REAL-TIME DIAGNOSIS OF CEREBRAL STATUS FOLLOWING TRAUMATIC BRAIN INJURY USING FUZZY MIN-MAX NEURAL NETWORKS

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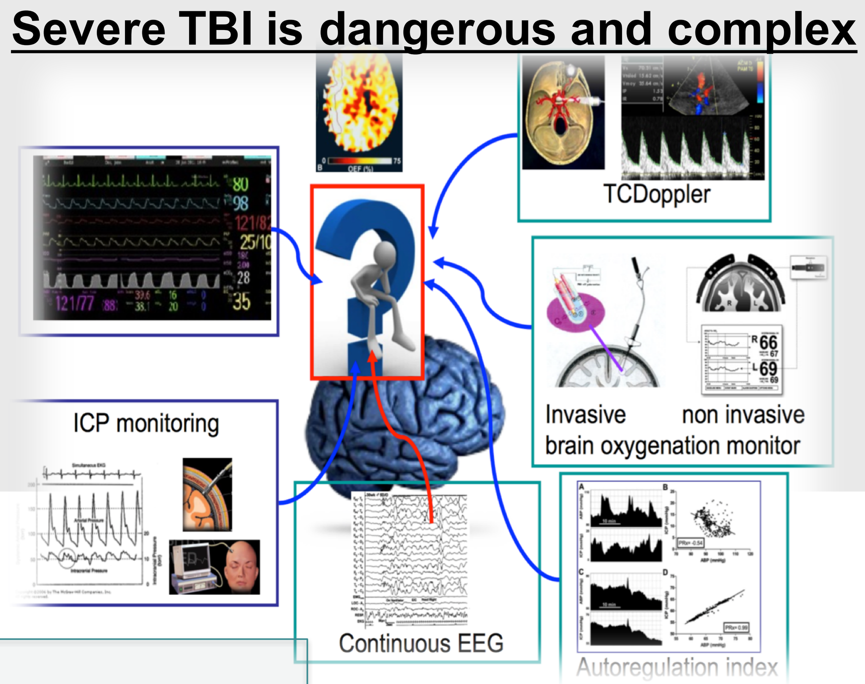
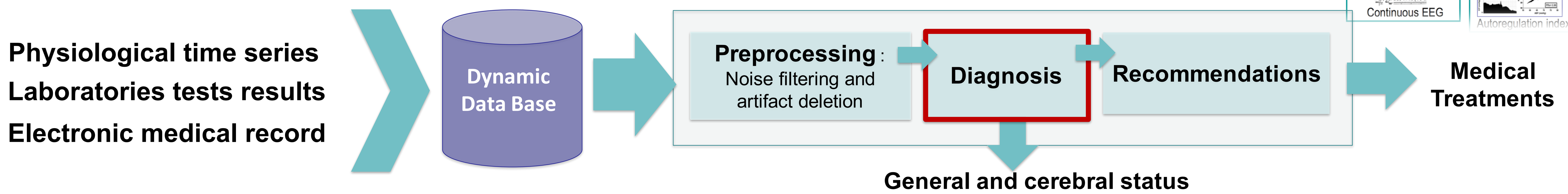
Problematic

- Severe Traumatic Brain Injury (TBI) is the **main cause of mortality** in teenagers and young adults.
- Rapid and efficient management is required to minimize secondary injuries, and **reduce permanent sequelae** risks.
- Clinical Decision Support System (CDSS) can help Intensive care staff improve patient management :
  1. **Overwhelming data flow in Intensive Care Units** : Human brain multivariable analysis capacity is limited.
  2. **Standardization of the care** provided regardless of the medical staff's expertise : Better adherence to medical guidelines.
  3. **TBI is a very complex and rapidly changing condition** : Fast computation power helps detect changing condition quicker.

Severe TBI is dangerous and complex

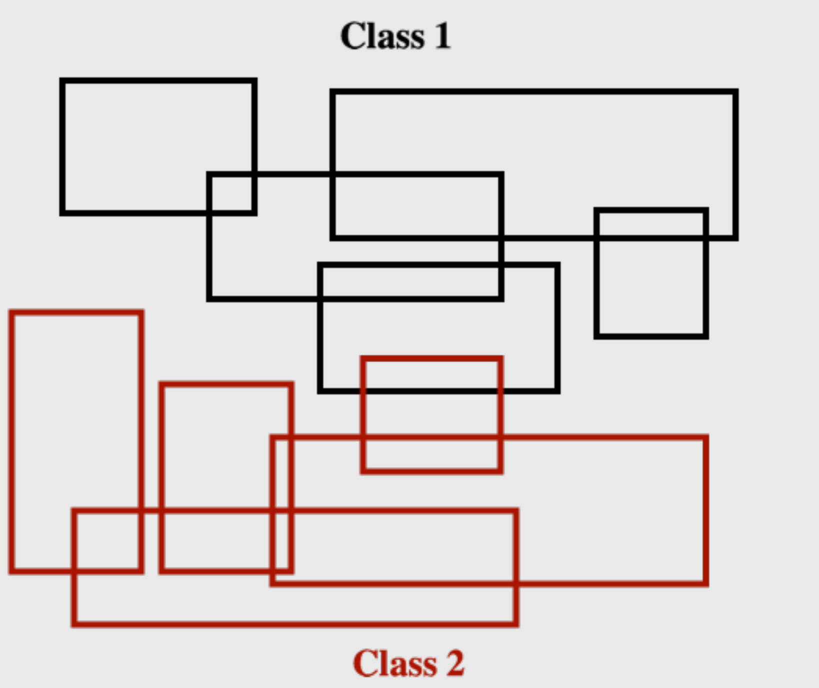


TBI specific Computerized CDSS

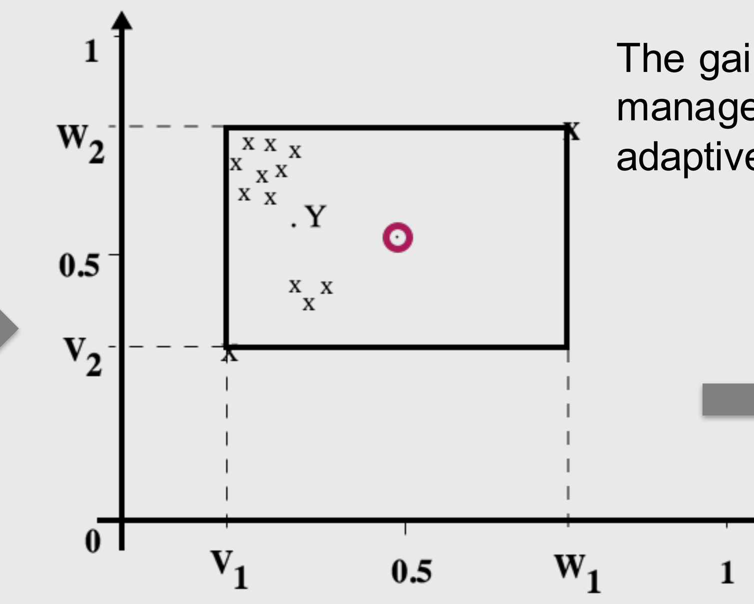


Diagnostic module: Gain Data Core Fuzzy Min-Max Neural Network (GDCFMMN)

An improved supervised Fuzzy Min-Max Neural Network : New membership function **simplifies classification in overlap regions** and allows online parameters modification for an **adapting diagnosis as the patient condition evolves**.



A **FMMN classifier** separates a classification space of n dimensions in m hyperboxes (bj). Each of them belonging to one specific class p. **Interclass overlaps can occur and present a classification difficulty.**



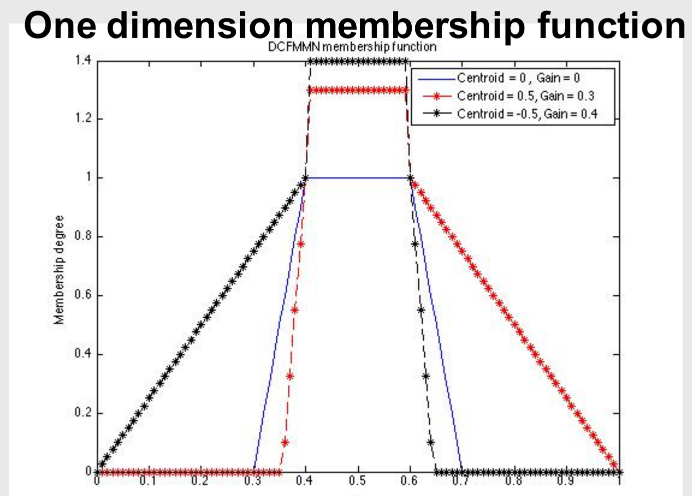
A Hyperbox b_j is defined by its minimum v_{ji} and maximum w_{ji} points. Data dispersion in the region determine its centroid (c_{ji}). A gain factor g_{ji} is computed by

$$g_{ji} = \frac{P_j}{N}\left(1-(w_{ji}-v_{ji})\right)$$

P_j is the number of data points in hyperboxe b_j and N the total number of data points.

The gain factor modulates maximum membership degree facilitating overlap management. Centroid controls the shape of the function enabling data adaptive classification.

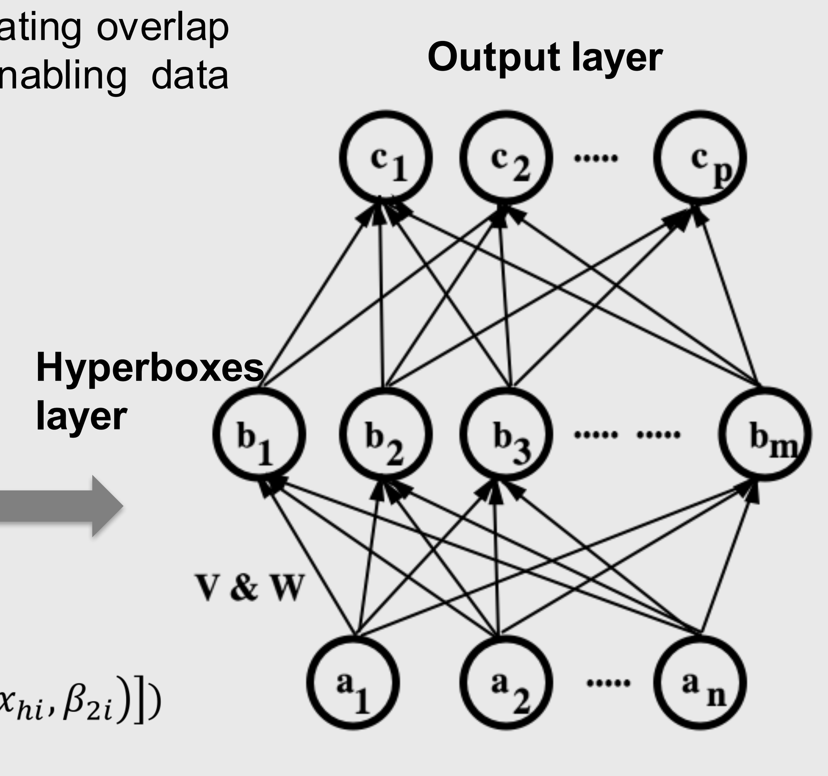
One dimension membership function



$$b_j(X_h) = \min_{i=1\ldots n}\left(min[1-f(x_{hi}-w_{ji},\beta_{1i})],\ [1-f(v_{ji}-x_{hi},\beta_{2i})]\right)$$

with , $\beta_{1i} = \gamma\,(1-c_{ji})^2$, $\beta_{2i} = \gamma\,(1+c_{ji})^2$

$$f(r,\beta) = \begin{cases} 1, & r\beta > 1 \\ r\beta, & 1 \geq r\beta \geq 0 \ ,o = 1,2 \\ -gj_i, & r\beta < 0 \end{cases}$$

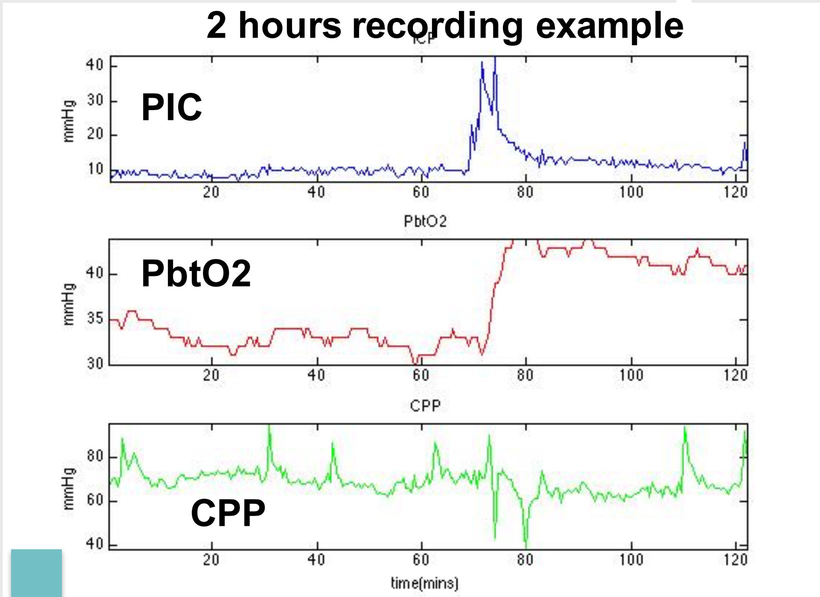


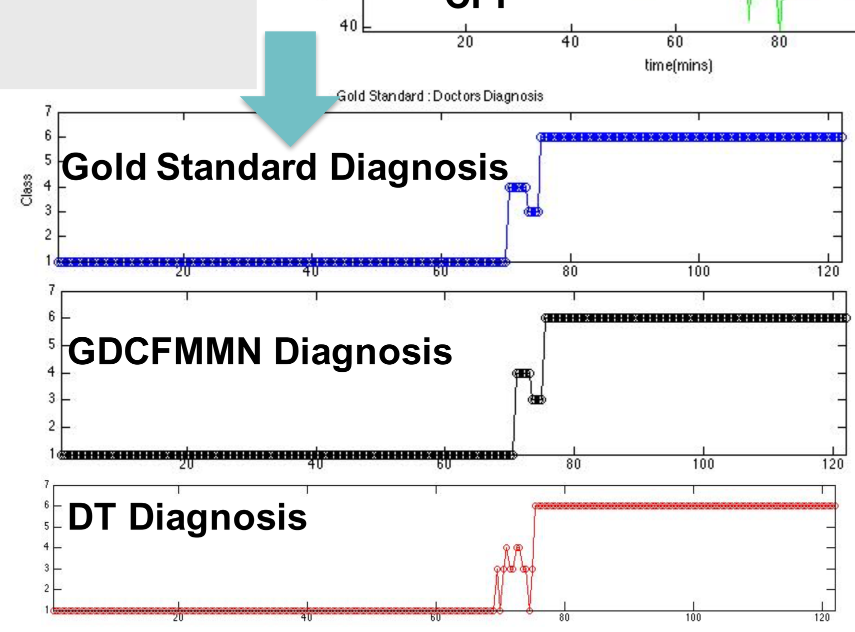
The classifier is implemented as a 3 layers feed-forward online learner neural network.

Results : Cerebral Status Diagnosis

- A **6 hours training** set was created with digitalized time series recording published in the literature. (30 sec. sampling)
- Validation was done on more **9 recordings** from patients with severe TBI representing more than 44 hours in total.
- Variables considered : **Intracranial pressure** (ICP), **Brain Tissue oxygenation** ($PbtO_2$) and **Cerebral Perfusion Pressure** (CPP).
- 6 States defined : 1- **Controlled condition**, 4- **Mild intracranial hypertension** (ICH), 2,3- **ICH with ischemia or with hyperemia** 5,6- **Brain ischemia/hyperemia without ICH.**
- **GOLD STANDARD :** All data were analyzed and diagnosed by intensivists.

2 hours recording example



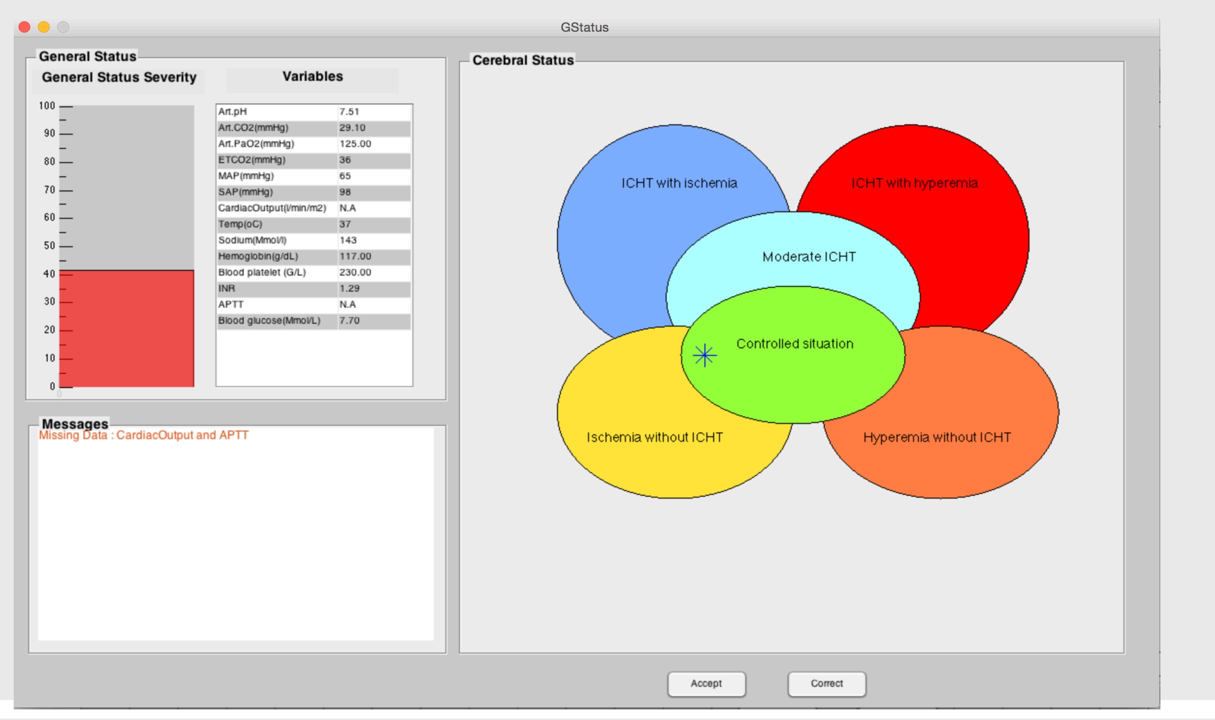


Comparison
- GDCFMMN training time < DCFMMN by 30 % for the most complex network : high number of small hyperboxes .
- It also presented best diagnosis accuracy compared to 8 other classifiers.

Algorithm	Accuracy (%) Median (IQR)
DCFMMN	84.56 (31.84)
GDCFMMN	**98.39 (2.89)**
Neural Network (NN)	94.92 (7.84)
Decision Tree (DT)	97.95 (11.05)
K-nearest neighbors (KNN)	83.63 (32.72)
Fuzzy K-nearest neighbors (FKNN)	83.63 (32.72)
Adaptive neural fuzzy inference system (ANFIS)	97.33 (8.34)
ARTMAP network	85.48 (23.56)
Naïve Bayes Classifier	66.03 (49.96)

Conclusion

- An efficient improved fuzzy min-max neural network was developed to automatically and continuously categorize the patient brain condition.
- This algorithm can also be used to categorize the general status as well.
- This classification tool will permit to develop easily interpretable graphic interface to facilitate rapid assessment by the team, and is the first step before the implementation of management recommendations in the CDSS.



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