# iGLU: Non-invasive Device for Continuous Glucose Measurement with IoMT Framework

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# Outline of the Talk

- Diabetes Issues

- Need of Continues Glucose Monitoring

- Design of iGLU

- iGLU Proof of Concept with Prototyping

- DNN Based Glucose Prediction

- Conclusions

- References

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# Diabetes Issues

- Diabetic patients have doubled since last decade with an estimated 422 million diabetic people have been reported in 2019.

- There is a requirement to design the solution for the glucose measurement of the diabetes patients.

- People would be more aware of their diet control after continuous monitoring [2].

- No smart healthcare solution for glucose measurement is available in the market till date.

- Diabetes can be of Type 1, type 2 and Gestational Diabetes.

- The risk of getting type 2 diabetes has been widely found to be associated with lower socio-economic position across countries
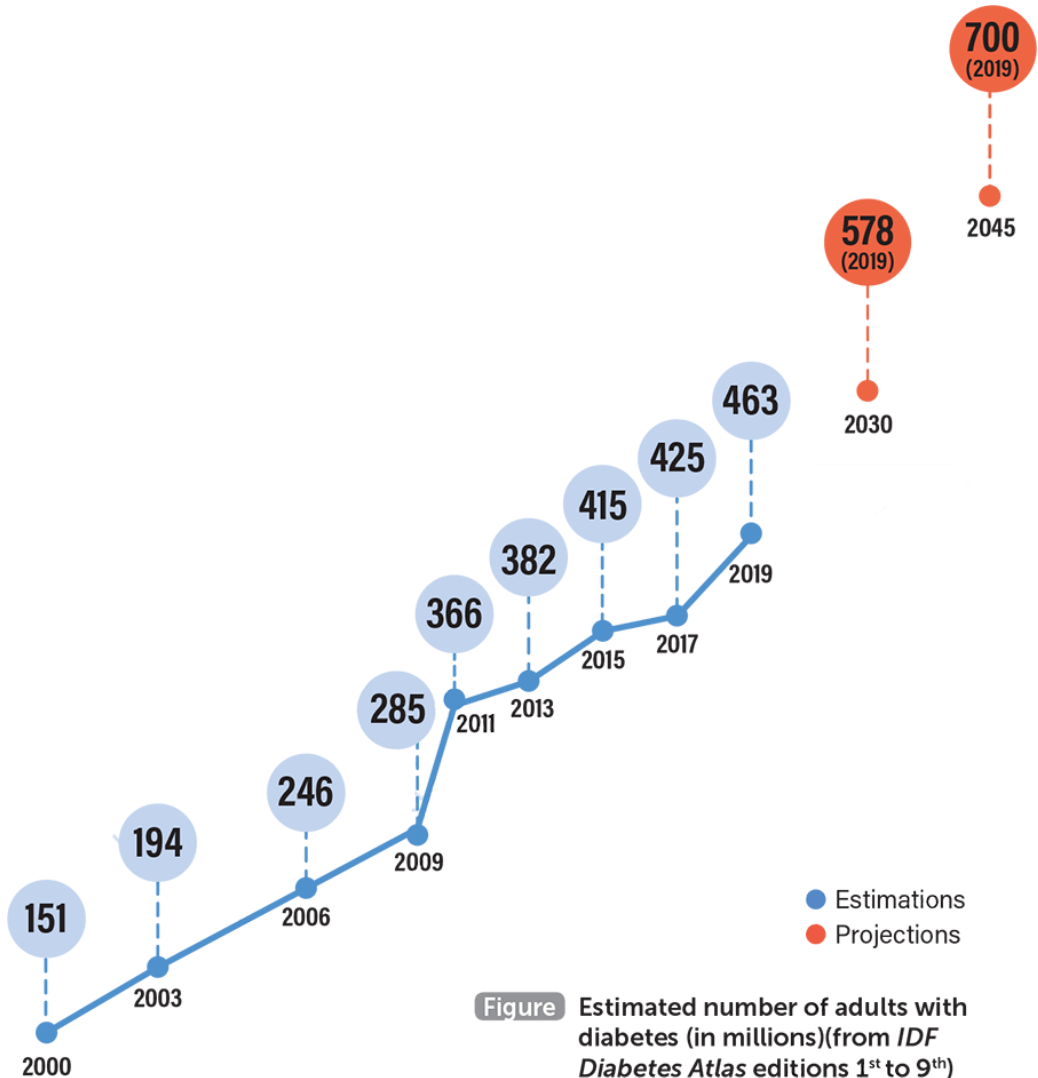
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# Diabetes is a Global Crisis



**Figure** Estimated number of adults with diabetes (in millions)(from *IDF Diabetes Atlas* editions 1st to 9th)

- ● Estimations
- ● Projections

Source: https://diabetesatlas.org/en/sections/worldwide-toll-of-diabetes.html

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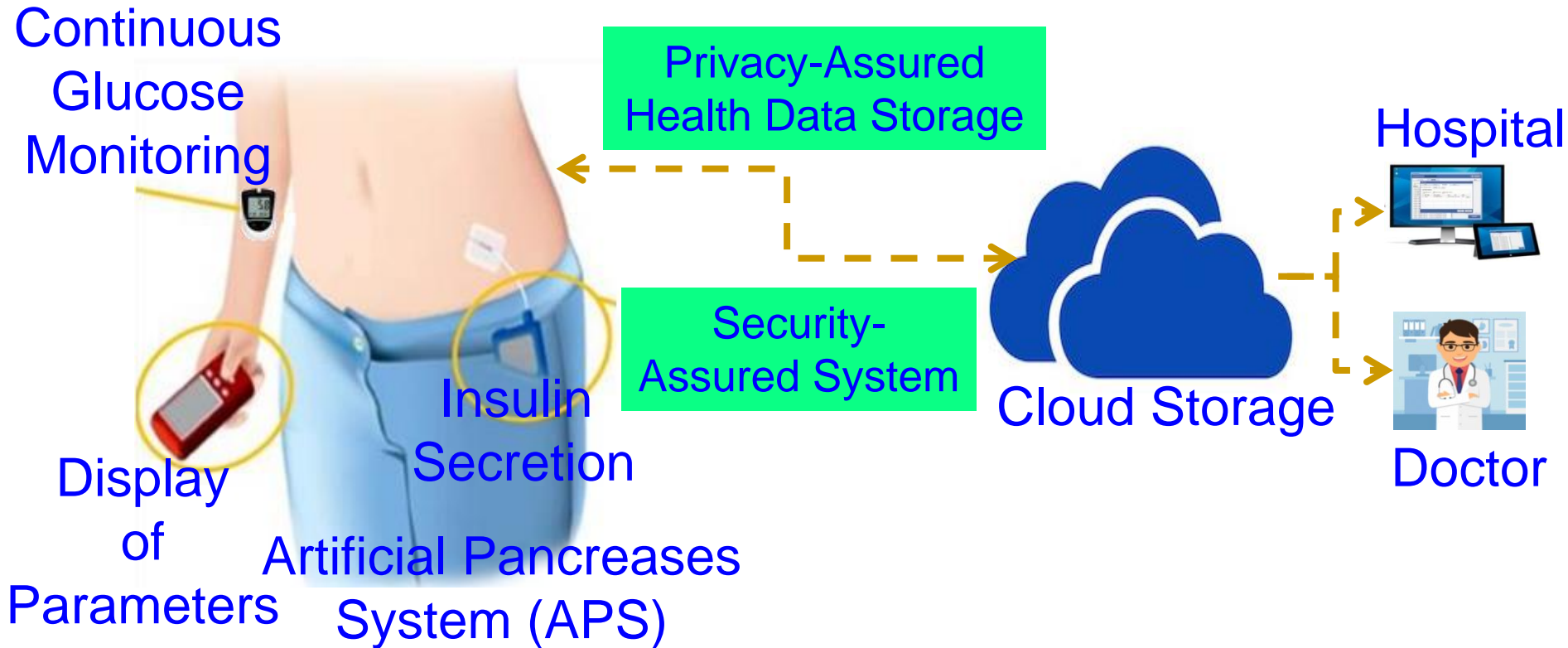
# Need of Continues Glucose Monitoring

- Sometimes diabetic patients require to measure the glucose at least 3-4 times in a day during some critical condition [3].

- The traditional method of blood glucose measurement is through pricking blood drop.

- The present available Continuous Glucose Measurement (CGM) devices are neither accurate nor cost-effective [4].

- In order to mitigate the issues, we present a non-invasive iGLU device with Internet of Medical Things (IoMT) framework to provide the state of art solution for smart healthcare.

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# Noninvasive Detection is Needed
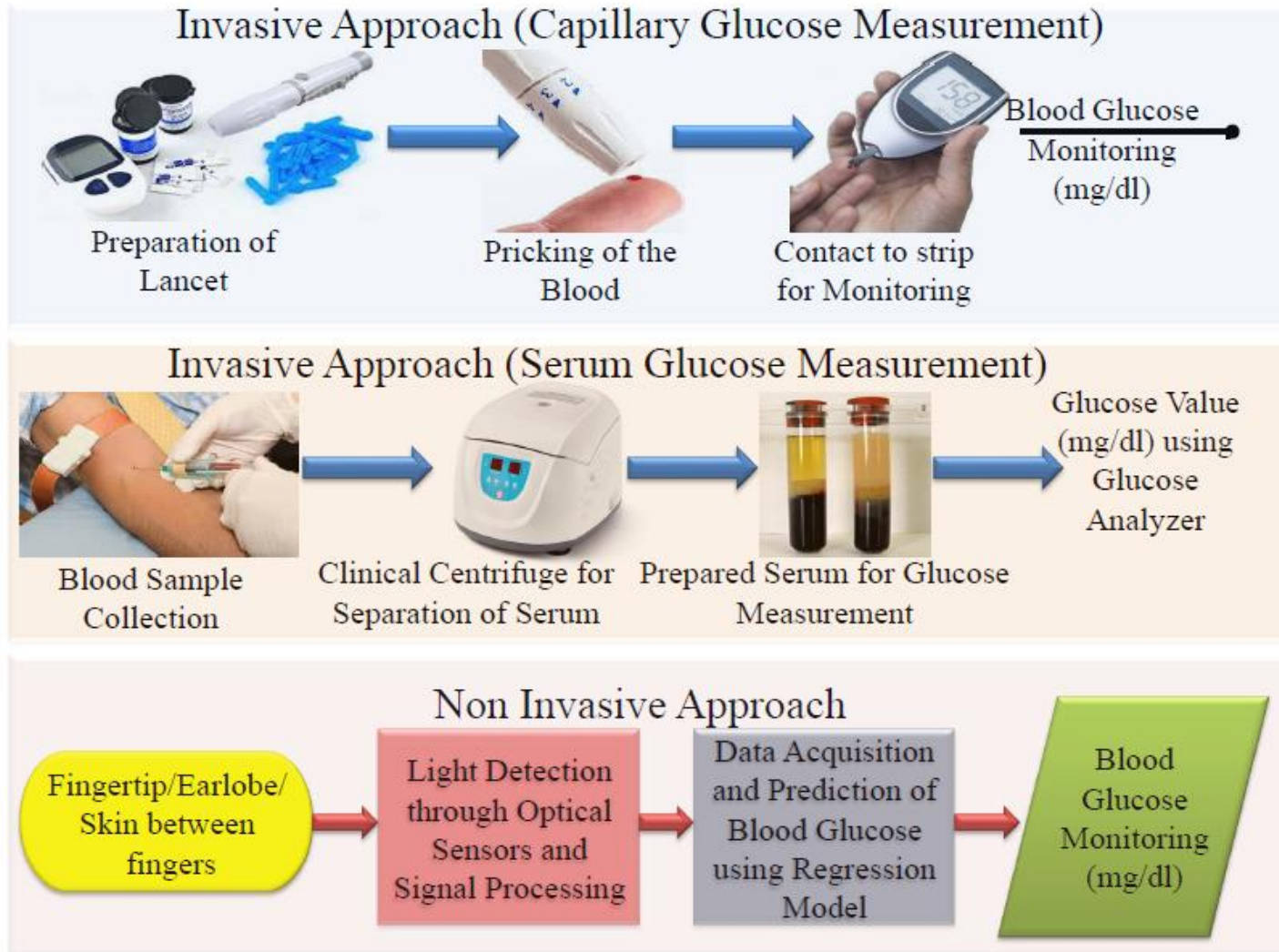


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# Our Vision – iGLU (Intelligent Noninvasive Monitoring and Control)



Continuous Glucose Monitoring

Privacy-Assured Health Data Storage

Hospital

Security-Assured System

Cloud Storage

Display of Parameters

Insulin Secretion

Artificial Pancreases System (APS)

Doctor

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# Design of iGLU

- iGLU is low cost and high accuracy solution to measure the blood glucose of any type of patients at any time.

- The device is user-friendly, fast operated and effective for smart healthcare [5].

- A novel non-invasive intelligent device is proposed using NIR light with specific wavelengths for instant glucose measurement.
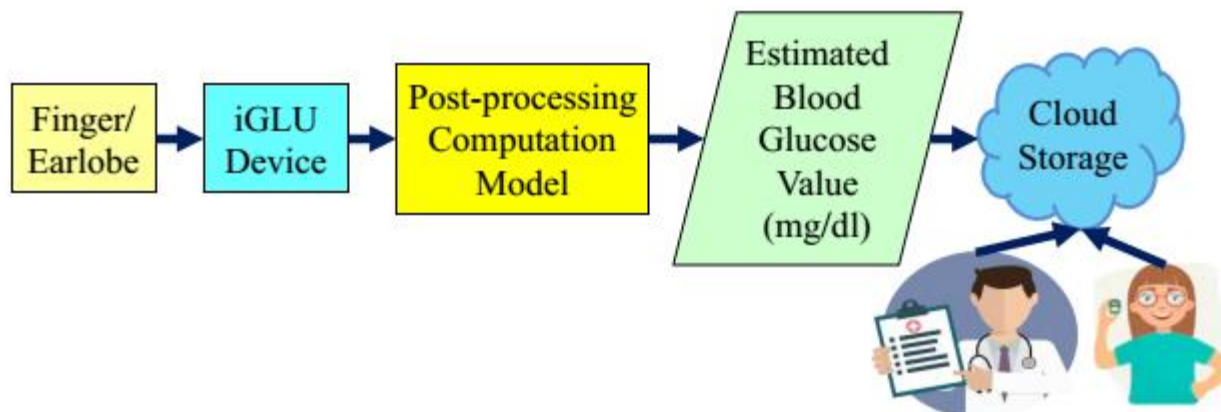


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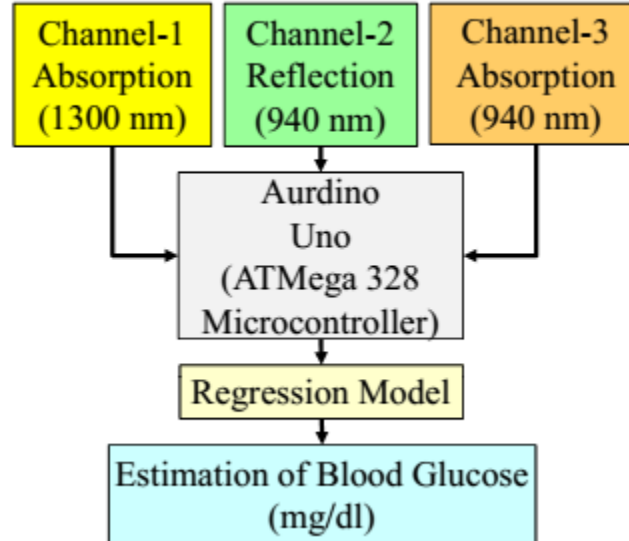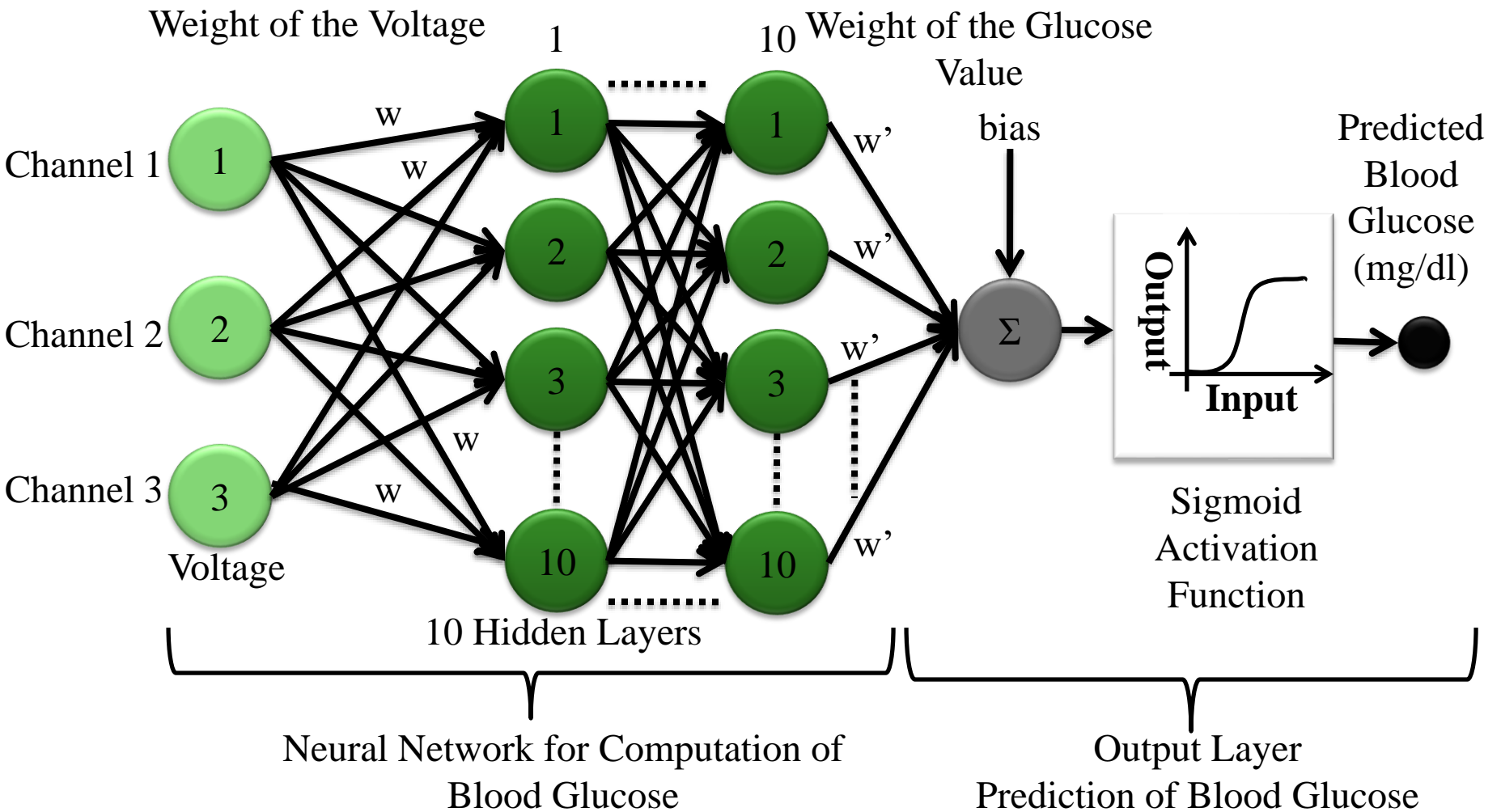
# iGLU 1.0:
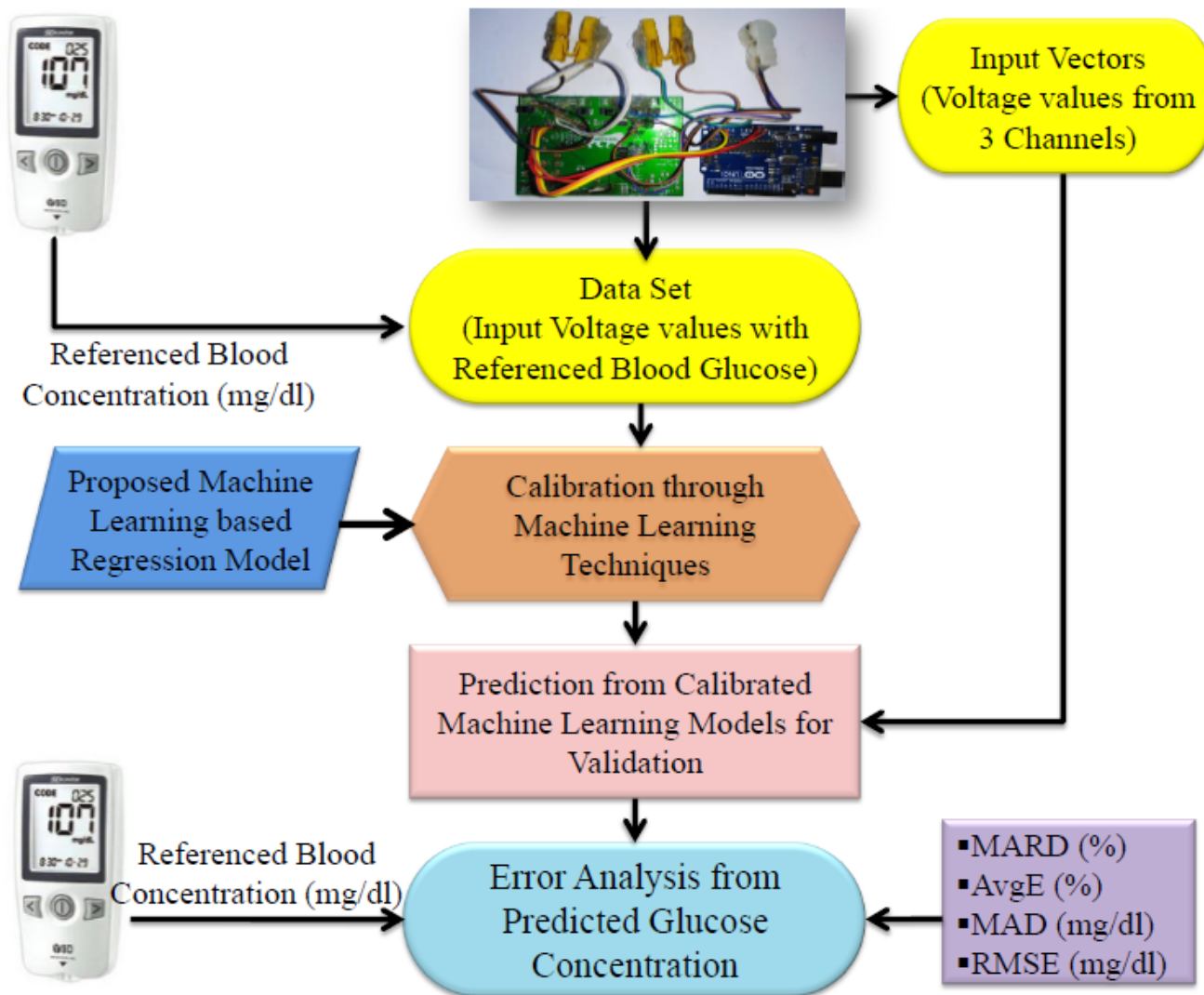


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# Proposed iGLU

- Proposed iGLU device uses the concept of NIR spectroscopy with multiple short wavelengths.

- The device is implemented with three channels where each channel is embedded for particular wavelength with emitter and detector.



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# DNN Based Glucose Prediction



Weight of the Voltage

1

10 Weight of the Glucose Value

bias

Channel 1 — 1

Channel 2 — 2

Channel 3 — 3

Voltage

w

w

w

w

1  2  3  10

1  2  3  10

10 Hidden Layers

w'

w'

w'

w'

Σ

Sigmoid Activation Function

Output

Input

Predicted Blood Glucose (mg/dl)

Neural Network for Computation of Blood Glucose

Output Layer Prediction of Blood Glucose

# DNN Based Glucose Prediction

- The coherent averaging has been applied on these collected data to stabilize the value.

- The Deep Neural Network (DNN) is applied to predict the blood glucose values.

- The output from one neuron of a hidden layer is the input the next layer neuron. The overall structure would provide the prediction output value of blood glucose (in mg/dl).



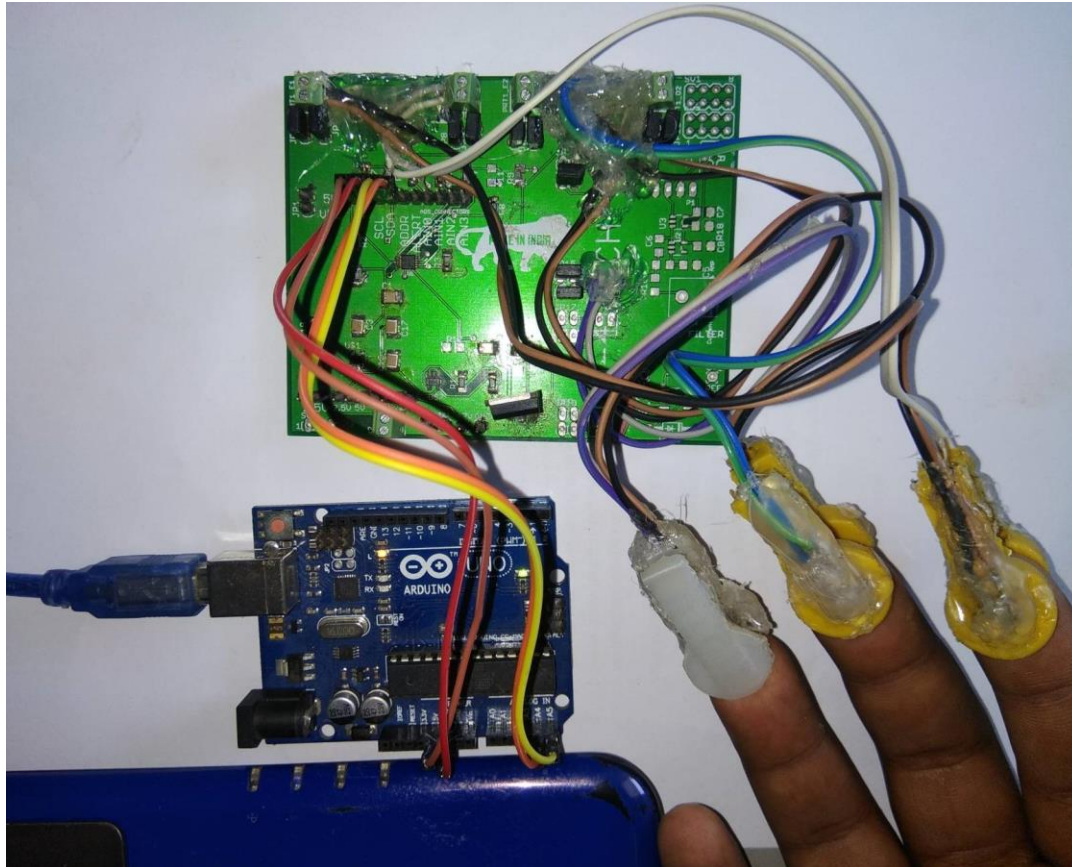(a) Three channel Data     (b) Time interval of 60 minutes

# iGLU PROOF OF CONCEPT PROTOTYPING

- The proof of concept of iGLU is prototyped using system on chip (SoC) with components like LEDs, detectors, ADC with noise filtering capability and frame acquisition controllability.

- These components are embedded on single 2 layer PCB to have portable continuous glucose measurement device.

- The data is collected and is further processed with help of 16 bit ADC at sampling rate of 128 samples per second. The efficient model for regression is analyzed to have accurate blood glucose estimation.

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# iGLU - Prototyping

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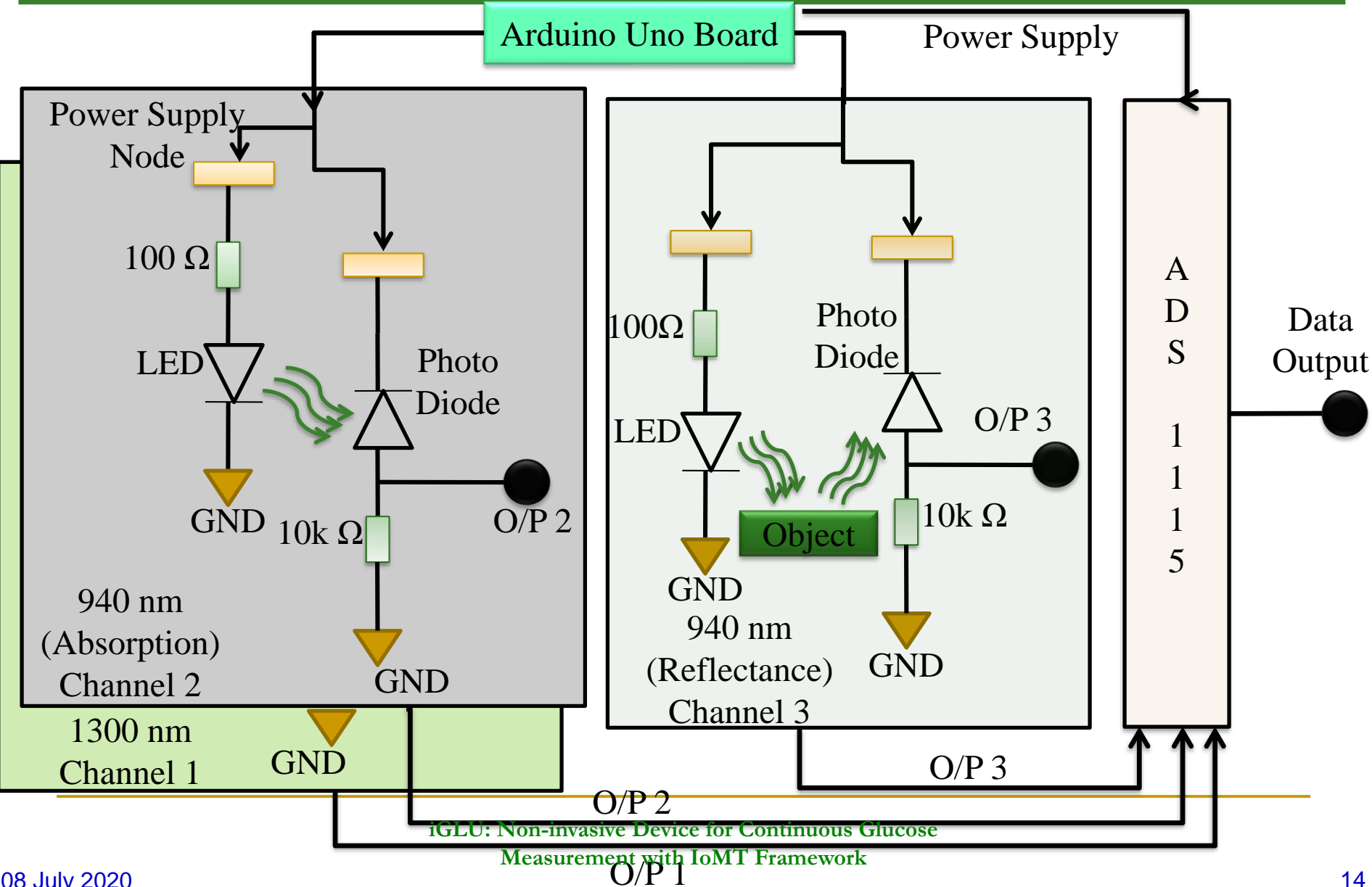
# iGLU – Real-Life Testing



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# Conclusion

- This work presents a novel non-invasive device for the continuous glucose measurement for smart healthcare.

- NIR lights of specific wavelengths are used for the device prototyping for glucose molecule detection.

- The developed device has been calibrated and validated through all kinds of subjects.

- The estimation of glucose values are done using deep neural network.

- The device has been integrated with IoMT framework for patient monitoring, storage of glucose values and cloud access by caregiver for further treatment.

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# References

[1] P. Jain, A. M. Joshi, and S. P. Mohanty, "iGLU: An Intelligent Device for Accurate Noninvasive Blood Glucose-Level Monitoring in Smart Healthcare," IEEE Consum Electro Mag, vol. 9, no. 1, pp. 35–42, 2019.

[2] A. Facchinetti, "Continuous glucose monitoring sensors: past, present and future algorithmic challenges," Sensors, vol. 16, no. 12, p. 2093, 2016.

[3] G. Wang, M. D. Poscente, S. S. Park, C. N. Andrews, O. Yadid-Pecht, and M. P. Mintchev, "Wearable microsystem for minimally invasive, pseudo-continuous blood glucose monitoring: The e-mosquito," IEEE Tran. Biomedical Circuits & Syst., vol. 11, no. 5, pp. 979–987, 2017.

[4] S.-J. Ruan, "Intelligent systems for smart health care: Leveraging information for better well-being," IEEE Consumer Electronics Magazine, vol. 8, no. 2, pp. 71–71, 2019.

[5] P. Jain, A. M. Joshi, N. Agrawal, and S. Mohanty, "iGLU 2.0: A new noninvasive, accurate serum glucometer for smart healthcare," arXiv preprint arXiv:2001.09182, 2020.

[6] P. Jain, R. Maddila, and A. M. Joshi, "A precise non-invasive blood glucose measurement system using NIR spectroscopy and Hubers regression model," Optical and Quantum Electronics, vol. 51, no. 2, p. 51, 2019.

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# Thank You !!!

## Slides are Available at:
http://www.smohanty.org