Material Classification driven by Multimodal Perception using LSTM-FCN

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Abstract

- In this work, we proposed a dual-modal sensing—a soft robotic finger that combines triboelectric principles and optical tactile for tactile sensing.
- Second, we built our own experimental platform and collected multimodal time series datasets containing triboelectric and optical image data.
- Afterwards, an advanced time series classification model was built to realize the accurate identification of five materials under different pressure and texture interference, with an identification accuracy of 94.42%.

Motivation

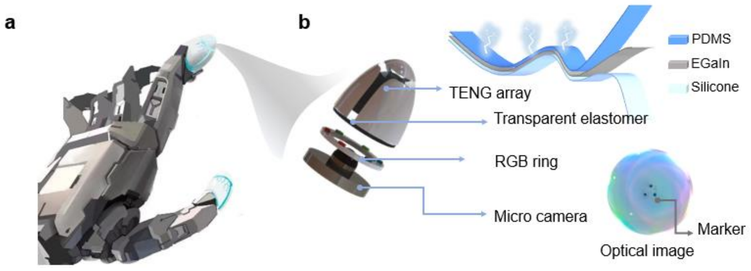


Fig: Schematics of the touchless and tactile systems

- Various robots appear in people's life and work[1], and the expansion of the machine's tactile perception ability has received high attention.
- However, some existing works are limited in further applications due to their shortcomings such as single function, non-integration, or being easily disturbed by the environment.

Introduction

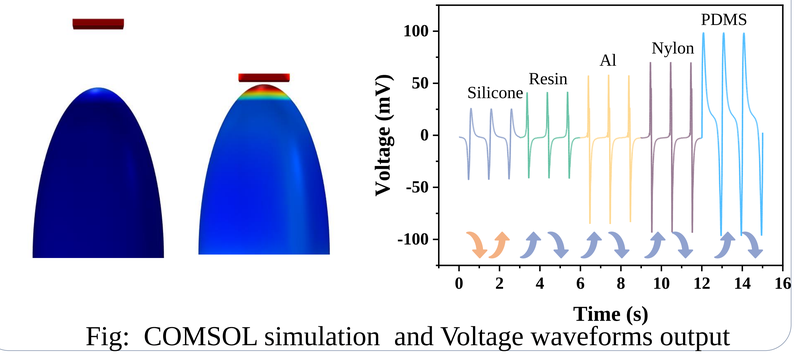


Fig: COMSOL simulation and Voltage waveforms output

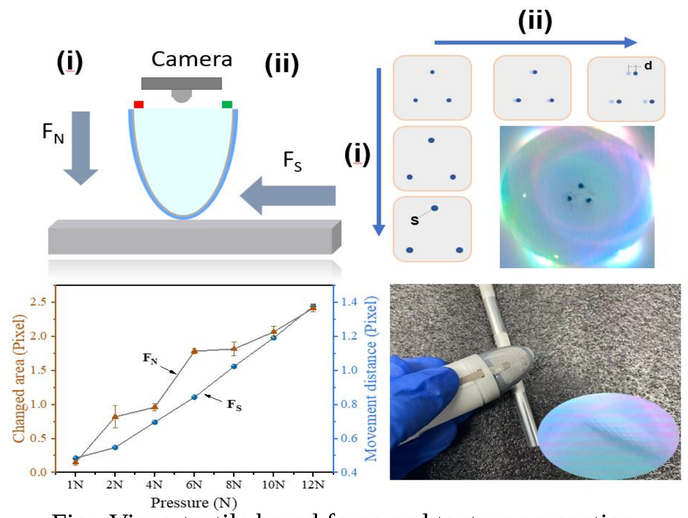
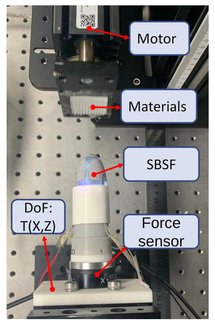


Fig: Visuo-tactile based force and texture perception

Dataset



Pressure range	PDMS	Silicone	Al	Resin	Nylon
2N	112	112	112	112	112
4N	112	112	112	112	112
6N	112	112	112	112	112
8N	112	112	112	112	112
10N	112	112	112	112	112
All	**560**	**560**	**560**	**560**	**560**

Table: Dataset of five material under five pressures and textures

Method

- **Prepocessing**
  - **Normalization:** MinMaxScalar(0, 1)
  - **Dynamic time warping(DTW)**

$$DTW(i,j) = M_{i,j} + min\begin{cases} DTW(i-1,j). \\ DTW(i,j-1). \\ DTW(i-1,j-1), \end{cases}$$

- **Improved model**

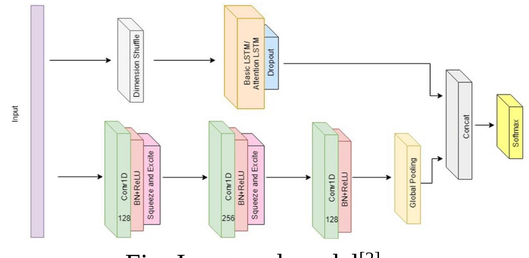


Fig: Improved model[2]

Results

Method	Train loss	Val loss	Val acc	Model size
InceptionTime[2]	0.157637	0.1356	0.9292	456,074
1DCNN	0.4390	0.4134	0.8618	2,746
ResCNN[3]	0.16117	0.10123	0.9191	257,803
Improved model	**0.09432**	**0.09289**	**0.9482**	**15706**

Table: Comparison among DL Algorithms

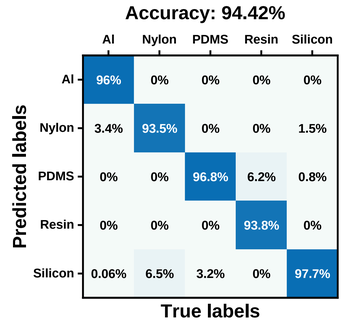


Fig: Accuracy of Improved model

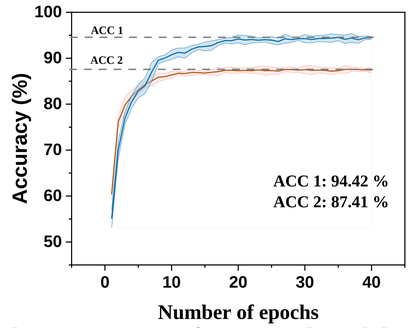


Fig: Loss of Improved model

Discussion

- The four models built can better distinguish five different materials. We judge the performance of the model by the model size, loss and accuracy. Among them, the LSTM-FCN model has the highest recognition accuracy and the best performance.
- Multimodal tactile perception data and time series algorithm solve the problem that a single sensor cannot accurately distinguish material information.
- It is expected that the model can achieve good performance in more material scoring classification tasks and be able to be deployed in real-time systems.

References

[1] Ji W, Wang L. Industrial robotic machining: a review[J]. The International Journal of Advanced Manufacturing Technology, 2019, 103(1): 1239-1255.

[2] KARIM, Fazle, et al. LSTM fully convolutional networks for time series classification. IEEE access, 2017, 6: 1662-1669.

FAWAZ, Hassan Ismail, et al. Inceptiontime: Finding alexnet for time series classification. Data Mining and Knowledge Discovery, 2020, 34.6: 1936-1962.

[3] FAWAZ, Hassan Ismail, et al. Inceptiontime: Finding alexnet for time series classification. Data Mining and Knowledge Discovery, 2020, 34.6: 1936-1962

[4] ZOU, Xiaowu, et al. Integration of residual network and convolutional neural network along with various activation functions and global pooling for time series classification. Neurocomputing, 2019, 367: 39-45.