Artificial Intelligence and Internet of Things for the Prediction of Glucose in People with Diabetes

LIMSI PhD Day

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Dates : 2017 – 2020

Groupe : AMI

Doctoral School : Sciences et technologies de l'information et de la communication (STIC)

Funding : DigiCosme

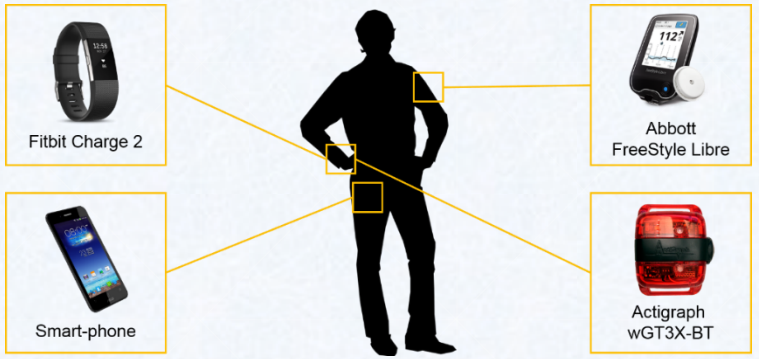
Thursday 6th June 2019 - Maxime DE BOIS

What is Diabetes?

- **Diabetes by the numbers**:
  - 8% of the French population in 2016 [WHO, 2016]
  - Inputed 1,5 million of deaths in 2012 [WHO, 2016]
- **Diabetes day to day**:
  - Goal: regulate glucose level between hypo- and hyperglycemia
    - Hypoglycemia ($< 70\ mg/dL$) : clumsiness, coma, mort (short-term)
    - Hyperglycemia ($> 180\ mg/dL$): cardiovascular diseases, blindness (long-term)
- **Glucose prediction**:
  - To warn the patient of incoming hypo-/hyperglycemia events
  - To help the patient to know its disease better (therapeutic patient education)

Data

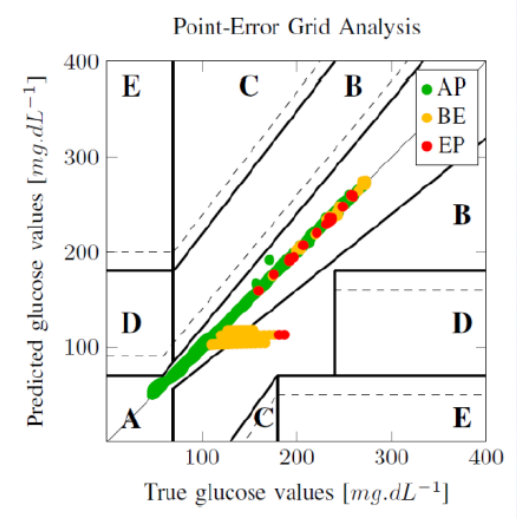
- **T1DMS**:
  - Approved by the FDA
  - Simulation of 30 *in-silico* type 1 diabetic patients
  - Data (4 weeks/patient): glucose (mg/dL), insulin (unit), carbohydrate (g)
- **OhioT1DM dataset**:
  - Blood Glucose Level Prediction Challenge (2018)
  - 6 type 1 patients
  - Data (8 weeks): glucose, insulin, carbohydrate, physical activity, heart rate, sleep
- **IDIAB dataset**:
  - Project with Revesdiab and Dr. JOANNIDIS
  - Accepted by the French *Comité de Protection des Personnes* (ID RCB 2018-A00312)
  - 5 type 2 patients
  - Data (4 weeks): glucose, insulin, carbohydrate, physical activity, heart rate, sleep, emotions

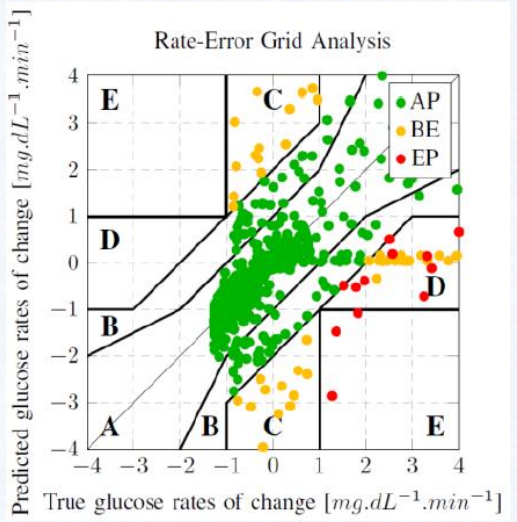


Experimental system

Preliminary Study

- **Dataset**: T1DMS
- **Study of state-of-the-art predictive models**:
  - Autoregressive (AR, ARX, ARIMAX) models
  - Support vector regression (SVR)
  - Gaussian processes
  - Neural-networks : extreme learning machine, feed-forward and recurrent (LSTM) neural networks
- **Prediction horizons**: 30, 60, and 120 minutes
- **Metrics**:
  - *RMSE*: accuracy of the predictions
  - *CG-EGA*: clinical acceptability of the predictions
- **Conclusion**:
  - Superiority of SVR and neural-network-based solutions
  - Each model has each own specific strengths and weaknesses
  - Consecutive predictions are not consistent with each others
    - => lose of clinical acceptability

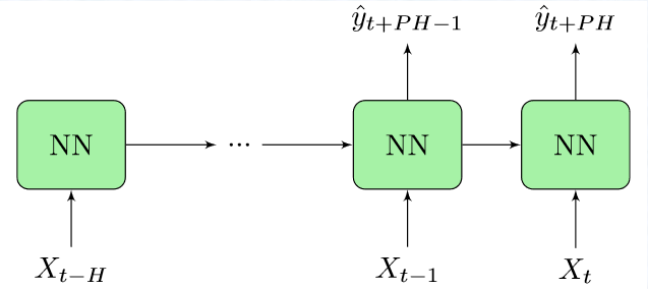




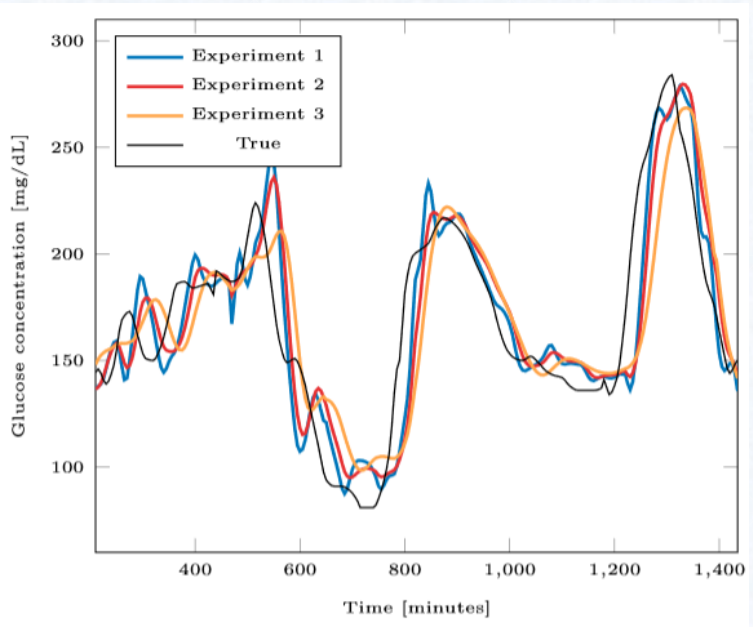
CG-EGA of feed-forward NN

Prediction-Coherent Recurrent Neural Network

- **Goal**: Make consecutive predictions coherent with each others
- **Datasets**: OhioT1DM and IDIAB (*only* glucose, insulin and carbohydrate)
- **Means**:
  - New loss function : $Loss = MSE(\boldsymbol{y}, \hat{\boldsymbol{y}}) + c \cdot MSE(\boldsymbol{\Delta y}, \boldsymbol{\Delta \hat{y}})$
    - Penalizes the model on the predicted variation errors
  - Use of a two-outputs LSTM RNN (1 hidden of 128 neurons)
- **Conclusions**:
  - Improved clinical acceptability
  - Same improvement in both datasets (type 1 and 2)
  - Different optimal c values depending on the patient



Two-outputs RNN architecture



Glucose predictions during a day against ground truth

Forthcoming Research

- **Use of the entirety of the datasets**
  - Analysis of the impact the following added pieces of information:
    - Physical activity, sleep, emotions
  - Pretrain the models with data from other patients and from other datasets
- **Focus on the interpretability of the models**
  - Paramount importance in the biomedical field
  - Use of attention-based neural networks
- **Therapeutic patient education**
  - Simulation of the diabetic patient's day with *anticipated events*
    - Make the patient plan his/her day ahead
  - Emphasis on the interpretability of the model
    - Make the patient understand the simulation and learn from it

Publications (1)

- **Journals**:
  1. (Submitted) M. De Bois, M. A. El Yacoubi et M. Ammi, «Benchmark of Personalized Glucose Predictive Models for Type-1 Diabetic People,» *IEEE Transactions on Biomedical Engineering,* 2019.

- **International Conferences**:
  2. (Submitted) M. De Bois, M. A. El Yacoubi et M. Ammi, «Model Fusion to Enhance the Cinical Acceptability of Long-Term Glucose Predictions,» International Conference on Artificial Neural Networks (ICANN), 2019.
  3. (Submitted) M. De Bois, M. A. El Yacoubi et M. Ammi, «Prediction-Coherent Recurrent Neural Network for Safer Glucose Predictions in Diabetes,» European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (ECML-PKDD), 2019.
  4. (Accepted) M. De Bois, M. A. El Yacoubi et M. Ammi, «Study of Short-Term Personalized Glucose Predictive Models in Diabetes,» International Joint Conference on Neural Networks (IJCNN), 2019.
  5. M. De Bois, H. Amroun and M. Ammi, «Energy Expenditure Estimation Through Daily Activity Recognition Using a Smart-phone,» at IEEE World Forum on IoT, Singapour, 2018.

Publications (2)

- **Posters**

6. M. De Bois, H. Amroun et M. Ammi, «Energy Expenditure Estimation Through Daily Activity Recognition Using a Smart-phone,» chez *FéDeV*, Vélizy-Villacoublay, 2017.
7. M. De Bois, M. A. El Yacoubi et M. Ammi, «Study of Short-Term Personalized Glucose Predictive Models in Diabetes,» *Journée IMT IA & Santé,* 2018.

- **Softwares**

8. M. De Bois, “Glyfe,” 2019, doi: 10.5281/zenodo.3234605. [Online]. Available: https://github.com/dotXem/GLYFE.