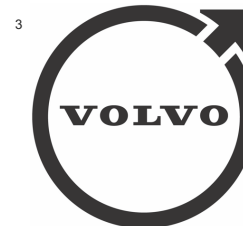
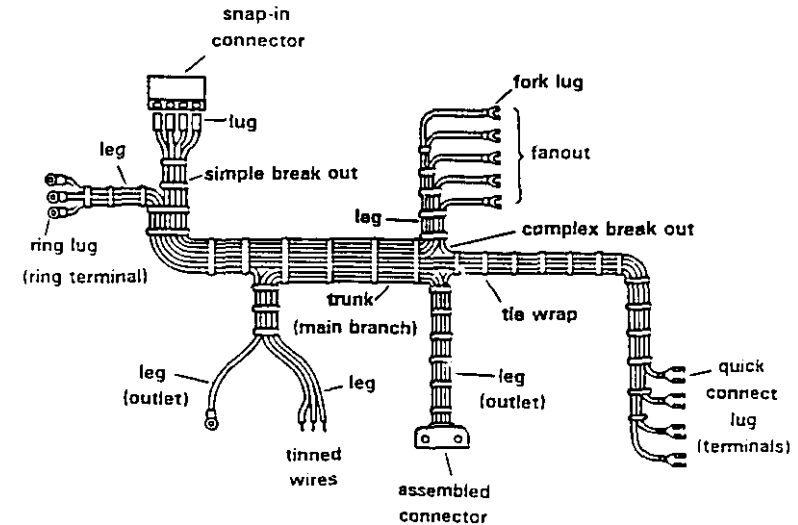


Overview of Computer Vision Techniques in Robotized Wire Harness Assembly: Current State and Future Opportunities

Hao Wang¹, Omkar Salunkhe¹, Walter Quadrini², Dan Lämku³, Fredrik Ore⁴, Björn Johansson¹, Johan Stahre¹



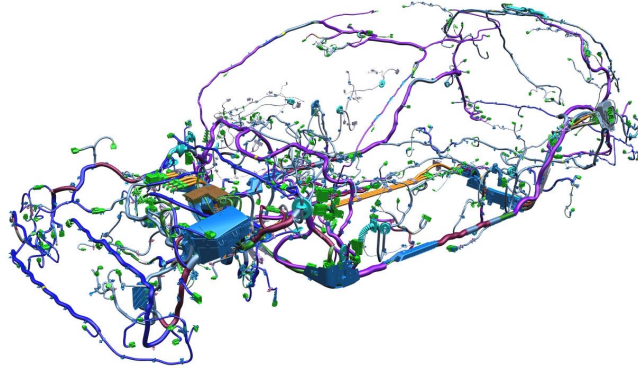
Wire harnesses



Source: Aguirre and Raucent (1994)

A bundle of routed cables with various components in a tree-like structure

Wire harness assembly



(Images provided by Volvo Car Corporation)



Year 2000

1000 m



Year 2003

1500 m



Year 2008

2000 m



Year 2020

2800 m

(Images provided by Volvo Car Corporation)

**Essential
infrastructure**



Increasing usage



Electrification



Critical to guarantee the safety and quality of the assembly

Wire harness assembly

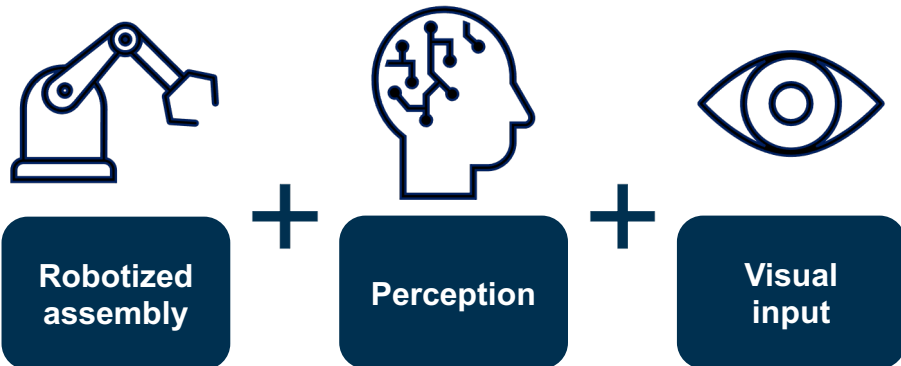


Current assembly operations

- Manual
- Skill-demanding

Problem

- Quality
- Productivity
- Safety
- Ergonomics



Methodology

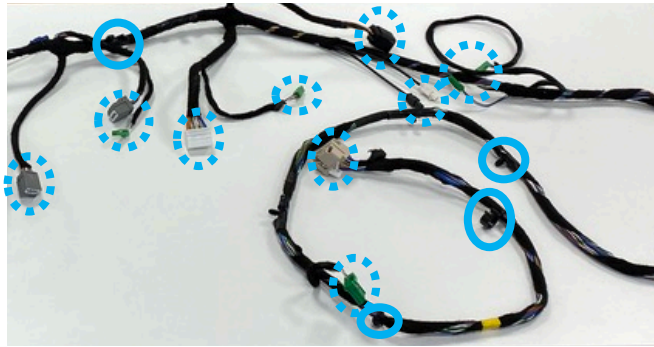
Literature search

- Scopus
- (wir* OR cabl*) AND (harness* OR bundl*) AND assembl*

Literature selection

- Final assembly of wire harnesses onto other products
- Proposing vision systems for the robotized assembly
- Not review and conference review
- English

Component manipulation



Clamp insertion

- Clamp (cover) pose estimation

Connector mating

- Connector detection & pose estimation
- Vision-guided mating
- Fault detection

Table 1. Vision systems in articles for manipulation on components of wire harnesses.

Component	Article	Type of cameras	Location of cameras	Number of cameras
Clamp	[13]	-	Hand-eye	4
	[7, 8]	CCD cameras	Global-fixed + Hand-eye	10 fixed + 6 on end-effectors
	[9]	Point Grey Firefly MV	Hand-eye	1
Connector	[27]	MC1362, Mikrotrotron	Global-fixed	1
	[30]	RealSense D435, Intel	Hand-eye	1
	[32]	Industrial cameras	Global-fixed + Hand-eye	1 fixed + 2 on robot arms
	[3]	In-Sight 5100	Global-fixed	1
	[26]	CCD cameras	Global-fixed	2
	[2]	CCD cameras	Global-fixed	2
	[25]	FL2G-13S2C-C, PGR	Hand-eye	1

(Reference numbers are the same as those in the paper)

Component manipulation

Clamp insertion

- Clamp (cover) pose estimation
- Additional clamp covers were attached
- Rule-based computer vision
- Facilitate detection and manipulation
- Occupy space and add operations
- New clamp designs are desired

Connector mating

- Connector detection and mating monitoring
- Mainly 2D vision-based detection
- Mainly rule-based computer vision
- 2D data is easier to process than 3D data
- 3D info (position, orientation) is required
- Capture and process 3D data

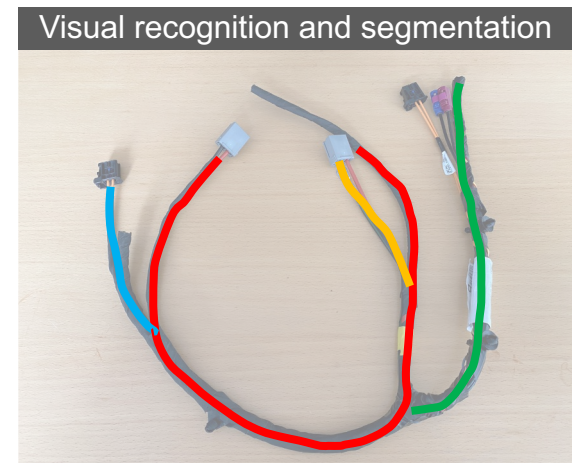
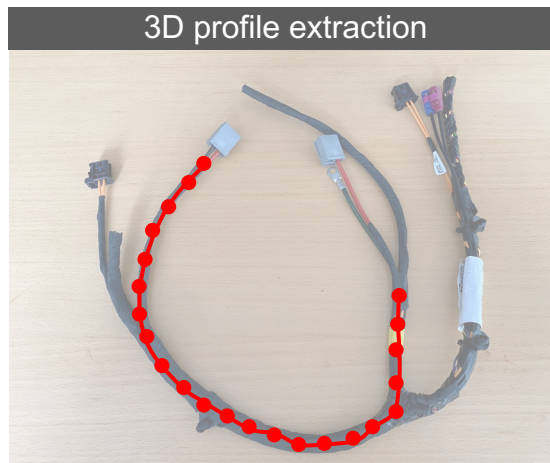
- Learning-based algorithms + 2D & 3D vision needs to be explored
- Practicality and reliability need to be evaluated in actual scenarios

Structure perception

Table 2. Vision systems in articles for perceiving the structure of a wire harness.

Article	Purpose	Type of cameras	Location of cameras	Number of cameras
[12]	Interpretable classification	RealSense D435, Intel	Global-fixed	1
[19]	3D profile extraction	Helios Time-of-Flight camera	Hand-eye	1
[4]	Visual recognition	RGB-D	-	-

(Reference numbers are the same as those in the paper)



RGB-D data + learning-based algorithm on other components

Conclusion

- Previous studies proposed various vision-based solutions for:
 - Manipulation of different wire harness components
 - Perception of the wire harness structure
- Future research opportunities:
 - Developing new learning-based computer vision algorithms to exploit 3D information
 - Evaluating the practicality and reliability of vision systems in actual production to promote practical applications
 - Exploring new product designs of wire harnesses to enable a more efficient visual perception and robotic manipulation

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Thank you!