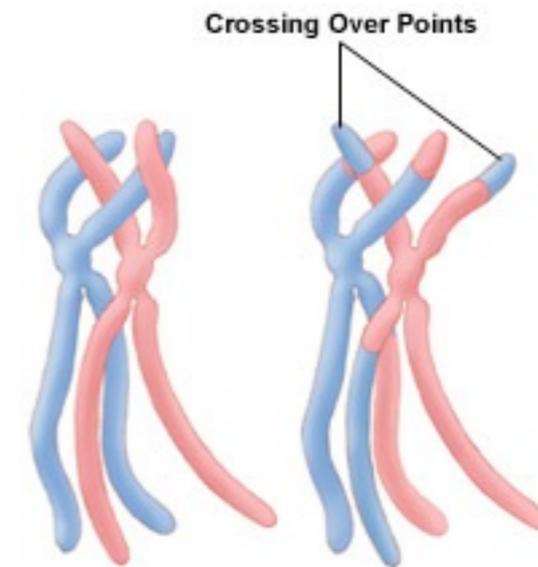
Genetic Algorithm

- Optimization / Machine learning (loosely) based on biological evolution; ***natural selection of genes***



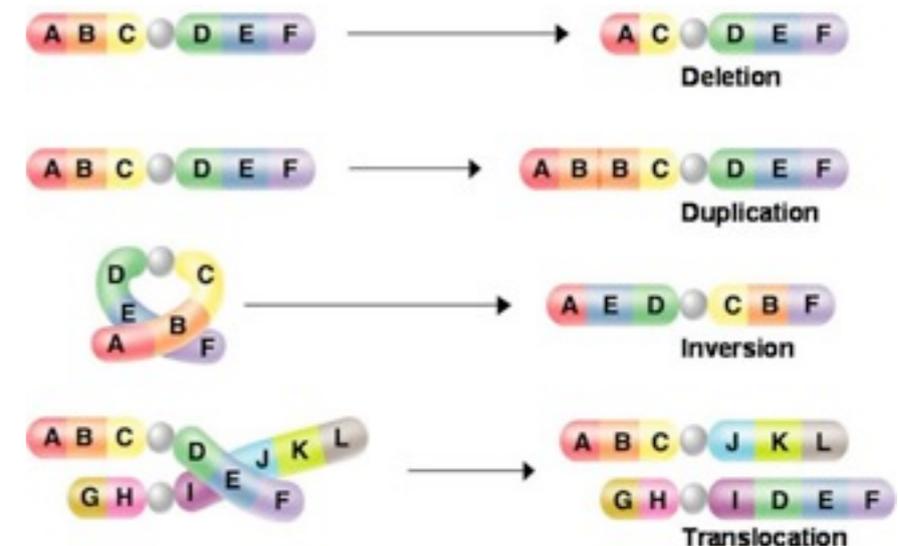
- Five components
 - encoding solutions into chromosomes (**string**)
 - an evaluation function
 - initialization of population of chromosomes
 - operators for reproduction: mutation and crossover
 - parameter settings for the algorithm, the operators, i.e., $N(\text{population})$, $N(\text{generations})$, $prob(\text{operators})$

crossover



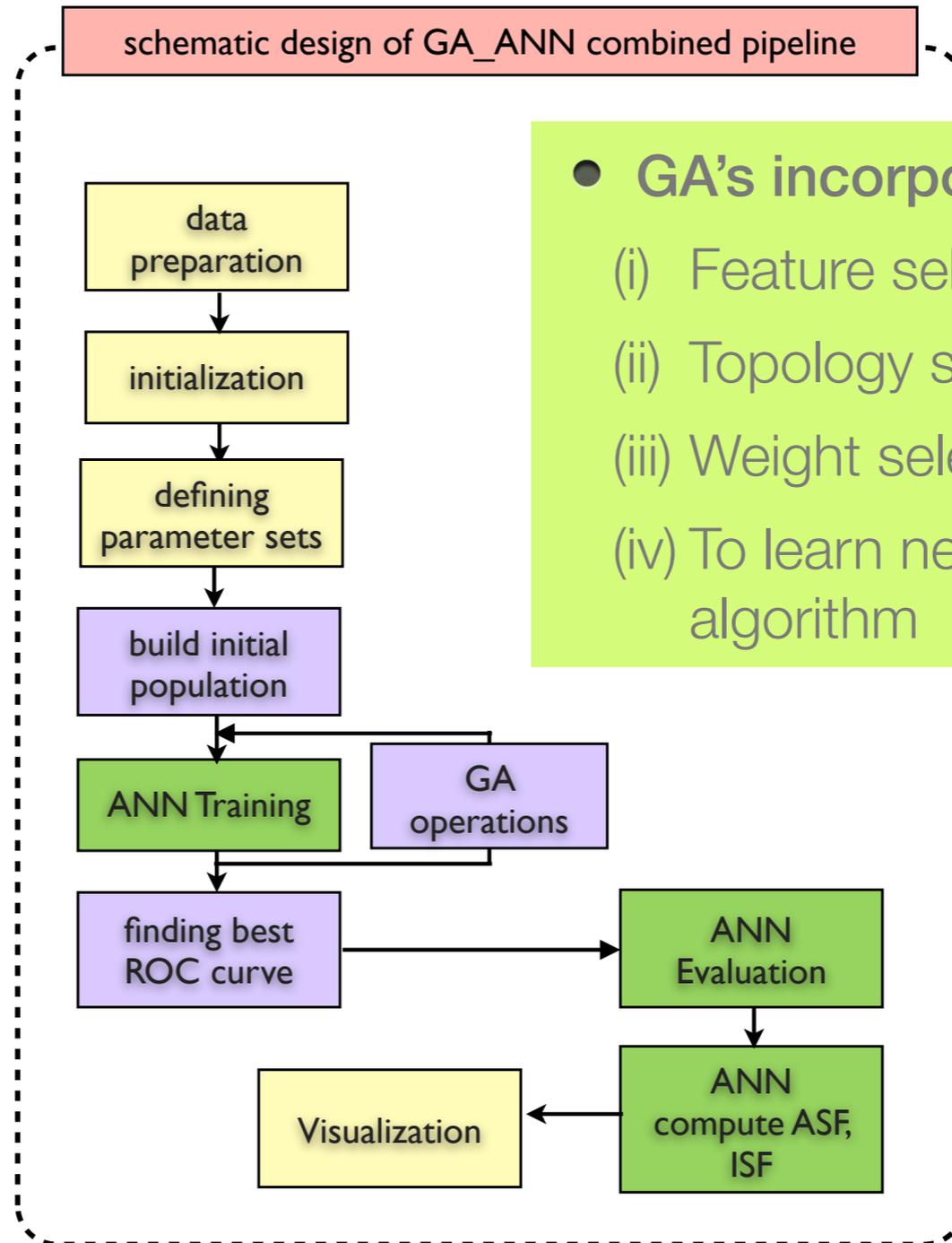
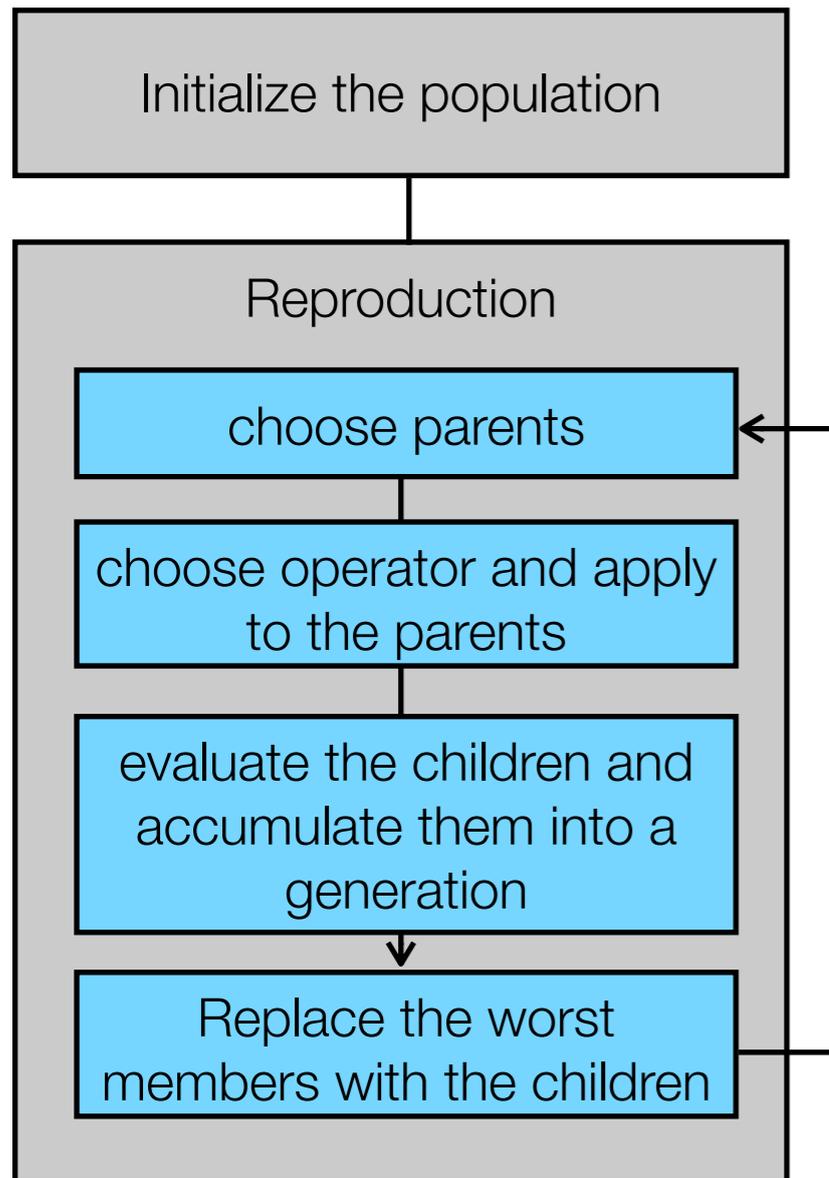
Text

mutation



Genetic Algorithm

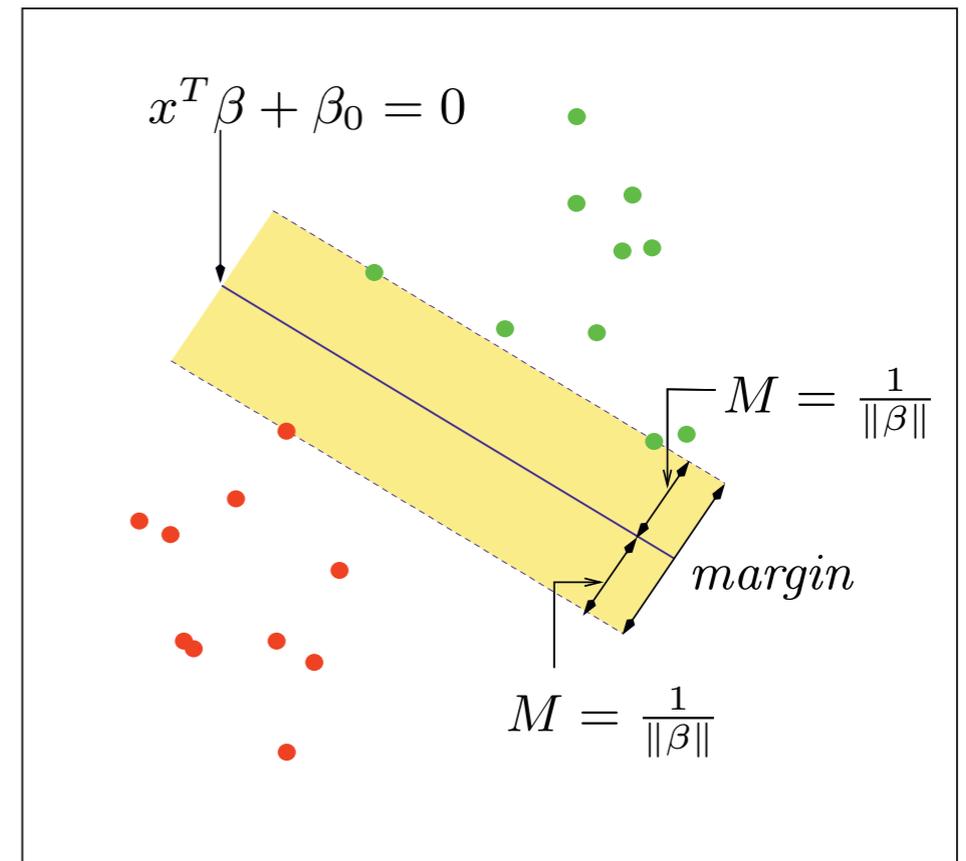
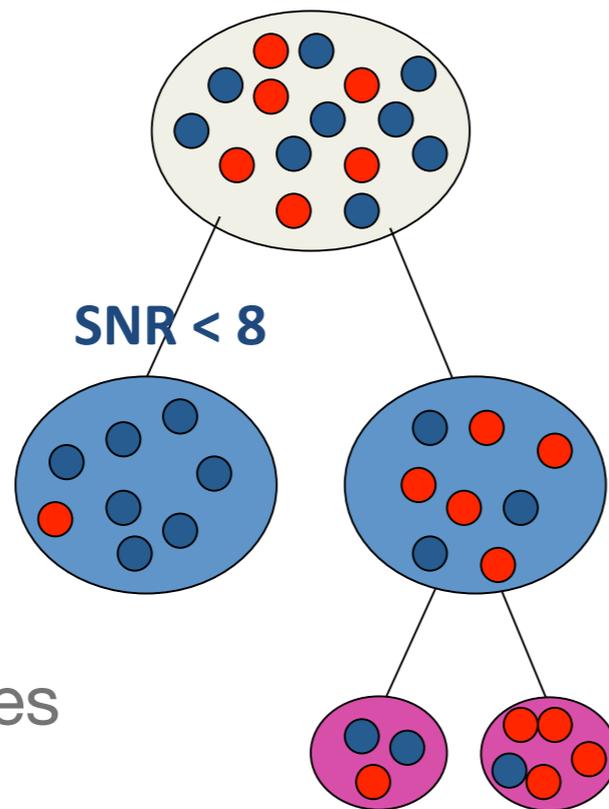
- Operation of GA



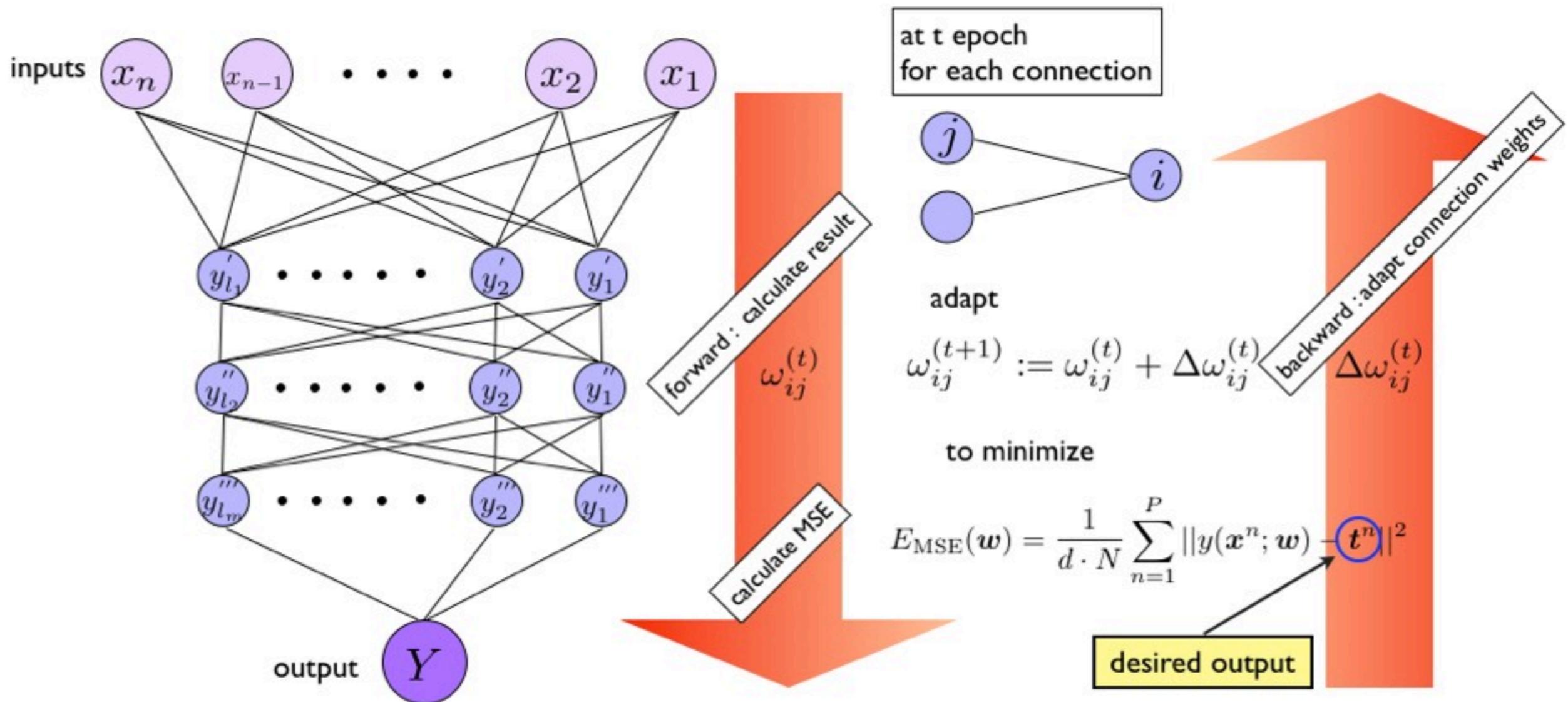
- GA's incorporation with ANN
 - (i) Feature selection
 - (ii) Topology selection
 - (iii) Weight selection
 - (iv) To learn neural network learning algorithm

Machine Learning Algorithms in practice

- MVSC
- SVN
- ANN
- Hierarchical vetoes



Artificial Neural Networks



Artificial Neural Networks

iRPROP (Igel & Hüsken, 2009)
implemented in FANN lib.

$$\omega_{ij}^{(t+1)} := \omega_{ij}^{(t)} + \Delta\omega_{ij}^{(t)}$$

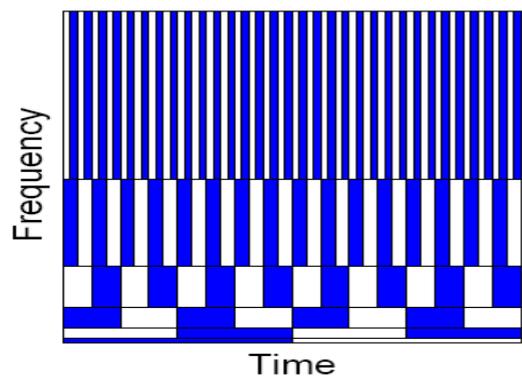
$$\Delta\omega_{ij}^{(t)} := -\text{sign}\left(\frac{\partial E^{(t)}}{\partial w_{ij}}\right) \cdot \Delta_{ij}^{(t)}$$

$$\Delta_{ij}^{(t)} := \begin{cases} \min\left(\eta^+ \cdot \Delta_{ij}^{(t-1)}, \Delta_{\max}\right) & , \text{ if } \frac{\partial E^{(t-1)}}{\partial w_{ij}} \cdot \frac{\partial E^{(t)}}{\partial w_{ij}} > 0 \\ \max\left(\eta^- \cdot \Delta_{ij}^{(t-1)}, \Delta_{\min}\right) & , \text{ if } \frac{\partial E^{(t-1)}}{\partial w_{ij}} \cdot \frac{\partial E^{(t)}}{\partial w_{ij}} < 0 \\ \Delta_{ij}^{(t-1)} & , \text{ otherwise } , \end{cases}$$

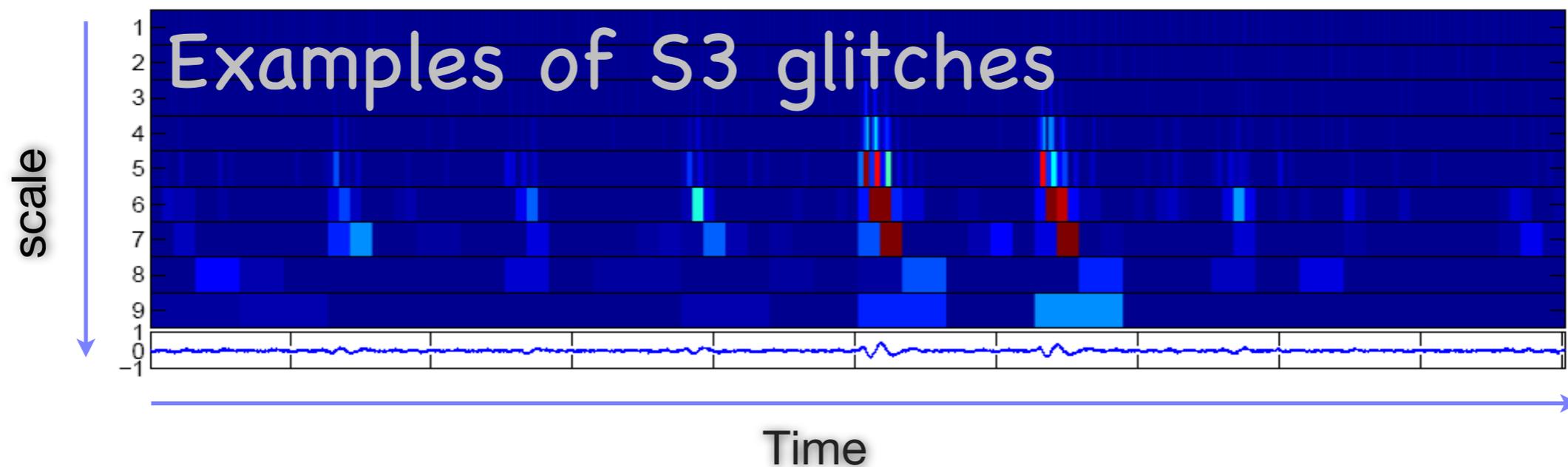
$$\frac{\partial E^{(t)}}{\partial \Delta_{ij}^{(t-1)}} = \frac{\partial E^{(t)}}{\partial w_{ij}^{(t)}} \frac{\partial w_{ij}^{(t)}}{\partial \Delta_{ij}^{(t-1)}} = -\frac{\partial E^{(t)}}{\partial w_{ij}} \text{sign}\left(\frac{\partial E^{(t-1)}}{\partial w_{ij}}\right)$$

Input Variables

KleineWelle Wavelet Transformation



Discrete Dyadic Wavelet transform to decompose the time series into a logarithmically-spaced time-frequency plane



Input Variables

- (a) Significance of loudest trigger within +/- 100ms, or significance of nearest trigger if none exists (sig is related to the SNR)
- (b) Δt to triggers in (a)
- (c) duration of trigger in (a)
- (d) freq of AUX trigger in (a)
- (e) npts in AUX trigger in (a)

signal (=glitch)	clean
loud glitches	random time