Mobile Robot for Tunnel Inspection

Rafael Lopez (ROBOTNIK)

Aging Tunnels – Safety in operation and during refurbishment. Dubrovnik 2015
COMPANY PROFILE

• SME – 2002
• Located in Valencia (SPAIN)
• 25 engineers
• Leading company in the market for Service Robotics in Europe.

Certifications:

– ISO 9001:08 Design, manufacturing and commercialization of products and systems based in robotics technology.
– UNE 166002:06 R&D Management in the development of robotics projects.
COMPANY PROFILE

• Robotics product manufacturing and reselling (mobile robot platforms, arms, hands, humanoids)
• Robotics R&D and Engineering projects:
  • Professional service robotics
  • UGV engineering
ROBO-SPECT SYSTEM

• Mobile vehicle and crane
• Robotic arm
• Vision system
• Ultrasonic system
• Ground control station
ROBO-SPECT

- Mobile vehicle and crane: Model Genie Z34
### Mobile Vehicle Characteristics

<table>
<thead>
<tr>
<th>Measurements</th>
<th>US</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working height maximum*</td>
<td>40 ft 6 in</td>
<td>12.52 m</td>
</tr>
<tr>
<td>Platform height maximum</td>
<td>34 ft 6 in</td>
<td>10.52 m</td>
</tr>
<tr>
<td>Horizontal reach maximum</td>
<td>22 ft 3 in</td>
<td>6.78 m</td>
</tr>
<tr>
<td>Up and over clearance maximum</td>
<td>15 ft 2 in</td>
<td>4.62 m</td>
</tr>
<tr>
<td>Platform length</td>
<td>2 ft 6 in</td>
<td>0.76 m</td>
</tr>
<tr>
<td>Platform width</td>
<td>4 ft 8 in</td>
<td>1.42 m</td>
</tr>
<tr>
<td>Height - stowed</td>
<td>6 ft 7 in</td>
<td>2.00 m</td>
</tr>
<tr>
<td>Length - stowed</td>
<td>18 ft 9 in</td>
<td>5.72 m</td>
</tr>
<tr>
<td>Storage height</td>
<td>7 ft 5 in</td>
<td>2.26 m</td>
</tr>
<tr>
<td>Storage length</td>
<td>13 ft 9 in</td>
<td>4.19 m</td>
</tr>
<tr>
<td>Width</td>
<td>4 ft 10 in</td>
<td>1.47 m</td>
</tr>
<tr>
<td>Wheelbase</td>
<td>6 ft 2 in</td>
<td>1.88 m</td>
</tr>
<tr>
<td>Ground clearance - center</td>
<td>5.5 in</td>
<td>0.14 m</td>
</tr>
</tbody>
</table>
## Mobile Vehicle Characteristics

### Productivity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lift Capacity</th>
<th>Platform Rotation</th>
<th>Vertical Jib Rotation</th>
<th>Turntable Rotation</th>
<th>Turntable Tailswing</th>
<th>Drive Speed - Stowed</th>
<th>Drive Speed - Raised**</th>
<th>Gradeability - Stowed***</th>
<th>Turning Radius - Inside</th>
<th>Turning Radius - Outside</th>
<th>Controls</th>
<th>Tires (Solid Rubber, Non-Marking, Treaded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 lbs</td>
<td>227 kg</td>
<td>180°</td>
<td>139°</td>
<td>355° non-continuous</td>
<td>zero</td>
<td>4.0 mph</td>
<td>0.68 mph</td>
<td>35%</td>
<td>7 ft</td>
<td>13 ft 5 in</td>
<td>24V DC Proportional</td>
<td>22 x 7 x 17.75 in</td>
</tr>
</tbody>
</table>

### Power

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Power Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>48V DC (eight 6 V batteries 315 Ah capacity)</td>
<td></td>
</tr>
</tbody>
</table>

| Auxiliary Power Unit            | 24V DC                                                                 |

| Hydraulic Tank Capacity        | 4 gal                                                                       |

| 15.1 L                                                                       |

### Weight****

<table>
<thead>
<tr>
<th>Weight</th>
<th>11,400 lbs</th>
<th>5,171 kg</th>
</tr>
</thead>
</table>
Mobile Vehicle Characteristics

- Joints of the platform have been sensorized by means of encoders and transducers, so every position and orientation is controlled
- Standard PC with ROS for control
- 2 laser scanners for obstacle avoidance and navigation
- PTZ Camera for teleoperation
- Lightning system
- Both road and tracks navigation
- The vehicle provides power supply for the rest of components
ROBO-SPECT Components

Robotic Arm: PA10 + servo driver + PC

Robotic manipulator

Servo Driver
ROBO-SPECT Components

- Robotic arm characteristics:
- **Mitsubishi PA-10 robotic arm specifications**
  - 7 D.O.F
  - 35 kg
  - 1.35 m long
  - Ø220 mm base
  - Max. load 10 kg
  - 0.2 mm position accuracy
  - Robot power requirements: Single-phase 100 to 240V±10% AC, 50/60 Hz 1.5kVA

- **Servo Driver Controller specifications**
  - 262mm x 331mm x 396mm
  - 22 kg
  - ARCNET communication
ROBO-SPECT Complete diagram
ROBO-SPECT Components

- Visual System includes
- Defect detection cameras
- Stereo vision system
- Laser distance measurement sensor
- Stereo cameras lightning system
- Full frame mirror less DLSR camera
- 3D laser profiler
ROBO-SPECT Components

- Defect Detection Cameras
- Stereo Cameras on stand
- 3D Laser Scanner positioned on the platform
- Laser measuring beam around internal tunnel perimeter
- 360 view of laser scanner ensured
- Laser scanner interface (pole with small platform)
ROBO-SPECT Components

• Ultrasonic sensors: Attached to the robotic arm end effector

• Components
  – Two piezo-electric ceramic transducers from James Instruments
  – One fiber-optic ultrasonic sensor
  – Electronic readout system
ROBO-SPECT Components

- Ground Control Station
  - Laptop based
  - Graphical User Interface
  - Wi-Fi Connection
**ROBO-SPECT Components**

Complete set of sensors

<table>
<thead>
<tr>
<th>SENSOR</th>
<th>LOCATION</th>
<th>MISSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Lasers + Camera</td>
<td>Vehicle</td>
<td>Navigation</td>
</tr>
<tr>
<td>dSLR camera + Light</td>
<td>Vehicle</td>
<td>Crack Detection</td>
</tr>
<tr>
<td>3D profiling laser</td>
<td>Vehicle</td>
<td>Tunnel</td>
</tr>
<tr>
<td>Laser / TOF camera</td>
<td>Robot Arm</td>
<td>Navigation</td>
</tr>
<tr>
<td>Ultrasonic sensor</td>
<td>Robot Arm</td>
<td>Crack Measures</td>
</tr>
<tr>
<td>Stereo cameras + Projector</td>
<td>Robot Arm</td>
<td>Crack Detection</td>
</tr>
</tbody>
</table>
ROBO-SPECT Physical architecture
ROBO-SPECT Inspection

- Inspection based on sections

- One pass inspection
- Tunnel closed to traffic
1. The mobile vehicle moves along the center of the tunnel and stops on each tunnel section. A 3D cloud of the section is computed.

2. The vehicle stops and the crane moves while the cameras take pictures of the tunnel wall.

3. If a crack is detected, the crane approaches the crack and the robot places the ultrasonic sensors in order to make measures.

4. When all the section is inspected, the vehicle moves to the next one and repeats the process.
Thank You!

Rafael Lopez
rlopez@robotnik.es
Robotnik Automation SLL
www.robotnik.eu