RadSort: Autonomous Contamination Classification for Nuclear Decommissioning

Team #8 - Robot ROCm
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📝 **Teaching Robots to Protect Humans from Radiation**

94%
Classification Accuracy
Across all contamination levels

0%
Critical Safety Errors
Zero High→Safe misclassifications

25
Hz Edge Inference
Real-time on Ryzen AI processor

73%
Faster than Manual
12.4s vs 45s per object sorting

🎯 The Challenge

Nuclear Decommissioning Crisis:

- 150,000+ workers exposed to radiation annually worldwide (IAEA data)
- $500 billion global decommissioning market projected by 2030
- 30-year timelines documented (Fukushima Daiichi example)
- Manual contamination sorting remains slow, dangerous, and prohibitively costly

Current Solutions Fall Short:

- **Teleoperation:** 2-3 second latency creates cognitive overload for operators
- **Rule-based robots:** Brittle systems requiring site-specific reprogramming
- **Supervised ML:** Demands 10,000+ labeled examples per deployment site

💡 Our Solution

Imitation Learning for Nuclear Safety

RadSort trains robots through human demonstrations to autonomously classify contaminated materials by radiation risk level, reducing manual handling time by 60% and dramatically decreasing worker radiation exposure. Our approach leverages state-of-the-art imitation learning to create safe, adaptable automation for one of industry's most dangerous tasks.

Key Innovation: Learn from just 50-100 human demonstrations versus 10,000+ examples required for traditional machine learning approaches. The system generalizes effectively to previously unseen objects and provides interpretable decision-making processes critical for regulatory approval in nuclear environments.

🔧 How It Works

01

Teleoperate & Demonstrate

Human operator provides 78 demonstrations over 8 hours of data collection, showing proper handling procedures for contaminated materials across all risk categories

02

Train Policy Network

ACT Transformer architecture processes 31,200 frames through 30,000 training steps in 4 hours on AMD MI300X GPUs, learning visuomotor policies

03

Deploy Autonomously

Real-time edge inference at 25 Hz on AMD Ryzen AI processor with integrated safety-aware decision logic and automatic abort mechanisms

🎨 Simulation Design

Contamination Level Mapping:

Level	Real Standard	Our Marker
🟢 SAFE	<0.04 Bq/cm²	Green UV paint
🟡 LOW	0.04-0.4 Bq/cm²	Yellow UV paint
🔴 HIGH	>0.4 Bq/cm²	Red UV paint

Multi-Modal Sensing Architecture:

- **Vision:** UV-reactive fluorescent markers visible under specialized lighting conditions
- **Audio:** Synthetic Geiger counter feedback ranging from 1-2 clicks/second (safe) to 15+ clicks/second (high contamination)
- **Haptic:** Force-torque feedback for distance estimation and collision avoidance

📊 Key Results

Accuracy: 94.2%

Safe: 96.2%
Low: 93.5%
High: 92.8%

Safety: 100%

Zero High→Safe errors (catastrophic failure type)

ALARA principle compliant

Speed: 12.4s

Per object processing

vs 45s manual baseline

73% improvement

🛡️ Safety Innovations

- Hard distance constraints enforce 20cm ALARA compliance boundaries
- Contamination-aware error weighting in loss function prioritizes critical misclassifications
- Automatic abort protocols triggered on unexpected contact forces
- Human-in-the-loop review queue for low-confidence predictions below 85% threshold

🌍 Real-World Impact

Deployment Roadmap:

- **2026:** Laboratory validation with regulatory certification processes
- **2027:** Pilot programs at Sellafield Ltd (UK) and CEA Marcoule (France)
- **2028+:** Full-scale Fukushima Daiichi deployment phase

Projected Benefits Per Site:

- $50 million annual operational cost savings
- 60% reduction in cumulative worker radiation exposure
- 3× acceleration of decommissioning timelines

Industry Partnerships: Sellafield Ltd | CEA Marcoule | Orano

Technology Stack & Resources

Hardware Platform:

- SO-101 6-DOF robotic arm with precision gripper
- AMD Ryzen AI processor for edge inference
- AMD MI300X GPUs for policy training
- UV lighting system with specialized camera sensors

Software Framework:

- LeRobot Framework (open-source robotics)
- PyTorch deep learning backend
- ACT (Action Chunking Transformer) policy architecture

Dataset Specifications:

- 78 demonstration episodes
- 31,200 total training frames
- Multi-modal sensor streams
- Available on HuggingFace Hub

Training Performance:

- 30,000 optimization steps
- 4 hours training duration
- Batch size: 32 trajectories

Project Resources:

Dataset Access: HuggingFace public repository