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Development of a High-Speed Event Vision-Based Roller Tactile Sensor for Large-Surface Inspection

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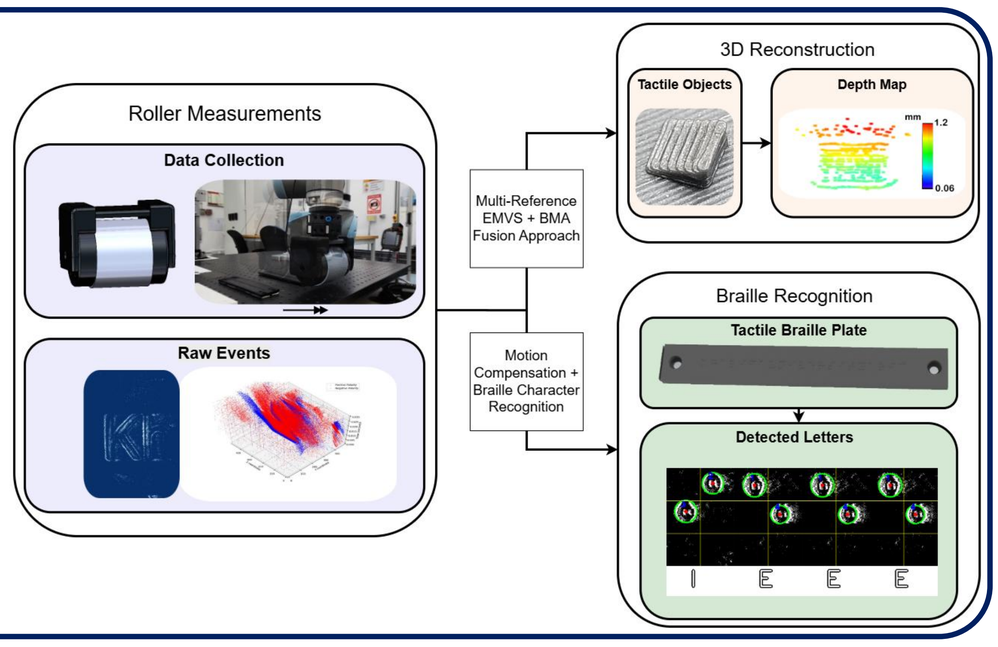
We introduce an **event vision-based roller tactile sensor** for continuous large-surface inspection [1]:

- The system combines **rolling tactile contact**, **event-based multi-view stereo**, and **multi-reference Bayesian fusion**.
- It achieves continuous 3D scanning at up to **0.5 m/s** with **sub-100 µm MAE**.
- The system is approximately **11× faster** than prior continuous tactile sensing methods and demonstrates Braille reading at **2.6×** the speed of previous tactile approaches.



Problem Formulation

- Large-scale aerospace and automotive inspection requires **rapid, high-resolution 3D surface measurement** to detect sub-millimeter defects such as cracks, dents, scratches, and coating faults [2].
- Optical scanners can cover large areas quickly, but their performance can degrade under **lighting variation** and challenging surface reflectance.
- Vision-based tactile sensors provide accurate local geometry, but planar designs rely on slow **press-and-lift** acquisition, while continuous roller/belt variants remain limited by **friction, motion blur, and frame-camera rate**.
- **Goal:** develop a continuous tactile scanning system that inspects large surfaces quickly while maintaining **sub-100 µm 3D accuracy**.

Methods

An event-based tactile roller captures deformation-induced brightness changes during rolling contact using a DVXplorer mini event camera.

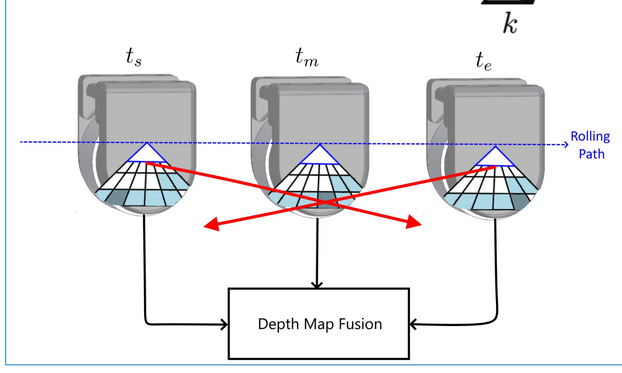
$$e_k = (x_k, y_k, t_k, p_k) \qquad (1)$$

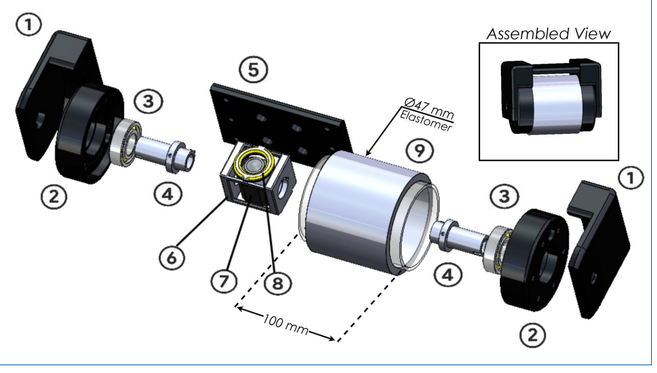
Events are accumulated over 20 ms and reconstructed using a constrained EMVS [3] depth search over the roller contact range. To reduce curvature-induced bias, depth maps from the start, midpoint, and end of the event window are warped to the midpoint frame and fused using Bayesian model averaging.

$$Z_f(\mathbf{u}) = \sum_{i \in \{s,m,e\}} w_i \, W_i(Z_i)(\mathbf{u}), \qquad \sum_i w_i = 1 \quad (2)$$

For Braille recognition, motion-compensated events are accumulated into an Image of Warped Events (IWE) and decoded using a 2×3 Braille grid.

$$I(\mathbf{u}; v) = \sum_k \delta\left(\mathbf{u} - W(e_k; v)\right) \qquad (3)$$

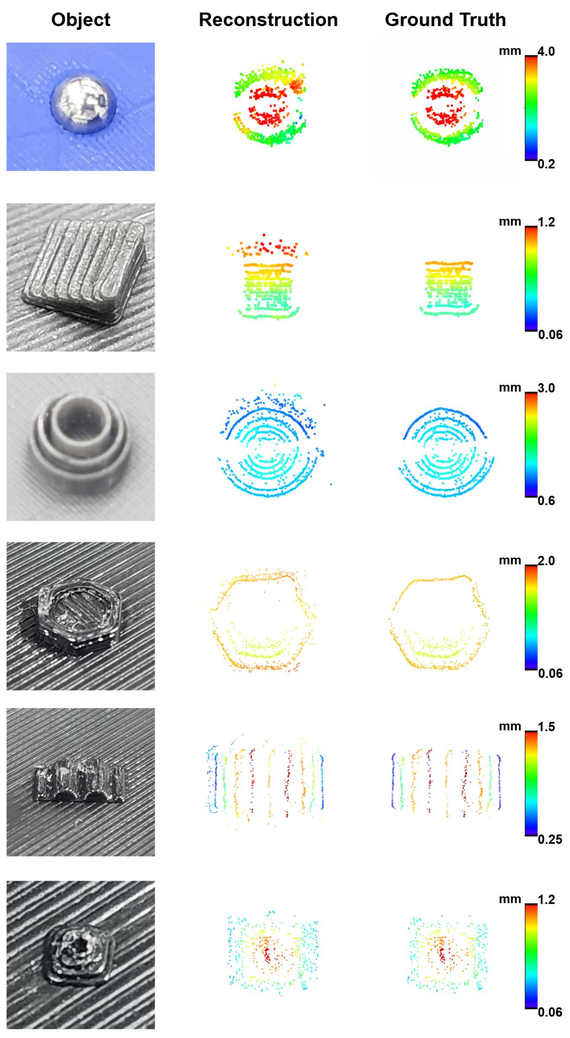




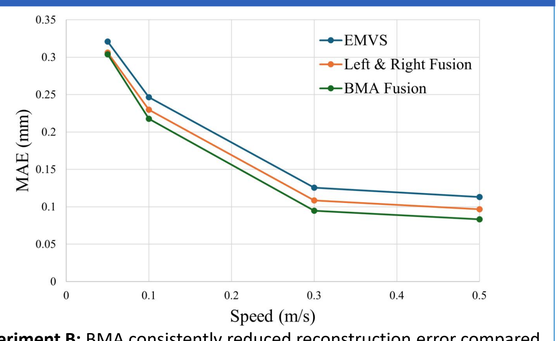
Experimental Setup

- The roller sensor was mounted on a **UR10 robotic arm** and scanned surfaces at controlled speeds from **0.05–0.5 m/s**.
- We evaluated three tasks: **single-object 3D reconstruction**, **stitched large-surface inspection**, and **high-speed Braille recognition**.
- Reconstruction accuracy was measured using **mean absolute error (MAE)** over valid reconstructed points; results were averaged over **five trials** unless otherwise stated.

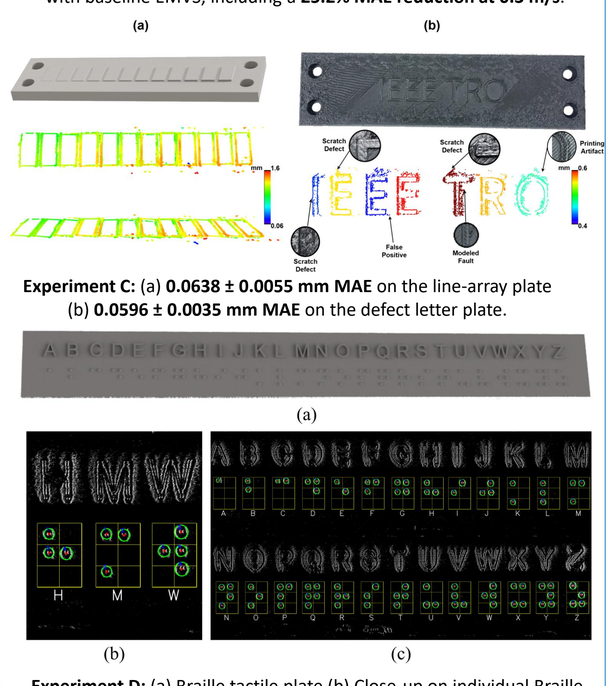
Results



Experiment A: Across six known-geometry objects, the system achieved an average MAE of **0.0620 ± 0.0047 mm**.



Experiment B: BMA consistently reduced reconstruction error compared with baseline EMVS, including a **25.2% MAE reduction at 0.3 m/s**.



Experiment C: (a) **0.0638 ± 0.0055 mm MAE** on the line-array plate (b) **0.0596 ± 0.0035 mm MAE** on the defect letter plate.

Experiment D: (a) Braille tactile plate (b) Close-up on individual Braille letter detection (c) Complete plate braille reading at **0.5 m/s**.

Conclusion & Future Work

This work presents a high-speed event vision-based roller tactile sensor for continuous large-surface inspection, combining rolling tactile contact with event-based multi-view stereo and Bayesian fusion [1], [3].

The system achieves **0.5 m/s** scanning with **sub-100 µm** error, approximately **11× faster** than prior continuous tactile sensing methods, while also supporting high-speed Braille recognition at **2.6×** previous tactile approaches [1], [4].

Future work will focus on **denser reconstruction**, **real-time processing**, improved **force/contact control**, and validation on larger curved industrial components with realistic defects.

References:

[1] A. Khairi *et al.*, "They See Me Rolling: High-Speed Event Vision-Based Tactile Roller Sensor for Large Surface Inspection," *IEEE Transactions on Robotics*, 2026.
[2] M. Futterlieb, J. Frejaville, F. Donadio, M. Devy, and S. Larnier, "Air-Cobot: Aircraft Enhanced Inspection by Smart and Collaborative Robot," 2017.
[3] H. Rebecq *et al.*, "EMVS: Event-Based Multi-View Stereo," *IJCV*, 2017.
[4] P. Potdar *et al.*, "High-Speed Tactile Braille Reading," *IEEE RA-L*, 2024.