RadioRoSo

Experiment Overview and Achievements

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RadioRoSo Project Facts

- Running under the umbrella of EU FP7 project ECHORD++
  - ECHORD++ mission is to bring results from lab to market
- ECHORD++ experiments:
  - Impact oriented use cases with industrial user participation
- RadioRoSo is one of 16 experiments
  - Starting 1st September 2016
  - Duration 18 months (to end March 2018)
- Budget: 295K Euro.

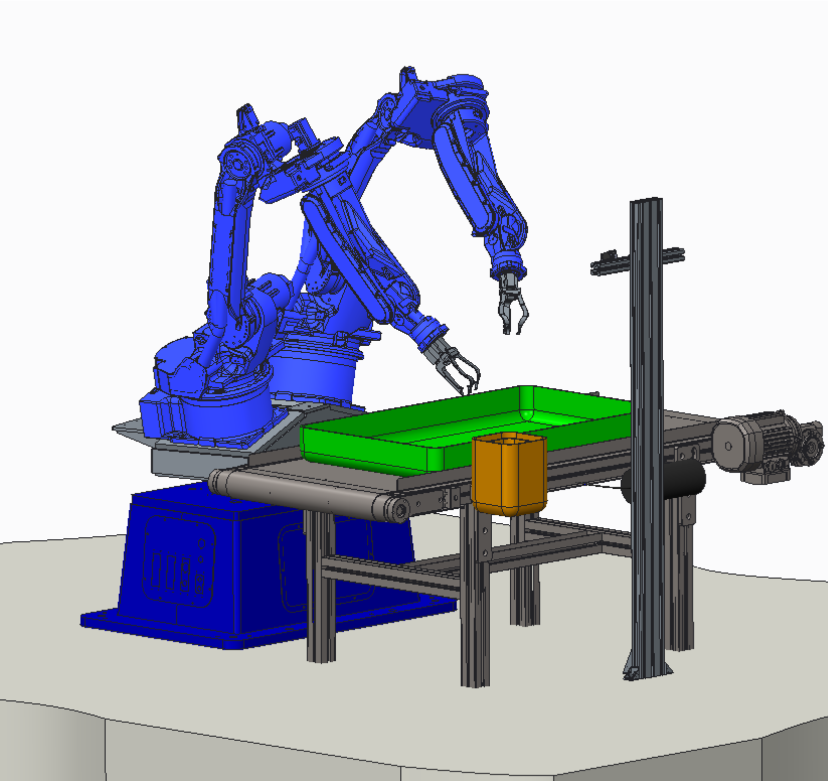
RadioRoSo Consortium

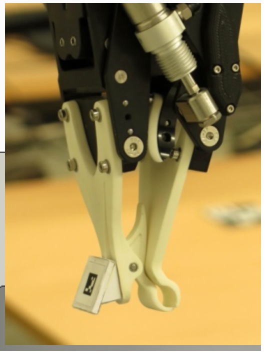
- **CERTH** - Center for Research and Technology Hellas (Greece)
- **NES** –ANSALDO Nuclear Engineering Services (UK)
- **SURO** – National Radiation Protection Institute, Prague (Czech Republic)
- **UniGe**– Universita degli Studi di Genova (Italy)
- **CVUT** - Czech Technical University in Prague (Czech Republic)

RadioRoSo Experiment Goal

- Demonstrate robust autonomous or semi-autonomous **sorting of nuclear waste.**
- Aiming at **reduction of cost** of nuclear plant decommissioning operations:
  - By improving process throughput.
- Improve **health and safety of workers** in such operations.
  - Typically the task is currently performed using manually operated master-slave robots and is tedious and error prone.

Shared Experimental Testbed





- Two independent industrial 6-DoF manipulators (Motoman MA1400) on a rotating base
- ROS based control software.
- Temporary pinch-like grippers to be replaced by RadioRoso grippers

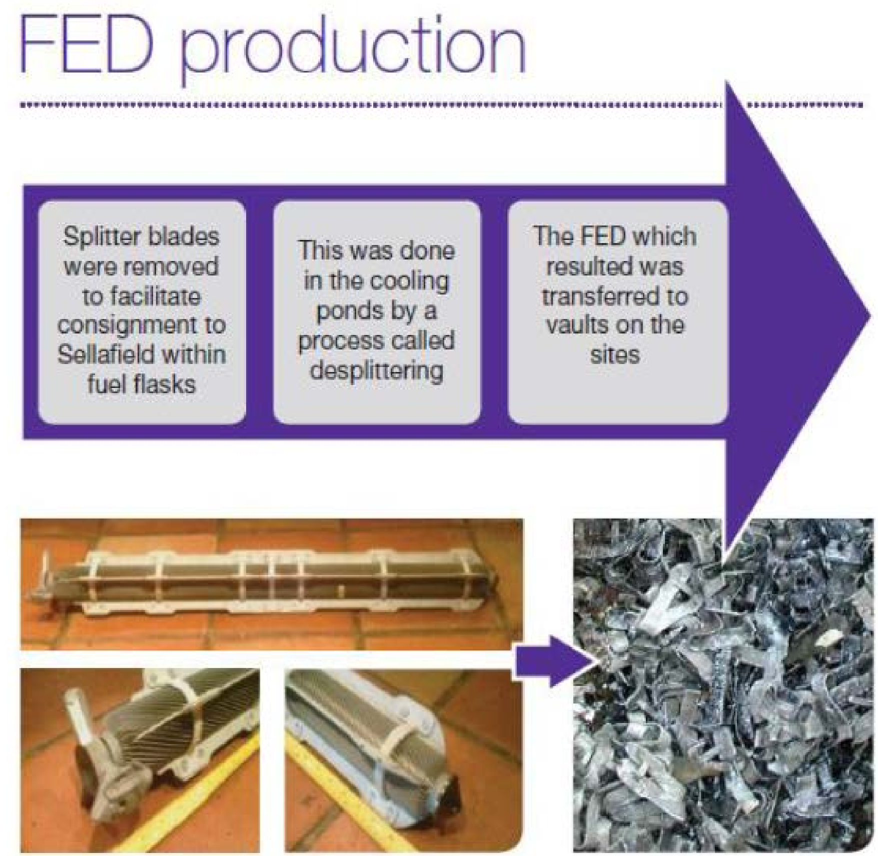
- Drivers for all hardware and basic software for collision-aware motion planning, calibration and control available from previous projects

Application Scenario I

Sorting of Magnox Fuel Element Debris

- uranium pellets immediately separated and reprocessed
- manganese/aluminum canister debris encapsulated in concrete and stored, or dissolved in acid
- springs (very radioactive) cannot dissolve in acid and cannot be encapsulated in concrete

→ picked up and usually carefully stored in led pots

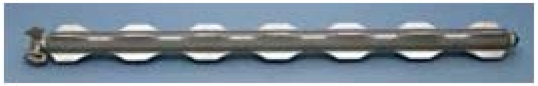


Large decommissioning market

- 11 Magnox power stations in UK (26 units or reactors), 1 in Italy, 1 in Japan at Tokai

Application Scenario I
Sorting of Magnox Fuel Element Debris

- Sorting of Magnox nemonic springs from fuel cell deconstruction debris (swarf)
  - Large quantities in several sites
  - Contained in silos at end life (need to dispose)
  - The hot material is the springs packing the pellets in the fuel rods (Nimonic with Co60)
- Now done by humans in teloperation
  - Slow, fatigue of operators, sorting errors



Application Scenario I

Sorting of Magnox Fuel Element Debris

- Environment:
  - Debris is put in a tray containing both low-activity waste (swarf) and high-activity springs (hot-spots).
  - Robots, sensors and grippers should be resistant to radiation.
- Robotic Skills
  - Detects springs using vision (maybe partially occluded).
  - Robot grasps springs and puts them away.
  - If no spring visible radioactivity sensor used to detect remaining springs covered by swarf.
  - Steer the contents of the tray and repeat the process until all springs have been recovered.
- Targets
  - Improve sorting speed compared to humans

Application Scenario II
Sorting of Mixed Waste

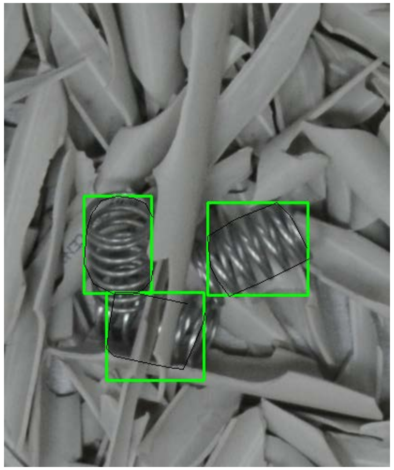
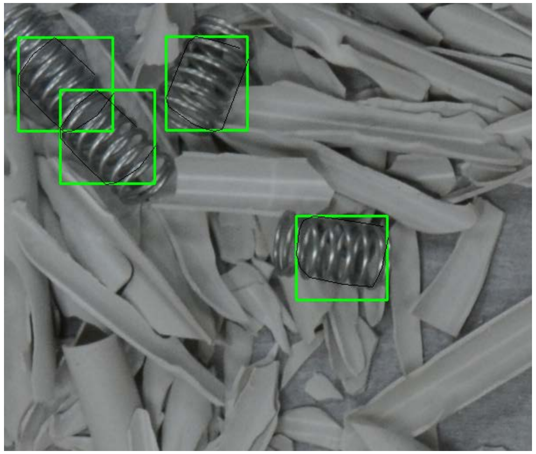
- Processing of mixed nuclear waste with semi-autonomous robotic sorting cells
  - Waste comprises low-level radioactive waste
  - Presence of material with different size (small to large)
  - Presence of compressible material (always low radioactive and soft items such as garments, gloves, wires)
- Challenges
  - Properties of objects unknown e.g. geometry, material.
  - Significant clutter.
  - Harsh environment (immersed in water).
  - Presence of bulky objects that have to be cut.
- Targets
  - Improve sorting speed compared to fully manual processing

Application Scenario II
Sorting of Mixed Waste

- RadioRoSo goals
  - Demonstration of grasping of previously unseen objects from a heap.
  - Demonstration of grasping of objects of different size and compressibility (e.g. garments).
  - Evaluation of radioactivity resistance of gripper.
  - Use of tactile cues (tactile sensors embed on grippers) to assess grasp stability.
  - Demonstrate dual-arm manipulation capabilities for picking long objects (e.g. ropes)

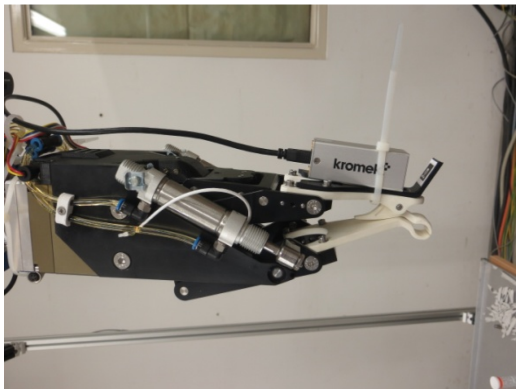
RadioRoSo Results
Vision-based localization and grasping

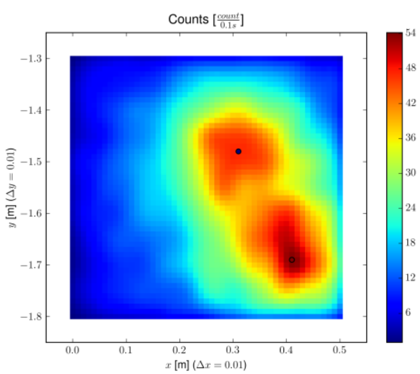
- Highly accurate detection of springs (accuracy ~ 98%)
- Autonomously learned push strategy for spring singulation.
- Grasping success ~ 98%
- Processing time < 1 min

RadioRoSo Results

Radioactivity sensor-based localization of hot spots



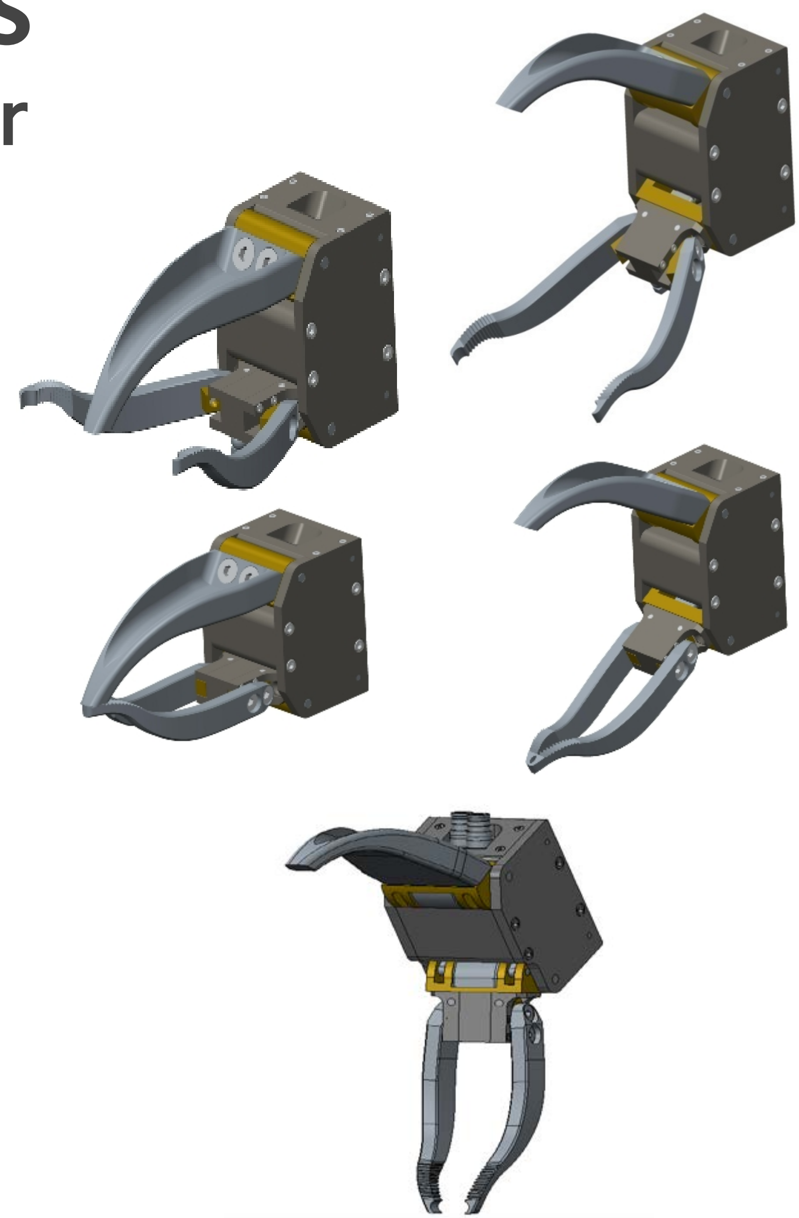


- Springs significantly more radioactive than the rest of the swarf and environment
- Detection of presence on the tray with a sensor developed by the partner SURO.
- Sensor placed on robot arm that scans the surface.
- Proof of concept with 3 detectors (CZT, TimePix, plastic scintillator)

RadioRoSo Results
Radioactivity proof gripper

- Two independent hydraulic actuated axes
- Separate power unit
- Passive finger compliance
- Different grasping configurations for different tasks and object dimensions.
- The paired fingers can form 2- and 3-point closures with the single finger
- Wrapping of soft items for power grasp

- Design robust and modular following nuclear standards
- Different fingers can be mounted



RadioRoSo Results
Other Results

- Demonstration of previously unseen object grasping with active vision
- Integration of garment detection and grasping

Deliverables

SB:	Storyboard [M03]
D1.1:	Detailed Experiment Specification and Evaluation Methodology [M3]
D2.1:	Gripper detailed design and interface specification [M6]
D5.1:	Phase 1 experiment report [M6]
D5.2:	Phase 2 experiment report [M12]
D5.3:	Phase 3 experiment report [M18]
MMR:	Experiment Multimedia Report [M18]

Key Performance Indicators
Technical

tKPI1: Percentage of wrongly detection of item radioactivity level. [M12]

• Visual detection of radioactive springs: 1.5% error
• Grasp failure < 1%.
• 200 randomized experiments.
• Hot target localization accuracy: ~3cm.

tKPI2: Sorting error for compressible/rigid items. [M12]

tKPI3: Average single item sorting time (grasping, classification, separation from heap, measurement) . [M18]

• Successfully grasping a spring from a tray: ~1 min.
• Radioactivity detection: ~1 min.

Key Performance Indicators
Impact

iKPI1: Production of a new radioactivity-proof gripper (possible product) [M6]

Gripper manufactured, tested and integrated on CERTH, CVUT testbeds.

iKPI2: Reduction of cost of sorting procedure [M12]

There is a significant cost reduction mainly from improvement of speed.

iKPI3: Improved health, safety and quality of work of personnel [M12]

Justified the benefit for workers.

iKPI4: Attract interest of possible stakeholders in RadioRoSo technology [M18]

Unofficial expression of interest by ZTS VVU Kosice, discussions with NES on possible products/services are ongoing.

iKPI5: Commercial viability of RadioRoSo results [M18]

- Gripper commercialization in several applications
- Detection pipeline in decommissioning projects (pending).
  - Highly regulated and safety aware industry which is conservative with respect to introduction of new technology
  - Cautius with respect to new partnerships.

TRL of experiment outcomes

- Gripper: TRL5
- Vision based grasping of Magnox Springs: TRL4
- Radioactivity detector: TRL5
- Grasping of previously unseen/soft objects: TRL3

Dissemination
Material

- ✓ **Website of experiment:** ***http://radioroso.ciirc.cvut.cz/***
- ✓ ***Youtube channel:***
  https://www.youtube.com/channel/UC8pW9Fv_jB3OQfCZS3Yk-ug
- ✓ ***Leaflet and project presentation***
- ✓ ***Project Video (multimedia report)***
- ✓ ***Newsletter: published by CERTH***

Dissemination

Networking

- ✓ EU project ROMANS (Ales Leonardis)
- ✓ Ladislav Vargovcik, ZTS VVU Kosice (key expert in nuclear industry)
- ✓ Networking by Prof Hulka (SURO) with nuclear regulatory associations and institutes (leaflet and project presentation).
- ✓ Networking during the ERF 2018 by Prof. Hlavac (leaflets and informal networking)
- ✓ Networking with EU project CONCERT (European Joint Programme for the Integration of Radiation Protection Research). SURO is Czech coordinator for CONCERT.
- ✓ Networking with International CBRNE Institute (UniGe).

Dissemination

Events

- ✓ Participation in Innorobo 2017 (March 2017)
- ✓ RadioRoSo paper on FAIM 2017 (June 2017)
- ✓ Open day at CERTH (May 2017).
- ✓ Open day at UniGe (Sep 2017)
- ✓ Lectures and Workshop within EMARO (European Master in Advanced Robotics)
- ✓ Two presentations in SIRI meetings.
- ✓ Eurobotics Forum 2018 (workshop presentation) by Prof. Hlavac: *Towards robotic sorting of radioactive waste. Outcomes of the Echord++ experiment.*

Use of Resources

- ✓ CERTH: 101%
- ✓ CVUT: 96%
- ✓ UniGe:
- ✓ SURO: 143%
- ✓ NES:

Thank You

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