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Quality Evaluation via PPG on the AVFs of Hemodialysis Patients Based on Both Blood Flow Volume and Degree of Stenosis

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1. BACKGROUND AND MOTIVATION

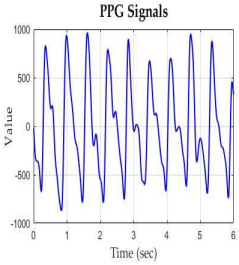
- **Support vector machine (SVM)** learning for assessing quality of **arteriovenous fistula (AVF)** at hemodialysis patients using **a new photoplethysmography (PPG) sensor** for providing
  - ✓ Monitoring Blood Flow at home.
  - ✓ Inexpensive, small-sized and easy-to-use solution needed.

The photo of the proposed PPG sensor for assessing AVF quality

2. THEORY AND PRINCIPLE

- **Photoplethysmography (PPG) sensor**
  - ✓ Non-invasive method aiming at sensing the pulsation of **Blood Vessel.**
  - ✓ Evaluating the reflective lights from LED and PD.
- The mathematical equation of a PPG signal using Beer Lambert's law, as

$$I_r = I_0 \cdot \exp(\varepsilon_t c_t s_t) \cdot \exp(\varepsilon_b c_b s_b)$$

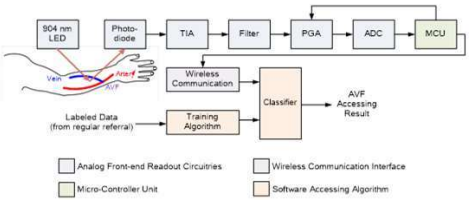


A typical experimental PPG waveform measured by the proposed BF sensor.

3. SYSTEM DESIGN

A. *Readout Circuitries*

- The readout architecture of the proposed PPG sensor systems consist
  - ✓ Front-end analog readout circuitries.
  - ✓ Micro-controller unit (MCU).
  - ✓ Wireless communication unit.
  - ✓ Accessing algorithm.



B. Input feature

Symbol	Features for DOS	Features for BFV	Measurement	Description
SBP,MAX	O	O	The proposed PPG sensors	The maximum length of light transmission path in blood
SB,MIN	O	O	The proposed PPG sensors	The minimum length of light transmission path in blood
SpO2	O	O	Oximeter	The blood oxygen saturation level
SBP	O	O	Electronic sphygmomanometer	The systolic blood pressure
DBP	O	O	Electronic sphygmomanometer	The diastolic blood pressure
Ω	X	O	The proposed PPG sensors	The heart rate

4. CLINICAL VALIDATION & EXPERIMENT RESULTS

- The patients are evaluated healthy when both
  - ✓ DOS smaller than 30% .
  - ✓ BFV larger than 600 ml/min.

Samples Number = 74		Ground Truth (Actual Class)	
		Positive	Negative
Classification Results of kNN (Predicted Class)	Positive	TP = 27 (36.49%)	FP = 8 (10.81%)
	Negative	FN = 7 (9.46%)	TN = 32 (43.24%)
Classification Results of NBC (Predicted Class)	Positive	TP = 24 (32.43%)	FP = 3 (4.05%)
	Negative	FN = 10 (13.51%)	TN = 37 (50.00%)
Classification Results of SVM (Predicted Class)	Positive	TP = 30 (40.54%)	FP = 5 (6.76%)
	Negative	FN = 4 (5.41%)	TN = 35 (47.30%)

5. CONCLUSION

- The optical theory of PPG is solved by analogy the telegrapher equation to determine the input features of classifiers.
- The experimental results successfully achieve **87.838% accuracy** in assessing AVF.
- The PPG sensor and the SVM algorithm show a more favorable solution in terms of sensor number, size and performance integrally

	Y.-C. Du et al. (2018)	D. F. Yeih et al. (2014)	J. X. Wu et al. (2015)	P. Y. Chiang et al. (2017)	This work
Sensor	Bilateral PPG	Stethoscope Auscultation	Ultrasound	Single PPG	Single PPG
Assessing Index	DOS	DOS	DOS	BFV	DOS & BFV
Principle	Optical	Acoustic	Doppler	Optical	Optical
Communication	Wired	Wireless	Wired	Wireless	Wireless
Assessing Algorithm	Neural Network	Support Vector Machine	Color Relation Analysis	Neural Network	Support Vector Machine
Size	Moderate	-	Bulky	9 cm × 8 cm × 4 cm	9 cm × 3.5 cm × 1.5 cm
Number of Subjects	11	22	50	40	74
Accuracy	94.82%	84.3%	83%	$R^2 = 0.7176$	$R^2 = 0.87838$
Type II Error	-	16.7%	-	> 50%	11.765%