Project component: Pr.5 *Intelligent control, with advanced techniques and navigation based on high-performance sensors, video-biometric system and visual servoing system of the complex autonomous system SAC-SI integrated in the technology of assisting people with severe neuro-motor disabilities*

Objectives Stage 4. Laboratory testing of the driving structure and navigation structure (based on high-performance sensors) of SAC-SI integrated in the technology of assisting people with severe neuro-motor disabilities

Stage 4 – P5. The research finally led to the implementation and real-time testing of the driving structure, navigation and obstacle avoidance for the complex autonomous system SAC-SI, autonomous robotic system consisting of wheelchair and robotic manipulator with 7-DOF integrated in the technology of assistance for people with neuromotor disabilities. The research of Stage 4 respond to the research objectives related to Activity 4.5, from the realization plan of the complex project, and finally led to the validation by testing of the real-time management of the complex autonomous system SAC-SI. The research for implementation / testing required the establishment of a procedure for planning the trajectory of the complex CAS-SI system. An algorithm for passing through narrow spaces (door) of the complex CAS-SI system has been developed. During this stage, a software package necessary to control the complex CAS-SI system through narrow spaces (door) - based on laser and video sensors - was developed and tested in laboratory conditions. The laser sensor was used to detect the space required for maneuvers to pass through the door frame and the video camera was used to detect the door (using QR codes).

Activity 4.5. Real-time testing of the control, navigation and obstacle avoidance structure for the complex autonomous SAC-SI system integrated in the technology of assisting people with severe neuro-motor disabilities in laboratory conditions.

Performance indicators:

- A control, navigation and obstacle avoidance structure was developed for SAC-SI integrated in the technology of assisting people with severe neuro-motor disabilities, tested in laboratory conditions;
- A structure of offer of research services regarding SAC-SI integrated in the technology of assistance to people with severe neuro-motor disabilities present in the *erris* platform of the partner institutions in the consortium was created:

UVT: https://erris.gov.ro/Valahia-University-of-Targoviste

UCV : https://erris.gov.ro/Computer-Aided-Design-CAD--C

In this activity, a control structure of a robotic platform with 2 driving wheels using a laser type sensor and a video camera (web) was tested, see figure 5.1.

An autonomous door crossing system becomes a very important module for the autonomous navigation of complex autonomous systems of the SAC-SI type, because when combined with the wall tracking modules, it ensures a complete navigation system for indoor environments.
The control of the two-wheeled robotic platform through a door, tracking a certain wall or following the corridor are skills used in the case of autonomous mobile robot navigation systems. In the real world there are few applications that take into account the movements of the mobile robot passing through narrow exits, requirements very common in the case of autonomous navigation systems.

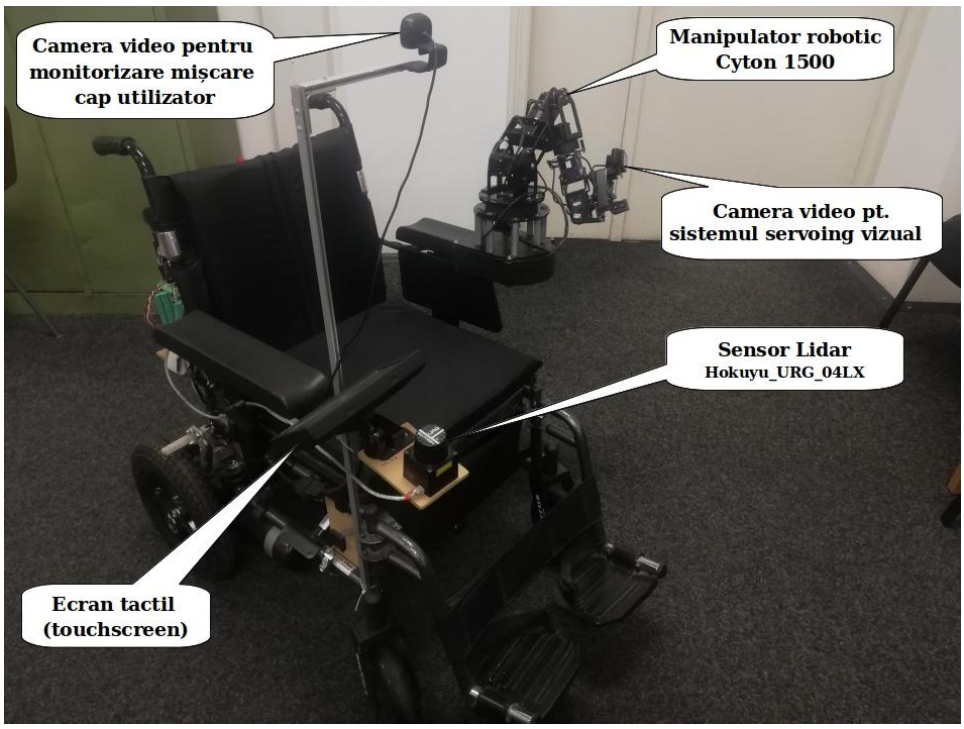


Fig. 5.1 The autonomous complex system SAC-SI integrated in assistive technology for people with severe neuromotor disabilities (front view).

The narrow space passage / movement algorithm consists of scanning the environment using a laser sensor and calculating the 6 points / positions that the mobile robot must reach. After reaching the last point, scan the environment again and calculate the next 6 points. This process is repeated until the mobile robot reaches the desired end point.
To determine the end point where the robot must reach, we need the "dial" where the door is. This information is obtained from a video camera that detects the door frame using a QR code (see Figures 5.2 and 5.3).

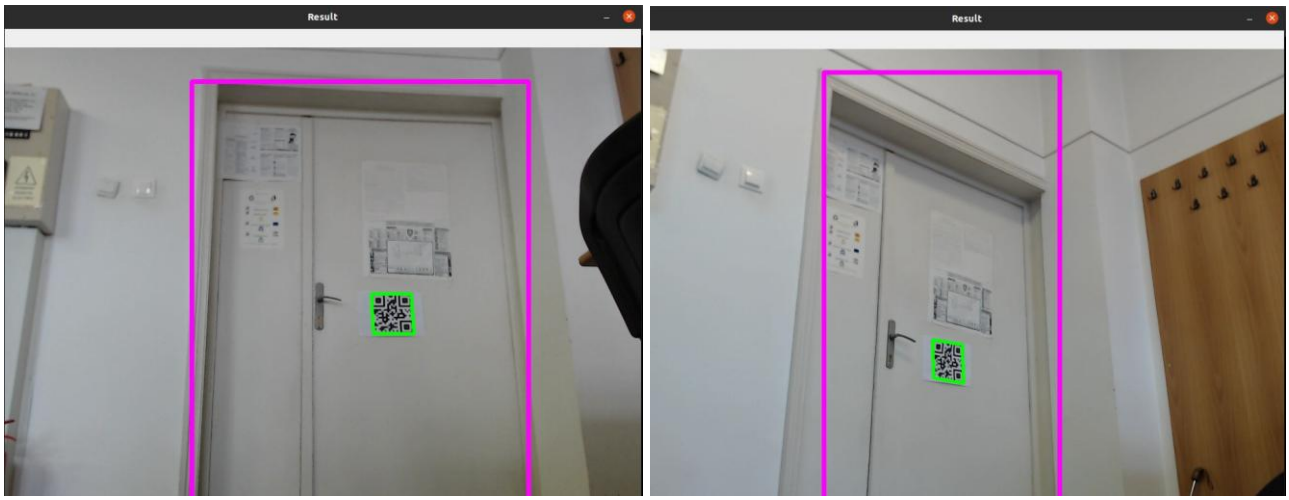


Fig. 5.2 Various images containing the door detected using the QR code

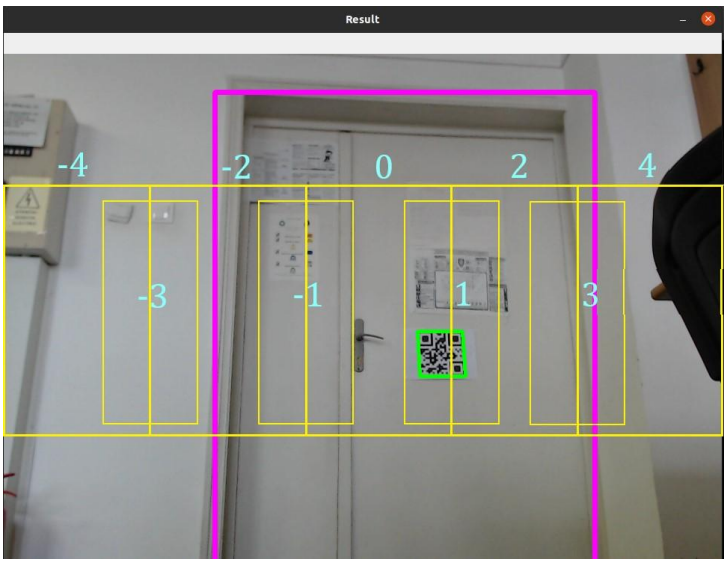


Fig. 5.3 Dividing the image into 9 quadrants (in this example the QR code can be found in quadrant no. 1).

The scheme of the algorithm used to detect a door is presented in figure 5.4.

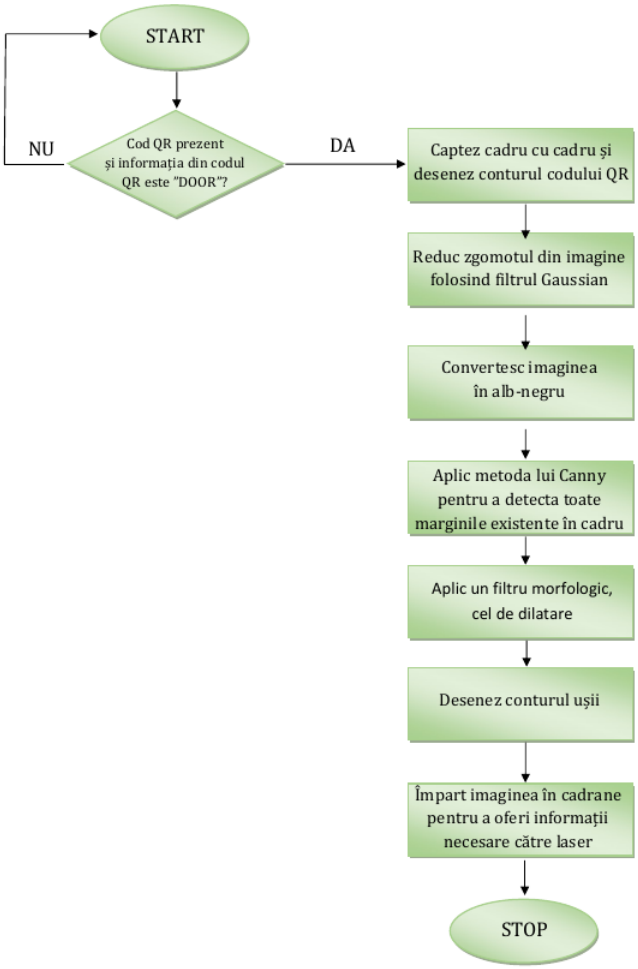


Fig. 5.4 The Logic diagram of the algorithm used to detect a door

.

To detect the space needed to move the mobile robot, use the laser sensor and the algorithm made in Matlab using a repetitive cycle of "for" type that "draws" several semicircles placed at a distance of 0.1m (from 0.3 m to 1 meter).

```
for arc = 0.3:0.1:1
    for i = 1:12
      for j = 1:43
        if arc == 0.3
            if citire_laser(j+((i-1)*43)) <= arc && citire_laser(j+((i-1)*43))> 0.2
              punct_fereastra(j, i) = 1; % fereastra ocupata
            else
              punct_fereastra(j, i) = 0; % fereastra libera
            end
         else
            if citire_laser(j+((i-1)*43))<=arc+0.2 && citire_laser(j+((i-1)*43))>arc-0.2
              punct_fereastra(j, i) = 1; % fereastra ocupata
            else
              punct_fereastra(j, i) = 0; % fereastra libera
            end
        end
      end
    end
```

The second repetitive cycle goes through the number of windows, 12 in number, using the "i" counter. What the third repetitive cycle goes through with the help of the counter "j" each window with the size of 15 degrees, which means a number of 43 readings. With the help of the "if" structure it is checked if there are obstacles inside the "i" window. If the window is occupied, the variable "window_point" is assigned the value 1, but if the window is free, the variable "window_point" is assigned the value 0. Next, the matrix "A" is used, inside which it is cumulated for each arc and each window the number of checked points and their type, free or occupied. A "degrees" vector is also defined, which contains the degrees of the window boundaries.

```
A(c, 1:12) = sum(punct_fereastra);
grade = [ 15 30 45 60 75 90 105 120 135 150 165 180];
```

The next step is checking matrix A to see which window has obstacles and which window is free. Occupied windows are assigned a value of 0 and free windows are assigned the value of the angle corresponding to the position, this can be seen in Figure 5.5.

Următoarea etapă realizează verificarea matricea A pentru a vedea care fereastră are obstacole și care fereastră este liberă. Ferestrelor ocupate li se atribuie valoarea 0, iar ferestrelor libere li se atribuie valoarea ungiului corespunzător poziției, acest lucru se poate observa în figura 5.5.

```
A =

    15    30    45    60    75    90   105   120   135   150   165   180
     0    30    45    60    75    90   105   120   135   150   165   180
     0    30    45    60    75    90   105   120   135   150     0     0
     0    30    45    60    75    90   105   120   135     0     0     0
     0     0    45    60    75    90   105   120   135     0     0     0
     0     0    45    60    75    90   105   120   135     0     0     0
     0     0    45    60    75    90   105   120   135     0     0     0
     0     0     0    60    75    90   105   120   135   150   165     0
```

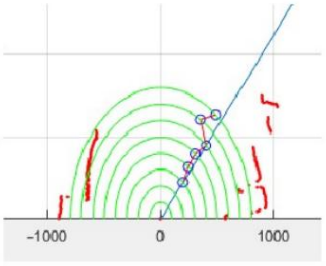


Fig. 5.5 The A Matrix associated to the presented graphic

The following are some examples of concrete cases

```
A =

    15    30    45    60    75    90   105   120   135   150   165   180
    15    30    45    60    75    90   105   120   135   150   165   180
    15    30    45    60    75    90   105   120   135   150   165   180
    15    30    45    60    75    90   105   120   135   150   165   180
    15    30    45    60    75    90   105   120   135   150   165   180
    15    30    45    60    75    90   105   120   135   150   165   180
    15    30    45    60    75    90   105   120   135   150   165   180
    15    30    45    60    75    90   105   120   135   150   165   180
```

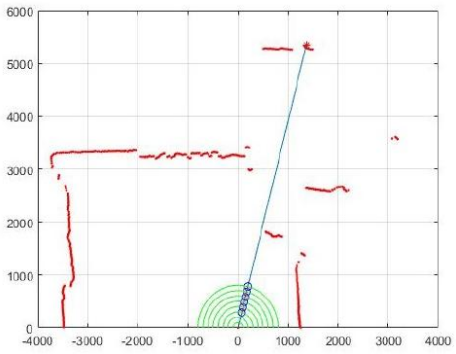


Fig. 5.6a On the mobile robot trajectory there are no obstacles

```
A =

    15    30    45    60    75    90   105   120   135   150   165   180
     0     0    45     0    75    90   105   120   135   150   165   180
     0     0     0     0    75    90   105   120   135   150   165   180
     0     0     0     0    75    90   105   120   135   150   165   180
    15     0     0     0    75    90   105   120   135   150   165   180
    15     0     0     0    75    90   105   120   135   150   165   180
    15    30     0     0    75    90   105   120   135   150   165   180
    15    30     0     0    75    90   105   120   135   150   165   180
```

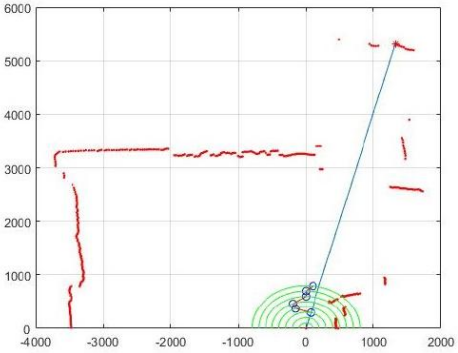
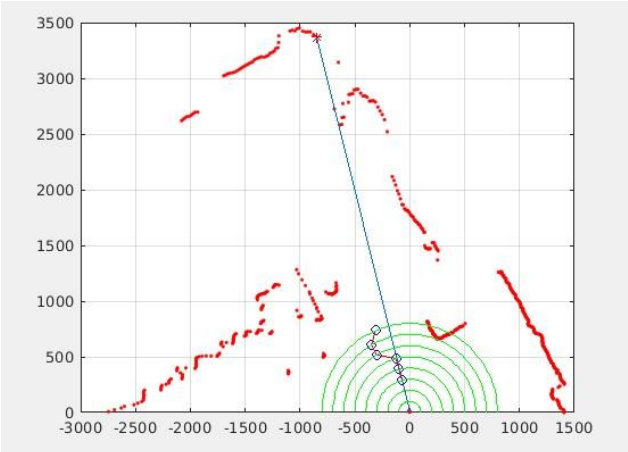
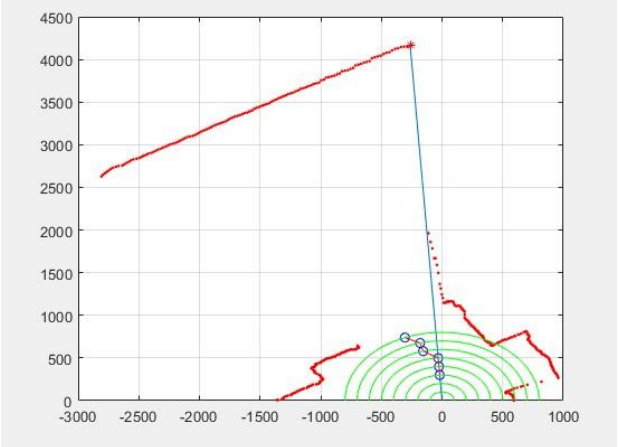


Fig. 5.6b On the mobile robot trajectory there are obstacles

Next, there some experimental results are presented. For these results, the size of the SAC-SI mobile robot was taken into account, as well as the range of the laser sensor used.





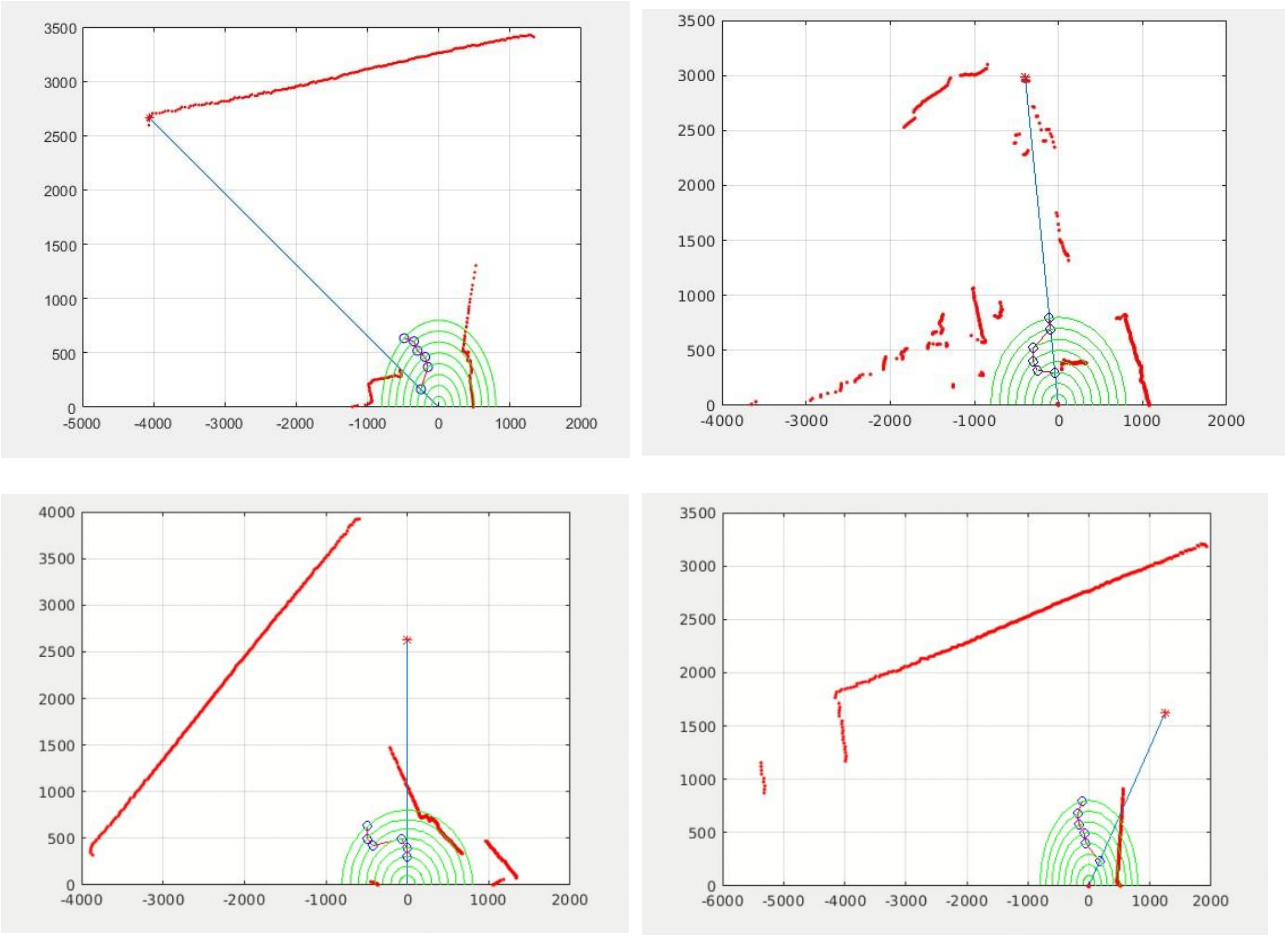


Fig. 5.7 Rezultate experimentale – ieşirea pe uşă a robotului mobil

CONCLUSION

The scientific report highlights the solutions that the Project 5 work team offers for the requirements of Stage 4. In the detailed scientific report uploaded on the P5 project platform (http://www.cidsacteh.ugal.ro), you can view the solutions and results research related to Stage 4."

„The results of the laboratory testing of the intelligent driving structure, of the navigation structure (based on high-performance sensors) and of the driving structure based on real-time visual servoing systems of SAC-SI integrated in the technology of assisting people with neuro-motor disabilities severe".

„Rezultatele testării în laborator ale structurii de conducere inteligentă, ale structurii de navigaţie (bazată pe senzori performanţi) şi ale structurii de conducere bazată pe sisteme servoing vizuale în timp real a SAC-SI integrat în tehnologia de asistare a persoanelor cu dizabilităţi neuro-motorii severe".

The Results for Stage 4

1) An algorithm for passing through narrow spaces (door) of a robotic platform with two driving wheels has been developed. During this stage, a software package necessary to drive a robotic platform with two drive wheels (SAC-SI type) through narrow spaces (door) - based on laser and video sensors - was developed and tested in laboratory conditions. The laser sensor was used to detect the space required for maneuvers to pass through the door frame and the video camera was used to detect the door (using QR codes).

2) A structure of offer of research services regarding SAC-SI integrated in the technology of assistance to people with severe neuro-motor disabilities present in the erris platform of the partner institutions in the consortium was created:

UVT: https://erris.gov.ro/Valahia-University-of-Targoviste
UCV : https://erris.gov.ro/Computer-Aided-Design-CAD--C