CLAIMS

1. A classifying sensing system comprising:

a first spiking neural network, SNN, encoder configured for encoding an event-based output of a vision sensor into individual vision modality spiking representations with a first output size;

a second SNN encoder configured for encoding an event-based output of a tactile sensor into individual tactile modality spiking representations with a second output size;

a combination layer configured for merging the vision modality spiking representations and the tactile modality spiking representations; and

a task SNN configured to receive the merged vision modality spiking representations and tactile modality spiking representations and output vision-tactile modality spiking representations with a third output size for classification;

wherein the task SNN is configured for classification based on a spike-count loss in the respective output vision/tactile modality representations compared to a desired spike count indexed by the output size; or

wherein the task SNN is configured for classification based on a weighted spike-count loss in the respective output vision/tactile modality representations compared to a desired weighted spike count indexed by the output size.

2. The system claim 1, wherein neurons in each of the first SNN encoder, the second SNN encoder, and the task SNN are configured for applying a Spike response Model, SRM.

3. The system of any one of claims 1 to 2, comprising the tactile sensor.

4. The system of claim 3, wherein the tactile sensor comprises an event-based tactile sensor.

5. The system of claim 3, wherein the tactile sensor comprises a converter for converting an intrinsic output of the tactile sensor into the event based output of the tactile sensor.

6. The system of any one of claims 1 to 5, comprising the vision sensor.

7. The system of claim 6, wherein the vision sensor comprises an event-based vision sensor.

8. The system of claim 6, wherein the vision sensor comprises a converter for converting an intrinsic output of the vision sensor into the event-based output of the vision sensor.

9. The system of any one of claims 1 to 8, comprising a robot arm and end-effector.

10. The system of claim 9, wherein the end-effector comprises a gripper.

11. The system of claim 10, wherein the tactile sensor comprises one tactile element on each finger of the gripper.

12. The system of one of claims 9 to 11, wherein the vision sensor is mounted on the robot arm or on the end-effector.

13. A classifying method performed using a sensing system, the method comprising the steps of:

encoding, using a first spiking neural network, SNN, encoder an event-based output of a vision sensor into individual vision modality spiking representations with a first output size;

encoding, using a second SNN encoder, an event-based output of a tactile sensor into individual tactile modality spiking representations with a second output size;

merging, using a combination layer, the vision modality spiking representations and the tactile modality spiking representations; and

using a task SNN to receive the merged vision modality spiking representations and tactile modality spiking representations and to output vision-tactile modality spiking representations with a third output size for classification;

wherein the task SNN is configured for classification based on a spike-count loss in the respective output vision/tactile modality representations compared to a desired spike count indexed by the output size; or

wherein the task SNN is configured for classification based on a weighted spike-count loss in the respective output vision/tactile modality representations compared to a desired weighted spike count indexed by the output size.

14. The method of claim 13, wherein each of the first SNN encoder, the second SNN encoder, and the task SNN is configured for applying a Spike response Model, SRM.

15. The method of any one of claims 13 to 14, wherein the tactile sensor comprises an event-based tactile sensor.

16. The method of any one of claims 13 to 14, comprising converting an intrinsic output of the tactile sensor into the event-based output of the tactile sensor.

17. The method of any one of claims 13 to 16, wherein the vision sensor comprises an event-based vision sensor.

18. The method of any one of claims 13 to 16, comprising converting an intrinsic output of the vision sensor into the event-based output of the vision sensor.

19. The method of any one of claims 13 to 18, comprising disposing one tactile element of the tactile sensor on each finger of a gripper of a robot arm.

20. The method of any one of claims 13 to 19, comprise mounting the vision sensor on the robot arm or on the end-effector.

21. A tactile sensor comprising:

a carrier structure;

an electrode layer disposed on a surface of the carrier structure, the electrode array comprising an array of taxel electrodes;

a plurality of electrode lines individually electrically connected to respective ones of the taxel electrodes;

a protective layer disposed above the electrode layer, wherein the protective layer is made from an elastically deformable material; and

a pressure transducer layer disposed between the electrode layer and the protective layer;

wherein electrical signals detectable in the electrode lines responsive to contact forces exerted on the pressure transducer layer via the protective layer provide spatio-temporal data for neuromorphic tactile sensing applications;

wherein the taxel electrodes of the electrode array are arranged with a radially varying density around a centre of the electrode array; or

comprising a plurality of encoder elements connected to respective ones of the electrode lines, the decoder elements configured to asynchronously transmit tactile information based on the electrical signals in the electrode lines via a common output conductor.

22. The tactile sensor of claim 21, wherein the density of the taxel electrodes decreases with radial distance from of the centre.

23. The tactile sensor of any one of claims 21 to 22, wherein the carrier structure is configured to be connectable to a robotic gripper.

24. The tactile sensor of any one of claims 21 to 23, wherein the electrode layer and/or the electrode lines are flexible.

25. A method of fabricating a tactile sensor, the method comprising:

providing a carrier structure;

providing an electrode layer disposed on a surface of the carrier structure, the electrode array comprising an array of taxel electrodes;

providing a plurality of electrode lines individually electrically connected to respective ones of the taxel electrodes;

providing a protective layer disposed above the electrode layer, wherein the protective layer is made from an elastically deformable material; and

providing a pressure transducer layer disposed between the electrode layer and the protective layer;

wherein electrical signals detectable in the electrode lines responsive to contact forces exerted on the pressure transducer layer via the protective layer provide spatio-temporal data for neuromorphic tactile sensing applications;

wherein the taxel electrodes of the electrode array are arranged with a radially varying density around a centre of the electrode array; or

comprising providing a plurality of encoder elements connected to respective ones of the electrode lines, and configuring the decoder elements to asynchronously transmit tactile information based on the electrical signals in the electrode lines via a common output conductor.

26. The method of claim 25, wherein the density of the taxel electrodes decreases with radial distance from of the centre.

27. The method of any one of claims 25 to 26, comprising configuring the carrier structure to be connectable to a robotic gripper.

28. The method of any one of claims 25 to 26, wherein the electrode layer and/or the electrode lines are flexible.