Spatial map and haptic feedback of textures using a tactile sensor equipped Soft finger.

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I. Problem Statement

The field of prosthetics has come a long way with numerous advancements in improving the lifestyle of physically disabled patients. Prosthetic robots can nowadays help patients pick up objects, feel the object, apply the right amount of pressure depending on the material the object is made up of, improve the gait of a patient, help the patient walk using a prosthetic leg and much more.

In this project, we aim at texture detection, increasing the resolution of the detected texture and transmitting the texture into human-readable signals such as haptics. Nowadays, prosthetic hands are equipped with tactile sensors to give a sense of touch to the artificial hands. These tactile sensors have a limited resolution, and it is difficult to detect and identify minute textures. Our goal is to make a system that can identify, make a spatial map and send the corresponding signals of the minute and fine textures to the finger/hand amputees.

II. Approach

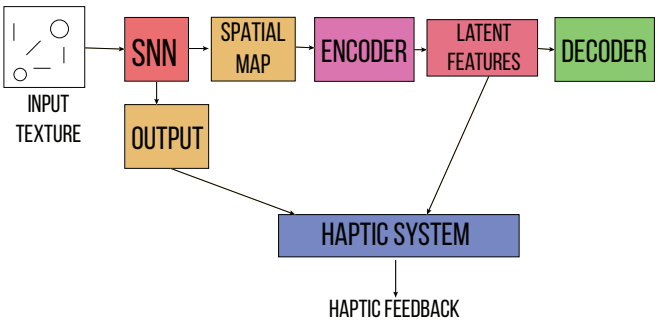

Fig. 1. Schematic of the network

A. *Spiking Neural Networks (SNNs)*

SNNs are based on bio-inspired neuronal learning. These use an algorithm that is similar to neural connections in the brain. As the texture classification task has not been done using SNNs. We need to classify the texture as our final aim is to give haptics feedback to the amputee. As we are trying to give feedback of unknown texture, it is necessary to identify the texture and hence we can appropriately give feedback to the amputee. It helps the amputee to feel the texture. Moreover SNNs are fast, more/similar accuracy to ANNs and energy efficient. Our goal of using SNNs is to effectively classify and get better results than traditional texture detection. We believe that neural networks are the way to go because neural networks are capable of using hidden features which are normally not used in traditional methods.

B. *Spatial Map*

Spatial map is the visual representation of the texture obtained. Spatial Map will be helpful as it will try to present the texture in 2D/3D and assist in classification tasks. We will make spatial maps by using the SNNs' output data and the input obtained.

C. *Variational AutoEncoder(VAE)*

A Variational Autoencoder provides a probabilistic manner for describing an observation in latent space i.e. unlike normal autoencoders, it uses the mean and variance of the output of the encoder network to formulate the latent space. VAE are well known for effective noise reduction in the input data and thus increasing the resolution of the reconstructed data. The main advantage of a variational autoencoder is to be able to represent a large spatial data into a simple 1 dimensional array. These arrays are unique for each input and can be used instead of the entire input for further training. Thus, reducing the network size.

D. *Combination of SNN and VAE*

We are thinking of combining SNNs along with VAE to get better feedback from the network. SNN being a time series network, gives a sequential output of data. SNNs alone can be used to give haptic feedback, but the output of SNNs are quite noisy given the precision of the tactile sensor is limited. So, we can take advantage of spatial data obtained from the SNNs. The spatial data contains additional information which can enhance the haptic feedback we give to the user. Hence for every n time steps, we pass the data through the VAE network r times. This would ensure that the n-r steps take care about the time for the inference and the r steps ensure the accuracy and precision of the model is high.

*E. **Haptics***

Finally the output of the network is to be trained in a manner that the patient gets a haptic feedback/sensation of the texture. We are going to train the haptics feedback system such that the patient gets accurate and unique feedback for each texture he/she touches using the finger. Thus, completing the entire network.

To achieve the above goals, we intend to follow the steps:

1) The process would include collecting data from the soft finger. This step involves making a set up analogous to a 2D/3D-plotter, which could palpate over the whole texture. We intend to use the most readily available 2D/3D plotter i.e. the 3D printer. A custom mount would be made over the nozzle of the 3D printer, thus helping the soft finger (which contains the tactile sensors) to move over the texture.
2) Using neuromorphic computing and spiking neural networks (SNNs) to classify the textures using the input data from the tactile sensors.
3) Along with the SNNs, one of our objective is to visualize texture which are not known. For this, we intend to use Variational Autoencoders (VAE).
4) The intermediate weights i.e. the hidden features can be used to get useful information about the spatial mapping of the system. Moreover, as we would be palpating over the texture continuously, we will use LSTMs to capture the temporal aspect for the same. This spatial and temporal data combined will help us give the spatial texture map.
5) To convert the neuromorphic encodings to haptics, we intend to use the weights and hidden features as an input to the haptic system. The haptic system consists of a cluster of small vibration motors, which would rest on the wrist of the subject. So, on suitable input to the vibration motors, one could feel the sensation of the particular texture.

III. Timeline

Week	Dates	Tasks
1	17 May - 23 May	Finger mount and printing the textures
		Procure materials and fabrication of Finger
		Hands-on understanding of STM32 board.
2	24 May - 30 May	Designing the circuit related to the STM32 board
		Collecting Data using the setup
		Classifying the data using available codes
3	31 May - 6 June	Use SNNs and VAE to classify known and unknown data.
		Start learning the concepts of Haptics.
4	7 June - 13 June	Changing the environment of the texture.
		Printing custom textures.
		Converting the SNNs to spatial map
5	14 June - 20 June	Converting the SNNs to spatial map
		Implementing simple haptic concepts.
6	21 June - 27 June	Make haptics circuit
		Converting neuromorphic encoding to haptics
7	28 June - 4 July	Buffer Period
8,9,10	5 July - 31 July	Completion of remaining work and documentation

IV. Short Term & Long Term Goals

Neel: My short term goal is to achieve the novelty in my internship work. I further want to publish a paper in a reputed conference on Soft Robotics. My long term goal is to opt for higher studies in field of Robotics and Data Science. I will prepare for GRE in my next semester and work on the application process. I am targeting Ivy league Universities for the MS in USA.

Rwik: I am interested in the field of Artificial intelligence and robotics.In the current internship I want to learn the aspects of prosthetics, designing the robot, playing with the sensors and designing the algorithm for it using ML and AI concepts. Moreover I intend to make something novel at the end of the project and want to publish that. I see myself doing a PhD in robotics keeping AI as the integral part. Along with the internship I plan to study for the GRE to enable me pursue my long term goal at some prestigious university.