TrimBot2020 Deliverable D7.2

Demonstrator Plan

Principal Author: UEDIN
Contributors: UEDIN
Dissemination: PU
Deliverable due: Month 3

Abstract: The TrimBot2020 project will create 3 demonstrators, each building on the capabilities of the others:

1. **Vehicle localisation and navigation (Month 21)**
2. **Fixed arm clipping (Month 33)**
3. **Mobile vehicle localisation and clipping (Month 45)**

This document specifies the intended demonstrations in detail.

1 Introduction

The TrimBot2020 project will create 3 demonstrators, each building on the capabilities of the others. The demonstrators will show that the project has achieved its main goal (development of a garden trimming robot), to provide the content for research publications and public awareness, to provide evidence for the strengths and limitations that can guide future research and exploitation, and to verify that the technology developed has achieved TRL 6. The first demonstrator will take place in an outdoor test garden at Bosch. The second demonstrator will take place at WU/DLO in an outdoor garden. The third demonstrator will take place in outdoor test gardens at Bosch and WU/DLO.

The project will design the layout of the garden as part of Task T7.1, and there be some indoor development but the main demonstrators will be outdoors. The indoor facility will allow all-weather development and testing. The gardens will be designed to have several shapes of hedges and trimable bushes, several ground types (small gravel, grass, concrete path) with varying slopes, and several obstacles (rocks, small trees). The variety of features will allow testing of localisation, feature detection, obstacle avoidance, path planning, navigation, visual servoing into trimming location and both hedge, rose and boxwood bush trimming. The outdoor test gardens at both Bosch and WU/DLO will have similar sets of plants and layouts, but will not be identical, so as to evaluate robustness.

The year 1/2 platform will be a modified robot base with the sensors, and usable for navigation and data acquisition. The second platform will be a mobile vehicle with the arm mounted, and will travel so development and evaluation can take place at both Bosch and WU/DLO. Copies of the visual sensors will be mounted on the platform as well as there being duplicates at other relevant partners.

The demonstrators are:

1. **Vehicle localisation and navigation (Month 21)**: This demonstrator will test the ability of the vehicle to localise itself based on the user sketch map, 3D data and previous 3D SLAM-based representations of the garden (acquired from manual navigation). The robot will navigate from a specified initial positions to sketch-map specified locations and align itself with the nearby hedges or bushes via local visual servoing.

2. **Fixed arm clipping (Month 33)**: This demonstrator will use a fixed robot arm. Test hedge, rose or boxwood bushes will be placed nearby. The robot platform 3D sensing and the on-arm 3D sensing will provide data. The arm will have the clipper mounted and will demonstrate trimming of the hedge, rose, and boxwood bush back to its desired shape. This will require registration of 3D shape models and visual servoing of the clipper as the vegetation will flex under the action of the clipping.

3. **Mobile vehicle localisation and clipping (Month 45)**: This demonstrator will combine the activities of the first two demonstrators, requiring additional capabilities such as enhanced onboard power and processing, management of reactive forces on the vehicle and arm from the vehicle, arm, and cutting actions, repositioning of the vehicle to trim other sides of the bushes and further along the hedges, and rose clipping. The vehicle will be able to start from a random position using a SLAM garden model acquired by an initial user navigated survey of the garden.

1.1 Specification

For each of the 3 demonstrators, we identify the robot capabilities that will be tested by the demonstrator, what components need to work (at least at a sufficient level, even if further refinements are still proceeding), the steps of the demonstration and how the degree of success will be measured.

Other capabilities and components might also be demonstrated at the review meeting if appropriate.

1. **Vehicle localisation and navigation**
   (a) **Capabilities Tested**:
      i. 3D scene data capture, surface recovery and fusion
      ii. User map-based target specification
      iii. 3D to map registration
      iv. Vehicle map-based registration self-localisation
      v. Point-to-point map-based path planning and dead-reckoning navigation
      vi. Obstacle detection and avoidance
   (b) **Necessary Components**:
      i. Modified lawnmower base + power supply + drive (Bosch)
      ii. Algorithms to control base movement (given a destination) (Bosch)
      iii. Outdoor test garden with a variety of content and some variation of terrain (Bosch)
      iv. Wireless vehicle monitor and control capability (Bosch)
      v. 3D sensor calibration (ETHZ)
      vi. 3D data capture (ETHZ, ALUF)
      vii. 3D data surface extraction and fusion (UEDIN)
      viii. User sketch map interface (UEDIN)
      ix. 3D to map deformable registration algorithm (UEDIN)
      x. Obstacle detection algorithm (UVA)
      xi. Vehicle motion planning and navigation module (Bosch)
      xii. Vehicle task sequencing, execution and monitoring module (Bosch)
      xiii. Vehicle self-localisation algorithm (Bosch, ETHZ)
      xiv. Component algorithm acceleration 1 (RUG)
      xv. Component Integration (all)
   (c) **Demonstration Procedure**:
      i. User sketches garden (display of map)
      ii. User indicates a point near { hedge, topiary bush, rose bush }
      iii. Vehicle navigates, while avoiding obstacles, to specified locations across a variety of terrain (observation of motion)
      iv. Vehicle servos (using the motion module) based on a 3D scene descriptions (from the 3D fusion odule), to specified real location (based on the user sketch map).

(d) **Success criteria**: a) vehicle sensor system can acquire accurate 3D shape data, b) vehicle can navigate on grass, loose but flat soil, pavement, c) vehicle can estimate its location, with a target accuracy of 5-10 cm, and d) vehicle can navigate to specified locations in the garden near hedges, and bushes without collisions.

2. **Fixed arm clipping**

   (a) **Capabilities Tested**:

      i. Clipper movement, control and strength
      ii. Robot arm carrying capacity, control and reachability
      iii. Effector end camera 3D sensing
      iv. Bush and rose stem 3D shape extraction
      v. Clipper servoing to bush and rose stem cutting locations
      vi. Bush and rose stem cutting
      vii. Bush surface compliant extended trimming to planar and curved (spherical or cylindrical) shape
      viii. Remote control and monitoring of arm

   (b) **Additional Necessary Components**:

      i. Computer controlled clipper (DLO/WU)
      ii. Robot arm and controller (DLO/WU)
      iii. Arm and cutter control algorithms (DLO/WU)
      iv. Mounting of 3D sensor on effector end and calibration into arm coordinate system (ETHZ)
      v. Local 3D points and surfaces (ALUF,UEDIN)
      vi. Bush visible and cutting surface extraction (UVA)
      vii. Rose stem extraction (UVA)
      viii. User map-based action specifications (UEDIN)
      ix. Cutter path planning and execution (DLO/WU)
      x. Component integration (all)
      xi. Component algorithm acceleration 2 (RUG)

   (c) **Procedure**:

      i. Place { square bush, spherical bush, rose plant } near arm/cutter assembly
      ii. Acquire local 3D scene description using external 3D sensor (perhaps mounted on a nearby robot base), and transform into arm coordinate system
      iii. Local 3D scanning of plant using clipper 3D sensor
      iv. Clipper servos to cut rose stem
      v. Clipper servos to trim planar frontal surface
      vi. Clipper servos to trim curved frontal surface

   (d) **Success criteria**: a) arm sensor system can acquire accurate local 3D shape data, and b) arm/clipper can restore overgrown bush surfaces, with the goal of 5-10 mm accuracy.

3. **Mobile vehicle localisation and clipping**

   (a) **Capabilities Tested**:

      i. All capabilities of first and second demonstrators
      ii. Outdoor data collection and navigation
      iii. Platform+arm+cutter load management
      iv. Platform+arm+cutter power capability
      v. Remote control and monitoring of platform and arm
      vi. Trimming over an extended surface

   (b) **Additional Necessary Components**:

      i. Outdoor garden (DLO/WU + Bosch)
      ii. Arm mounted and integrated with platform (DLO/WU + Bosch)
      iii. Arm and platform coordinate system registration (Bosch + DLO/WU)
      iv. Arm and vehicle localisation (ETHZ)
      v. Vehicle and cutter control for extended surface cutting (DLO/WU + Bosch)
      vi. Full component integration (All)
      vii. Component algorithm acceleration 3 (RUG)

   (c) **Procedure**:

      i. Place vehicle in garden
      ii. Vehicle surveys garden (under user control using the sketch map), with collision protection (display of recovered 3D scene)
      iii. User specifies cutting location and action for { rose bush, flat bush, extended length flat bush, curved bush }
      iv. Vehicle navigates with collision avoidance to cutting locations
      v. Platform performs cutting actions

   (d) **Success criteria**: a) vehicle can stably carry arm on a variety of surfaces, b) arm/clipper can locate and cut rose stems and trim bush surfaces, c) vehicle can plan and execute servo motions to get near to several sides of target plants, d) vehicle/clipper can maintain surface flatness, with a goal accuracy of 10 mm over extended trimmings.

