Prospectus

The Lonely Robot: An Automated Robotic Word Search Solver

(Technical Report)

Smarter Trash Collection Methods

(STS Research Paper)

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Introduction

The technical report explores the relationship of computation and physical application of the resulting output.

In the STS research portion, we found proper municipal waste management a major part of the infrastructure challenges that need to be overcome. Inefficiencies in this part of the infrastructure can lead to serious waste in taxpayer dollars, compounding public health issues, unsightly public views, and environmental issues. A major part of our project revolves around creating a comprehensive smart waste disposal and management system for future smart cities. In direct relation to the blueprint, I'm investigating which individual technologies can be applied to make the trash collection process itself smarter, which is just a part of a complete waste disposal and management system. In creating the blueprint, we realized that smart disposal solutions that work well for other cities may not scale well when considering a local Charlottesville context, particularly in how community attitudes and norms may affect adoption of IoT technology. To that end, I'll also delve into case studies of different communities and how their attitudes affect adoption of IoT technologies.

Technical Report: The Lonely Robot: An Automated Robotic Word Search Solver

Word search puzzles are relatively simple games used to learn spelling, word association, or simply to pass the time. The Lonely Robot is a device that will automatically read and solve any given word search. The user will place a word search into the mechanism, and after extracting the data from the printed page, the system will computationally solve the puzzle. Then, using that solution, a highlighter will physically mark the solution onto the word search.

Software and Firmware

Upon initialization, an Nvidia Jetson will control a camera to snap a picture of the puzzle. A computer vision algorithm will then utilize the picture to deduce a word bank and matrix of characters representing the puzzle grid. The algorithm will then map the matrix coordinates to their two-dimensional location on the physical platform holding the word search. In addition, the angle of the diagonally spaced words will be inferred from the image. A separate solving algorithm will then be used to map words from the word bank to their location on the grid. Using the solution map, the Jetson will communicate to a control board microcontroller (a Texas Instruments MSP430) that will control a two-dimensional drawing mechanism to physically solve the puzzle with a highlighter. For each word in the solution map, the microcontroller, by command of the Jetson, will: (1) ensure that the highlighter is off the paper, (2) move highlighter to the start cell, (3) drop the highlighter, and (4) move the highlighter to the end cell. Figure 1 details the software and firmware flow.

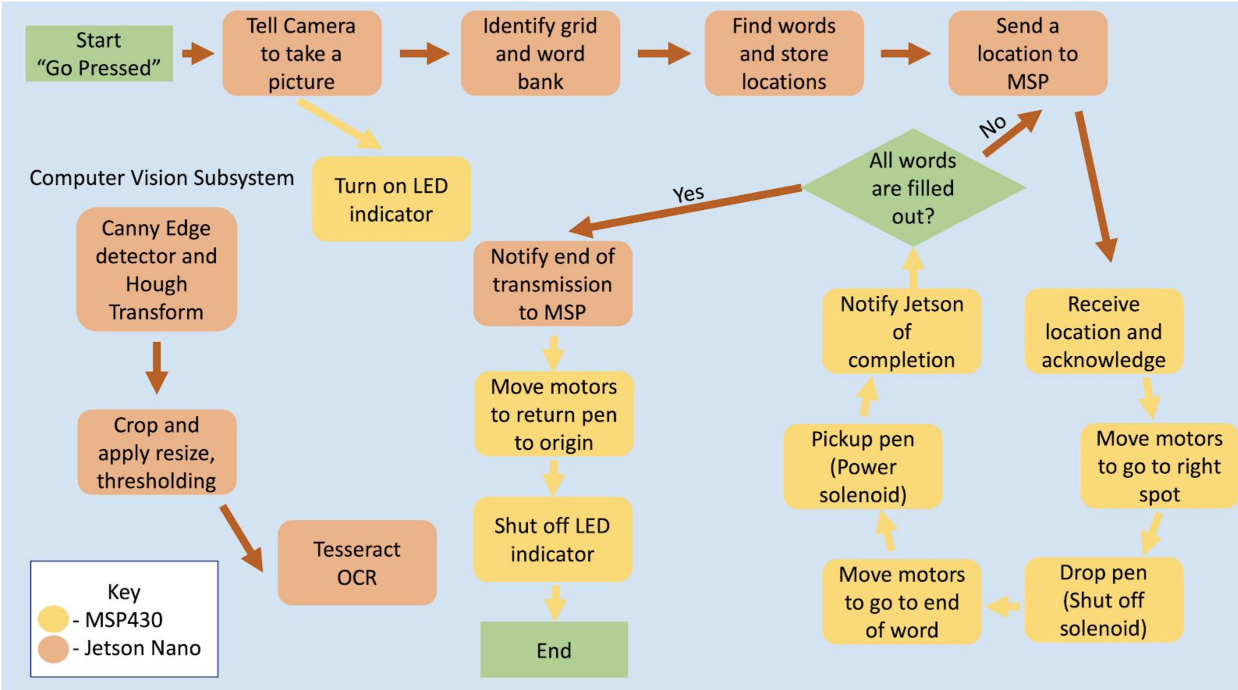

Figure 1. Software Flow Diagram

Electromechanical

The drawing mechanism ("XY Frame") will be driven by two stepper motors in charge of manipulating two timer belts. The system will be supported by a chassis made of aluminum rails configured in the shape of a rectangular prism. These rails will also serve as the adjustable mount for the camera. Each motor will power a timing belt for the axis and a beam will be connected to each belt. Together, the x and y beams carry the highlighter-holding mechanism ("highlighter holder") about the platform. To establish an origin point for the xy table, two limit switches will be used. Figure 2 details the base of the XY Frame.

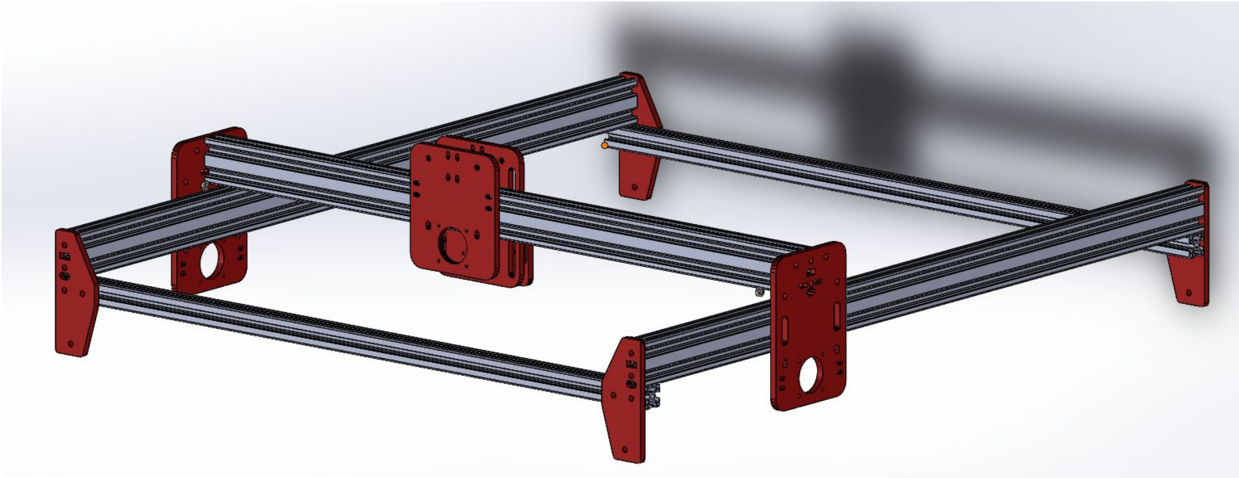

Figure 2. XY Frame Base

A function in the Jetson will be implemented that commands the microcontroller to control the drawing mechanism that moves the highlighter from the start cell of a word to its end cell. Each draw command from the Jetson will include the start coordinates of the word and the end coordinates of the word. From these two points, direction can also be deduced (positive/negative x direction, positive/negative y direction, or negatively/positively sloped diagonal direction). The direction of the word found by the function will signal which motor(s) will need to be used. This direction will also determine the spinning direction of the motor(s) involved.

The highlighter holder is in charge of keeping the highlighter from jostling in the grip of the beams, and to control when the highlighter physically draws on the puzzle. A push-pull solenoid will be attached to the highlighter, and be used to pull the highlighter off the paper. The microcontroller will control the power for the solenoid coil, which will induce a magnetic field in the opposite direction of the platform, lifting the highlighter. When it is time to draw on the paper, the microcontroller will kill the current in the solenoid, and the highlighter will fall to the paper. A conical catching mechanism ("catch") will be used to catch the highlighter. This catch will include a slit that only allows the non-chiseled tip of the highlighter to come in contact with the paper in a way that prevents excessive jostling of the highlighter.

Using this solution, a word search can be solved quickly and efficiently with a simple push of a button. The project has been given unlimited funding within reason. Soldering equipment, 3D printers, and the help of professional technicians at a local Charlottesville business are all at our disposal. Our technical project applies the power of current computing to solve a specific (somewhat inconsequential) problem. Yet, by solving this problem, we will create an adaptable framework that can be used to solve a range of much more impactful issues.

STS Thesis: Smarter Trash Collection Methods

In every human habitation, working solid waste disposal and management is an important factor in long term longevity and sustainability. Inefficiencies in trash collection generally lead to wasted time and energy, which can manifest in problems such as untimely trash collection, environmental damage and a decline in municipal well-being (Ferronato and Torretta, 2019). The local Charlottesville community in particular values environmental sustainability, with a focus on reuse, as evidenced by fixtures in public shared areas like IX Art Park - many of the sculptures there are created from scrap and waste material that would likely have ended up in a landfill, but instead have been transformed into something much more than the sum of their parts. We also see this codified in local policy, as evidenced by a local proclamation in 2003 for greater sustainability practices. The importance of a comprehensive waste solution management solution is evidenced by the fairly well documented procedures for the City of Charlottesville, in addition to an emphasis on encouraging sustainable practices ("A Green City", n.d). By aiming to minimize energy and time costs of waste disposal and management, we will not only work towards a greener planet, but also more efficiently use taxpayer dollars in the long term.

With the advent of miniaturized, always connected IoT devices, there exists an opportunity for these new technologies to be integrated into existing waste disposal and management systems in new and novel ways. The differentiating factor between previous systems and what is possible now boils down to the massive amount of data that can be collected and analyzed through a combination of widespread sensor endpoints and machine learning techniques. To that end, in what ways can we apply these new technologies to make waste disposal and management systems smarter and more efficient? In doing so, what are the socioeconomic effects and what kind of public policy changes need to happen in order to improve trash collection? And finally, how does the local context of Charlottesville change our answer to these questions? In particular, how do we balance between preserving local values and technological advancement while also dealing with technical challenges unique to smaller communities?

Literature Review

A recurring idea that pops up in literature is to, in some form or fashion, measure the fill level of trash collection bins (Hong, Park, Lee, Lee, Jeong, and Park, 2014; Tost, 2014). While the mechanism behind doing so can vary, in both implementation and efficacy, the basic idea remains the same - we can use this fill level data to determine what the most optimal collection routes would be. For example, collection bins could trend towards filling up at certain times of day, in higher traffic locations, on certain days of the week, or even seasonally. By continually receiving and analyzing this data, routes can be constantly adjusted to optimize for time, energy consumption, and local needs. These optimized routes can then be sent out to trash collection services through a mobile app or dedicated device (Hong et al., 2014). With this same sensor technology, we can even determine these trends on a granular, per waste type level. This would involve having separate bins for different types of waste, which is something that is already done in order to help with recycling sorting. With this data, we can identify high volume waste areas that are in need of more trash collection bins and simultaneously provide more targeted service to these areas. Research has shown that there is potential for these IoT solutions to be effective, given proper configuration towards local, environmental factors (Lundin, Ozkil, Schuldt-Jensen). Such technology has been commercialized by companies such as Bigbelly, Enevo, and Smartbin. For example, in their local study at the Technical University of Denmark, they noted that people tended to go towards closer, overfilled bins even if there was an unfilled one nearby. Social factors like this need to be taken into account;a more environmentally conscious community perhaps would act differently.

Stakeholders in a smarter trash collection system can generally be divided into three major groups: waste producers, private companies providing the technology implementation behind these IoT devices, and the government. Within the waste producers group, we're particularly interested in municipal waste producers, as they generate a significant portion of urban waste and have the most number of waste collection points to optimize for (in contrast to other types of waste which may have more specialized or centralized collection points). These municipal waste producers are essentially the citizens who live in these communities, and potentially the most vulnerable of the stakeholder groups. Policy-wise, there are serious considerations regarding the security, privacy, and ethics surrounding data collection at this level (Brynjolfsson, 2016). Ideally, the government should engage with the communities where IoT devices will be implemented, as an acceptable standard for data privacy and security needs to be negotiated between all affected parties. Without proper regulation, communities where these devices are placed are at a security risk ("Should the Government Regulate IoT Devices?", 2017).

Methods and Next Steps

Much needs to be done in terms of future work, especially regarding how the local context of Charlottesville changes things. In-depth talks on how receptive the community would be to these new technologies are needed. Unfortunately, just speaking with arbitrary citizens wouldn't be effective; we'd need to perform a wide reaching survey or work with the Rivanna Solid Waste Advisory Committee, which oversees solid waste management in Charlottesville. Lundin, et al., makes notice of social behaviors that may be prohibitive towards a well working municipal waste solution. A cost analysis of implementing smart bins is necessary to determine if the initial investment is worthwhile to make. In some cases, it might not be worth it in the long run to make trash collection smart, likely the case of extremely low trash output areas. After a careful analysis, we could then decide whether or not it would be an effective choice.

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