Request for information

Robotics: Smart path planning and collision avoidance

Out-reach to all industries

Although this market exploration survey concerns smart path planning and collision avoidance specific to nuclearized robotic systems, the National Nuclear Laboratory (NNL) on behalf of Sellafield Ltd is looking for solutions from across all industries – both inside and outside our nuclear community. NNL believes that technology may already exist that has been developed for the nuclear industry, or for other industries that could offer solutions to one, or all the requirements described in this survey.

Responders to this survey do not require any prior knowledge of the nuclear sector.

Purpose of the Capability Survey

The objective of this package of work is to identify systems and solutions which are either available now or are in the latter stages of development (High Technology Readiness Level (TRL))[1].

NNL and Sellafield Ltd. would like to engage with suppliers who respond to the Capability Submission form via Expressions of Interest (EOI) in order to assess availability and functionality of the technology and begin to quantify potential benefits. This will then inform stages of the procurement activity and possible future active demonstration phases using the alpha or beta-gamma remote cutting facilities.

Intellectual Property Protection

All replies to this survey will be treated as Commercial-in-Confidence by the NNL or Sellafield Ltd. All intellectual property (IP) belonging to the responding company that is contained in a reply will be protected and will not be disclosed outside of NNL or Sellafield Ltd.

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[1] *https://www.gov.uk/government/news/guidance-on-technology-readiness-levels*

Cost range for development of capability and other considerations

This survey does not include any commitment for any procurement or contract action and service providers will not be reimbursed for their contribution to the survey or response via EOI. However, to inform future NNL and Sellafield Ltd. decision making (and the potential for a future competitive tender process), the Capability Survey requests a cost range for each proposed solution. The proposed solutions will be considered with regard to:

- assurance of safety when delivering solution(s)
- evidence for, and the likelihood that solution(s) can be delivered to meet the requirement
- time required to use the solution(s) to perform the process(es)
- inter-operability between sub-requirements (modular open architecture of solutions)
- cost of the solution(s)
- portability of the solution

Introduction and Background

Robotic systems for size reducing contaminated waste are soon to be actively demonstrated at the Sellafield site. These systems use a laser cutting head, mounted on a 6-axis industrial robot and are Operator supervised by a closed-circuit television (CCTV). Systems also include 6-axis industrial robots with either magnetic or vacuum lift end effectors to grasp and remove cut sections from the work area.

Currently, robots within the alpha and beta-gamma robotic Active Demonstrator size reduction facilities function by executing a series of pre-programmed routines initiated by a process operator. The cutting plan for each of these routines is programmed manually in advance, based on pre-existing measurements of the workpiece which rely on accurate pre-defined alignment of the robot and workpiece prior to initiation of the program.

Simultaneously, the process operator must ensure that the robot and its end effector do not collide with any other infrastructure in the operating space as the robots are sensory unaware of their surroundings. At present, a process operator is required to step the robots through the various sub-routines and oversee their operation via CCTV. They must also intervene by activating emergency stop if an unplanned event/ error (most probably a collision of some sort) occurs or is likely to occur. A system recovery from such an event will then be necessary which could involve one or more of the following:

- system down-time
- putting plant into a safe state
- manual recovery intervention into a contaminated area
- replacement of broken parts
- re-datum system
- system re-set
- a degree of re-programming

These processes are considered labour intensive and require bespoke programming for each object to be cut based on accurate measurements, which may be difficult to achieve due to the radioactivity of the workpiece. As a result, the aspiration is to integrate the solution to this survey to existing robotic systems currently operating without it.

What are the objects to be size reduced?

Objects are mostly metallic: Gloveboxes or Pond Storage Skips. They are manufactured from stainless steel or mild steel that may be have been coated or painted for in-service use. Objects may display corrosion and/ or variation in surface topography and protective coatings.

Non-metallic object may also be present. Although these objects will not be cut with the laser, an assembly may contain, for example, glass or Perspex windows. It is not expected that the laser is used to size reduce these materials at present, but any proposed system will need to acknowledge their presence in the environment. Other non-metallic objects that form part of the object will also need to be recognised by the system for cut path planning and collision avoidance requirements.

The Challenge

1. Smart Path Planning

This scope of work aims to source or develop an automatic system to remove the need to manually create a bespoke cutting plan for each unique object presented to the laser cutting robot. The system should be able to generate surface models (or similar) of the workpiece object and generate appropriate executable cut path plans that may be further refined by an operator (if required), to automatically profile/ laser cut objects. The operator should not require knowledge of robotic system programming.

Once presented to the cutting robot the system should automatically localise/ orientate the workpiece object to the defined origin to enable the cutting routine to be performed.

2. Collision Avoidance

This scope of work aims to source or develop an automatic real time system to prevent a collision occurring, to ensure the successful execution of the robot program. Through analysing the automated routine, the system should be able to identify emergent hazards in real time and automatically halt operations (laser cutting and robot movement) and prompt the operator for validation via a simple alert or message displayed on the user interface. The effect being to minimise/ eliminate equipment damage and resultant system recovery/

intervention operations following an unplanned event. As an example, an unforeseen event may include loss of structural integrity of the object during cutting, causing the object to deform or obstruct a cutting path or result in an unsuccessful cutting instruction.

The objective of this package of work is to identify systems which are either available now or are in the latter stages of development (mid to high TRL). It should be possible to retrofit the solution to existing robotic systems currently operating without it. A solution that can be implemented onto any robot (and controller) independent of manufacturer is DESIRABLE. Implementation onto a single existing system within 18 months is ESSENTIAL.

Benefits

The benefits of such an automatic system include:

- Removal of the requirement to manually acquire dimensional parameters of each object to be size reduced - which could be a dose reduction.
- Reduction / elimination of the off-line manual programming required to re-program the laser cutting robotic system to understand the geometry of each object, and the bespoke cut paths required to size reduce each object.
- Minimal specialist staff required to operate.
- Increases of the throughput of the size reduction facility through greater automation of the process.
- Elimination workpiece alignment errors.
- Minimisation/ elimination of system recoveries.
- Prevention of collisions and hence costly damage from occurring due to unforeseen circumstances during normal system operation.
- Reduction/ elimination of reliance on the system operator to recognise fault conditions.
- Minimisation of unplanned manual intervention requirements.

Scope of Work

1. <u>Smart Path Planning</u>

A system should scan the 3D geometry/ surface profile/ orientation of an object or workpiece in front of the laser cutting robot (this could be performed in or outside the cutting facility). The system should be able to generate surface models (or similar) of the object, generated by the system, which are translated into executable cut path plans that may be refined by an operator (if required).

From a Graphical User Interface (GUI), a process operator should be presented with a 3D surface (or similar) representation of that object and be able to: specify truncation parameters (by size/ shape, weight, material, radiation levels), observe these parameters/ cut paths overlaid on the 3D model, modify elements of the cut paths (by e.g. 'drag and drop') where necessary, specify the sequence of cutting, prescription of robot path, and initiate and control the operation sequence. The following steps are suggested:

1.1. Develop a system to automatically define the 3D surface geometry/ profile/ orientation of the workpiece object in front of the robot, and to automatically generate and recommend cut path options based on this data and pre-defined criteria (e.g. size reduced components optimized for size/ weight/ radiation level) for the process operator to choose from.

1.2. The process operator shall be able to specify or further refine the truncation parameters suggested by the system which are reported as overlays on a 3D GUI representation of the object.

1.3. The Operator shall be able to:

- Modify elements of cut paths (e.g. via 'drag and drop') on screen to optimise
- Define the cutting plan order/ sequence
- Initiate each cutting operation sequence

1.4. The system shall ensure that the resulting cutting plan is automatically translated into executable cutting paths for the robot to follow.

1.5. The system shall ensure the robotic solution does not cause the robot to clash with adjacent infrastructure in the cutting cell.

1.6. Provision to be able to remotely recover the system from unplanned events which may occur during execution of the operations without requiring an operator to enter the cell is required.

2. <u>Collision Avoidance</u>

2.1. Provide a system to automatically detect in real time if:

I. area(s) of the surface geometry of the workpiece differ enough to the pre-programmed executable path that if it were followed without intervention, the objective would not be met, or a collision would occur.

II. a collision will occur due to an unplanned occurrence during the execution of a defined robotic routine and pause the routine so that the collision is prevented.

The system shall alert the Operator, indicating the reason for the intervention, and the operator then has to decide upon a method of system recovery. Example scenarios are given below:

<u>Example a)</u> the proposed system detects a small, unplanned change in geometry of the workpiece due to residual stresses being relieved upon cutting it. The

dimensional change is sufficient that a collision of the tool head could occur on the next pass, but the change would not be obvious to the process operator until too late.

Example b) during a cutting operation the workpiece does not behave as expected and part of it falls off (so there is a change of geometry), or the object slips in the robot gripper so its orientation changes. The proposed system recognises this and computes that a collision would occur on the next operation, so it automatically pauses and alerts Operator.

2.2. Provide a system as in (2.1) above, but upon detection of a potential obstruction/ collision occurring (as in Example a), the system will dynamically adjust the tool path trajectory in real time to complete the previously-defined action to ensure that the objective is met and no collision actually occurs i.e. provide an intelligent path planning system with dynamic obstacle avoidance capability that considers dynamic real-time information from its environment. The system shall ensure that the resulting robotic solution does not cause the robot to clash with adjacent infrastructure through constant automated monitoring of changes in its surrounding environment. For example:

Example c) while cutting an object, one of the laser cuts slightly re-welds. When the robot grasps the item to move it, it twists in the grip as the tab shears. The cut item is no longer in the anticipated orientation and could foul the next operation if not spotted. The system spots this and automatically adjusts orientation of gripper to successfully execute function.

2.3. Provide a system as in (2.2) above which can automatically compensate/ dynamically adjust the intended routine to account for unplanned dynamic changes in the environment to ensure that the high-level objectives can be met.

It is ESSENTIAL that the solution fails-safe with as-low-as-reasonably possible (ALARP) danger to operators and the facility infrastructure.

How to submit a market exploration Capability Submission

Responses to this market exploration must be submitted to NNL Procurement via the EU Supply Tender Management Portal (https://sharedsystems.eu-supply.com/app/rfq), project reference 11898.

There are **three questions** relating to your capability, where we are seeking to understand what and how much further development is required for a complete solution to all requirements, or whether a combination of separate solutions is required. The information you provide will assist in developing a statement of requirements for potential future activities. You will not be held to deliver to any of the timescales or cost estimates that you may give.

Please submit your response addressing the following questions:

1. Summarise your innovation: (300 words maximum)
   a) Describe what you propose to deliver
   b) Why it is important?
   c) Why you’re well placed to deliver?
   d) Describe your areas of specialism

2. Detail your idea and how you plan to deliver it (can include diagrams or pictures and the reviewers should be able to read and understand the proposal within 1 hour)

3. Innovation Details:
   a) State the requirements you believe are met by your solution
   b) Outline if and what further development is required
   c) Provide an outline cost range estimate
   d) Can you demonstrate your technology now?
   e) What robotic systems is your solution aligned to and can the technology be transferred to a robot from another manufacturer?
   f) Is the response as part of a consortium or via a sole organisation?
   g) Indicate the Technology Readiness Level (TRL) you believe your solution is at

Although the innovation would ideally match the requirements prescribed by NNL and Sellafield Ltd. in this document, suitable alternative solutions are welcomed. Submissions must be submitted by midday on 29th February 2020.

Please only provide details of one product/capability per submission. If you have a number of potential solutions, then please submit multiple forms. If you have any questions, then please use the EU Supply Tender Management Portal, project reference 11898.

How we use your information

Information you provide to us in a Capability Submission, that is not already available to us from other sources, will be handled in-confidence. By submitting a Capability Submission Form you are giving us permission to keep and use the information for NNL and Sellafield Ltd. internal purposes only. NNL and Sellafield Ltd. will not use or disclose the information for any other purpose, without first requesting permission to do so.