LED Strip Based Robot Movement Intention Signs for Human-Robot Interactions

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- Experimental testing and possible other applications
- Conclusions

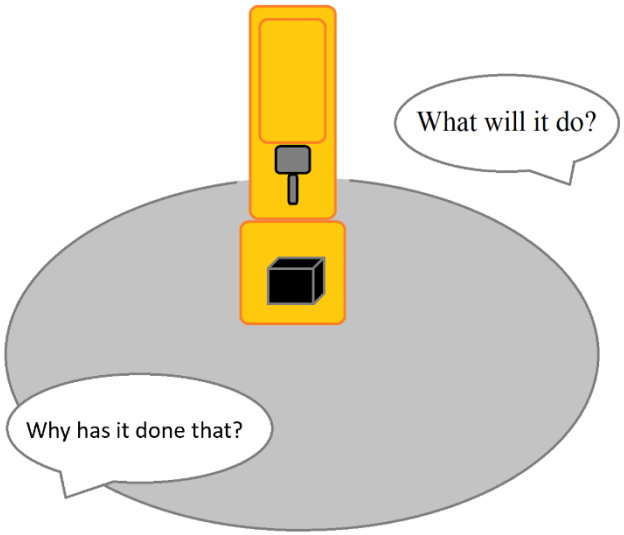
Introduction (1) – Robot as a black box

- First industrial robot made by Robert C. Devol, the UNIMATION
- Huge increase in performance
- Development of Cobots (Cooperative Robots)

https://artsandculture.google.com/asset/robot-first-unimate-robot-ever-installed-on-an-assembly-line-1961-devol-george-c-1912-2011/GQHHgKp0XejHeg

https://www.plasticstoday.com/automation/five-things-consider-buying-cobot

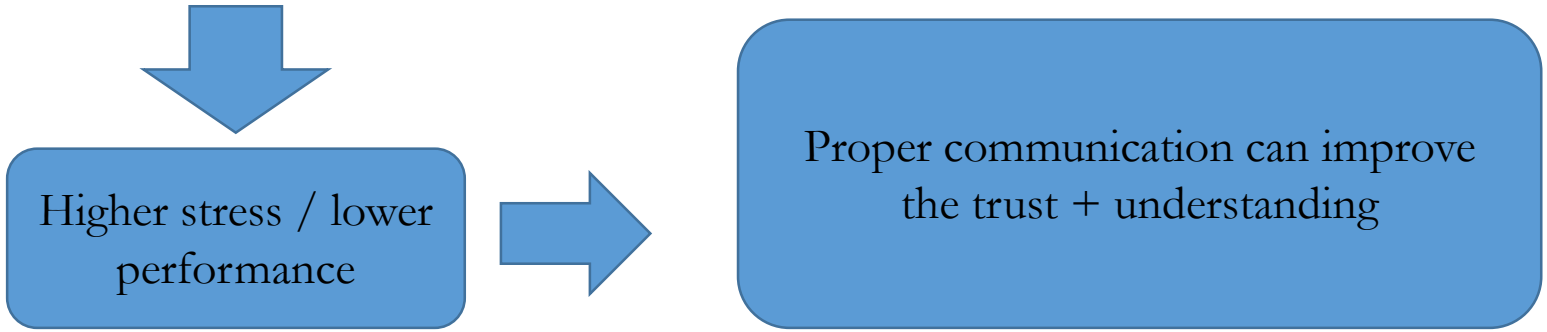
- In the majority of the applications the robots cannot communicate their inner state effectively → multiple types of danger (injuries, stress, productivity loss etc.)
- Robots are black-boxes from the perspective of the operators.



Introduction (2) – Why is it important to communicate ergonomically?

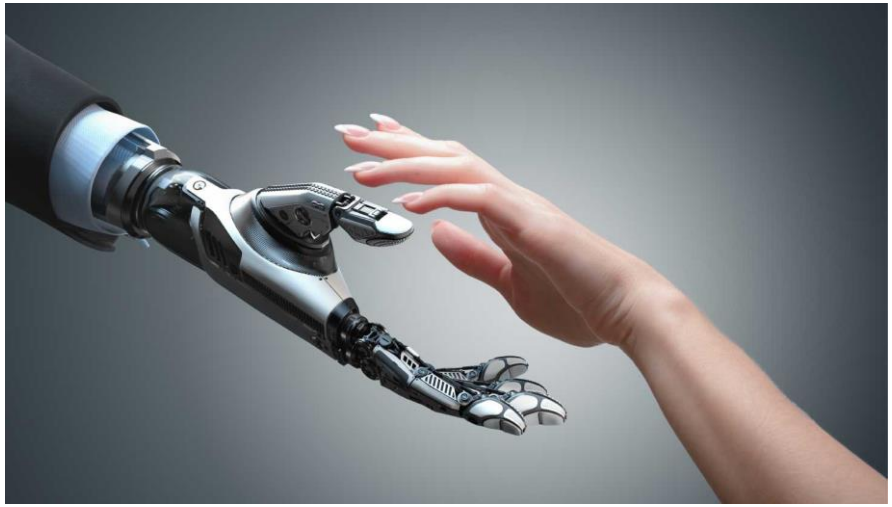
- In the majority of the applications the robots cannot communicate their inner state effectively → multiple types of danger (injuries, stress, productivity loss etc.)
  - There are publications claiming that the majority of Cobot applications is not even cooperative applications.
- Robots are black-boxes from the perspective of the operators.
- The new, unexpected situations that needs to be handled are caused by:
  - Fenceless robotcells → smaller occupied spaces → unitended entry of workspace
  - Closer interactions → higher performance → Unknown motions of the robot

https://www.diva-portal.org/smash/get/diva2:816519/FULLTEXT02.pdf



Introduction (3) – Trust in robots

- According to meta analysis, the key factors on trust in human-robot interactions are (in order from most to least significant):
  - Robot characteristics and performance
    - Size
    - Color
    - Movement behavior
    - Failures in task performance
    - Communication
    - Etc
  - Environmental factors
  - Human dimensions
- In other publications the followings are also mentioned:
  - Trust in automation
  - Situational awareness
  - Expertise
  - Expectations



https://towardsdatascience.com/the-evolution-of-robotics-27539c5752fc

Problem Statement (1) - What is currently used?

Signs that are used currently in industry:

- Sound
- Vibrotactile
- ***Light***

https://towardsdatascience.com/the-evolution-of-robotics-27539c5752fc

Screens with pictograms

- Limited information → (signs eg.: safe, dangerous, OK, help, off)
- Not at the potential source of danger / event → higher chance of damage made
- Etc.

Problem Statement (2) - Visual indicators

Tipically two types:

- Lights
- Screens

Screens with pictograms

Close cooperation needs something new that can give more information about the robot's inner state and intentions to the operator or the bystander

Advantages:

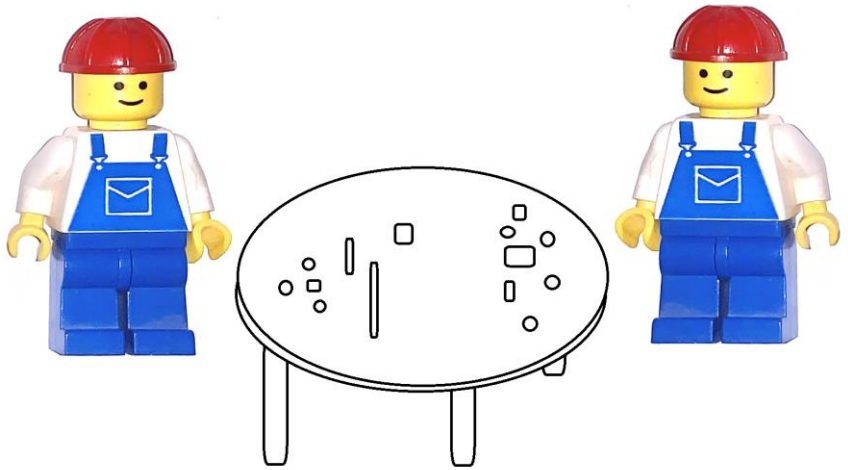
- Can be used in noisy areas

Disadvantages:

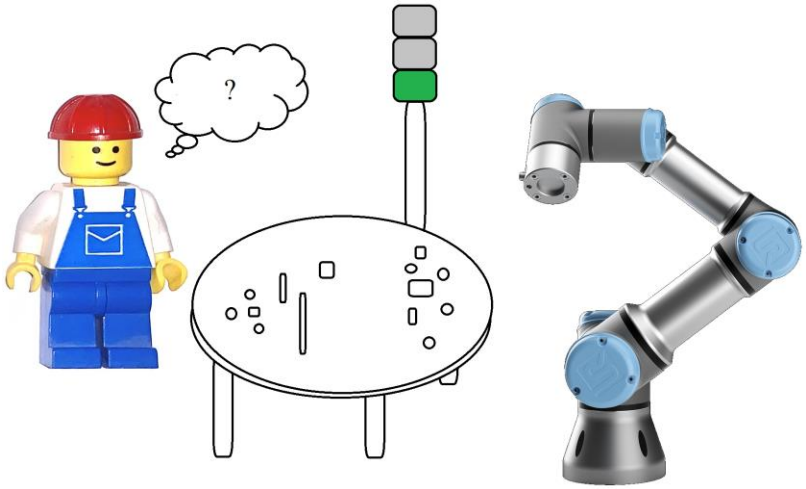
- Only can be effective when seen
- Attention is needed

Problem Statement (3) – Intention signs

- In a working task between two cooperators the information flow is crucial.
- The tasksharers are communicating with each other not just by verbal communication but also by body language (as lot of movement can be perceived beforehand)



Lego figure: https://www.brickowl.com/catalog/lego-construction-worker-with-red-helmet-minifigure-78474



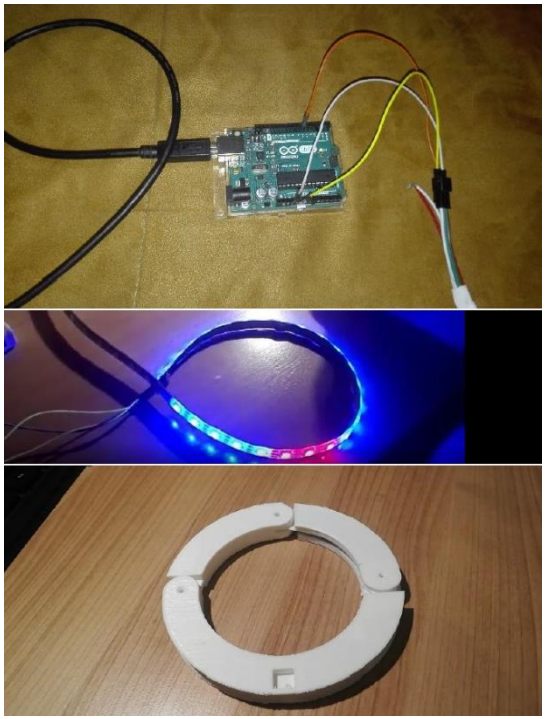
UR3e: https://www.robots.com/robots/universal-robots-ur3e

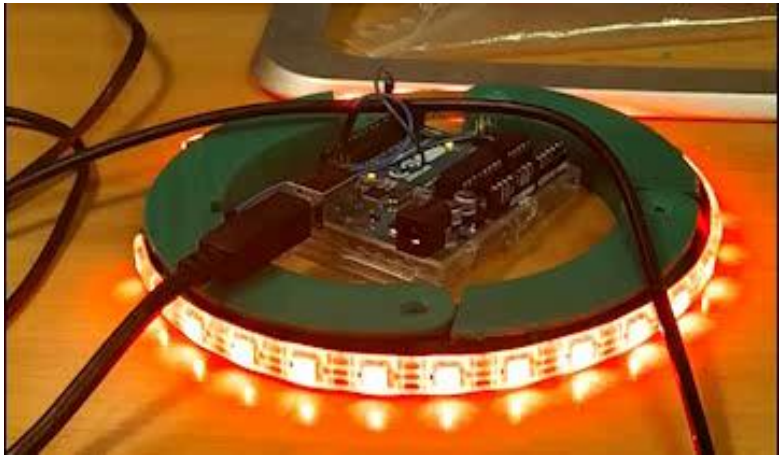
- For a robot it is harder to share its intentions. Possible way is to use visual signs at the base (or other static place but very close to the robot) to communicate more information.

LED Strip (1) - Hardware

Conceptional hardware consists:

- Arduino UNO
- WS2812B RGB LED Strip (24 LED this time)
- Supporting electronics (Supply etc.)
- 3D printed frame

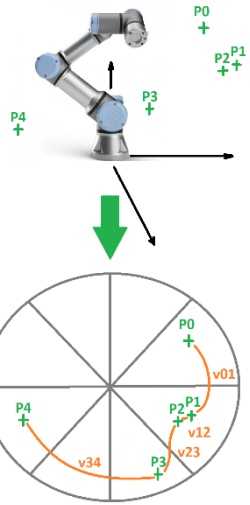


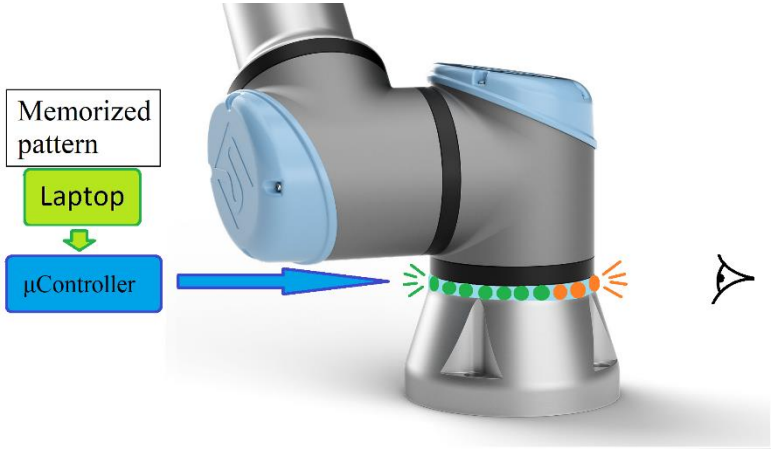


LED Strip (2) - Software

Current main function:

- Playback from previous robotmotion log file.
- Method:
  - Log file → projection to polar coordinates + z height: $[\phi, r, z]$
  - From the time differences calculate speed of movement
  - Calculate the lighting pattern according to the functional modes (described later)



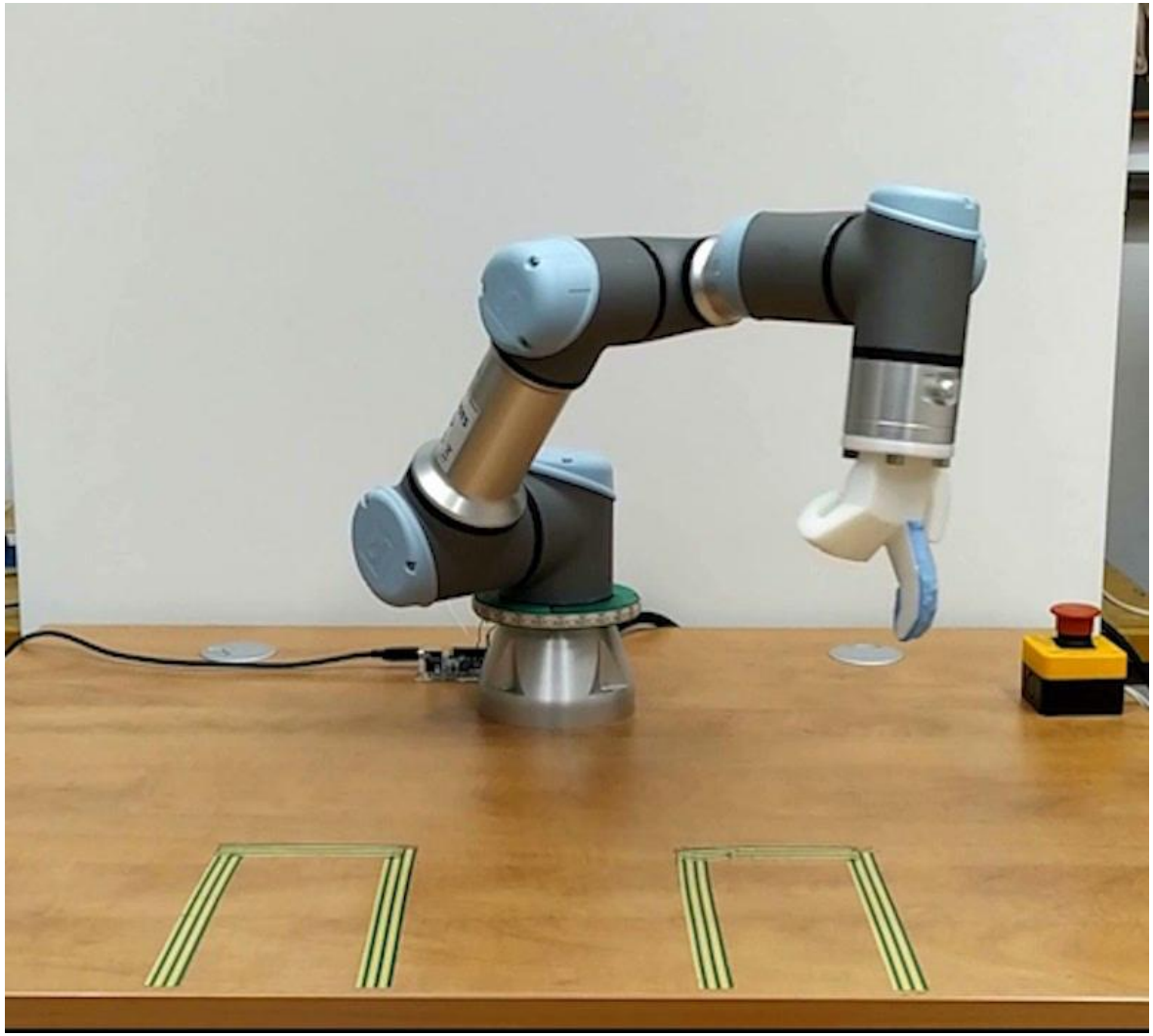


Other functionalities:

- Warning / Danger indication
- Greetings
- Emotion indication

LED Strip (3) – Software / Notification indication video

LED Strip (4) – Software / Greeting video



LED Strip (5) - Functional modes of the Strip

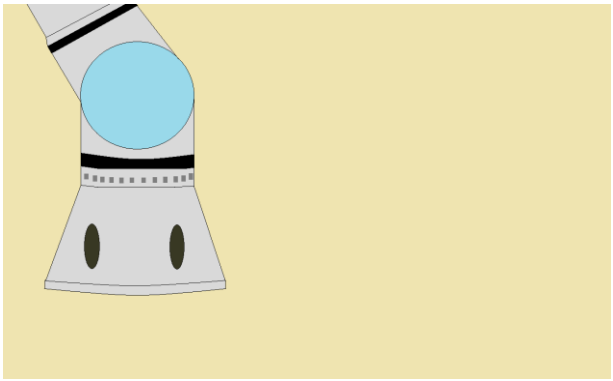
Two types of functional modes:

- Spacial based concept
- Color based concept

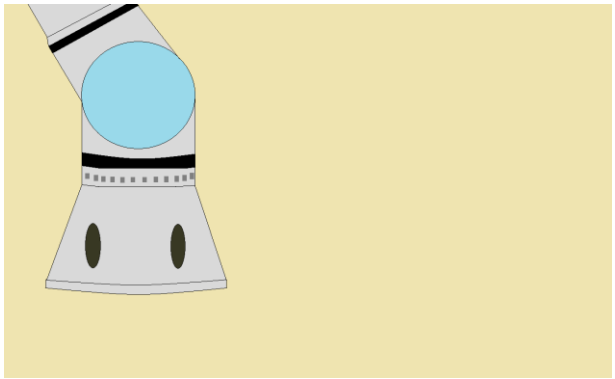
The signs center is always in the direction where the robot is pointing

- Using only one color
- Speed (dangerness / scariness) is represented in the width of the sign

- Using multiple colors
- Using fix width of sign
- Colors representing the speed (dangerness / scariness)



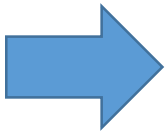
Three types of movement in the two modes (just as illustration)



LED Strip (6) - Functional modes of the Strip (2)

For an ergonomic and effective way of using this concept the near to optimal values need to be found of the following parameters:

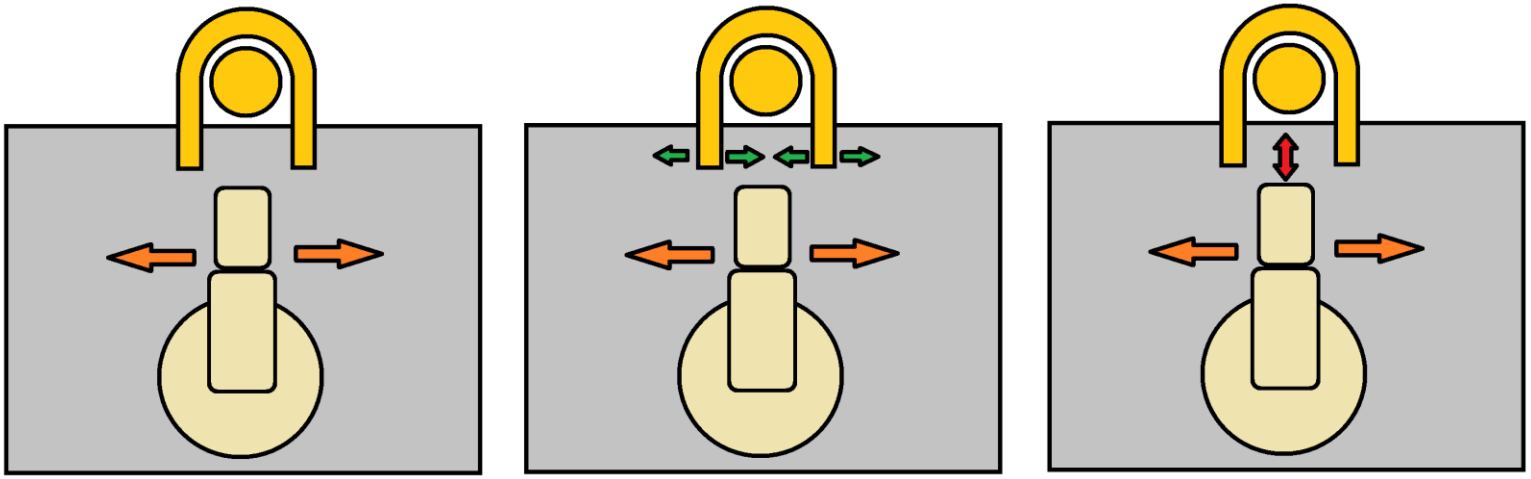
- Angle of the indication. (Function determining the amount of LEDs for a gesture based on the movement speed.)
- Time between the indication and the real movement.(Function determining the timing of the visual signal based on the movement speed or a predefined value.)
- The palette of the colors for the different movement speeds. (Function determining the color of each LED based on the movement speed.)
- The resolution of the indication in terms of colors. (How many colors are needed to effectively communicate a movement speed.)
- Etc.



Huge amount of data needs to be collected in further works

Experimental testing and possible other applications (1)

The experimental testing will be crucial in validation of the idea. The expected result is that this kind of usage of the LED strip is able to lower the mental stress during the cooperation with robots via a more ergonomic communication. The types of tests are based on the interaction levels between the human and the robot



Observation

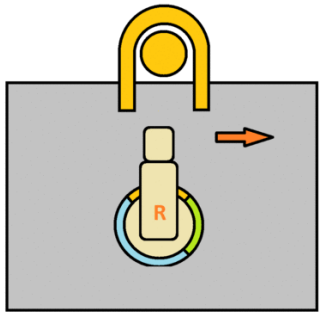
Shared workspace without shared task

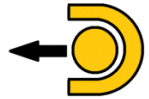
Shared workspace shared task / handing over

Experimental testing and possible other applications (2)

Other possible applications:

- Indication of awareness
  - In industrial applications
  - In mobile robots
  - In autonomous vehicles
- Indication of emotions
  - In social robotics





Conclusions

- In this paper a new way to use visual signals in human-robot interactions focusing mainly on the industrial robotics was proposed.
- The proposed idea can potentially result in a closer to ergonomic communication for situations described in this paper.
- The device is also usable in social robotics in different ways and in the communication systems of autonomous vehicles.
- The device was built and tested for functionality.
- To reveal principles to an ergonomic communication, huge amounts of tests needs to be done.
- Also the development of this device will be the target so in further works the experimental scenarios can step to the next, non static program, stage.

Thank You!