The Arrival of Omnidirectional 3D Printing

"Additive Outside the Box"

&

What it means for the growing 3D printing community

Petricor
FUTURE OF CONSTRUCTION

v.1

This document describes Petricor's view on omnidirectional 3D printing for micro to macro size applications, how the community benefits from this advance and how they can get involved with it.

Overview

Executive Summary

Petricor's Open House technology is an autonomous robotic device that is capable of building structures based off architectural designs. The proposed technology will create buildings through the use of additive manufacturing with novel materials for construction.

In 2018, there will be 1.6 billion people without adequate housing and the average cost of building a home in the United States is approximately $300,000. We feel that we can help reduce both of these numbers in the future with our Open House OmniPrinter. Petricor wants to create a 3D printing army by selling the Open House printers to individuals and businesses who will help by printing homes for those who are without adequate housing, research for using onsite sourced and recycled materials is underway. By using materials that are sourced locally, the cost of housing can be lessened by as much as 90 to 95%, making housing much more affordable for everyone.

The current construction industry has a lot of overhead. The intensive need for human resources makes this industry troublesome and cumbersome because human time is the most expensive resource we can tap into. Others have tried to automate the construction process with some success and using 3D printing as an aid has shown remarkable promise. However, it has been known that simply enlarging the design of a 3D printer is not feasible because moving the machine onsite will be unwieldy. Current technologies create the walls and then transport them to the construction site to be assembled, which is also not cost effective and still requires a lot of human labor and heavy equipment.

While this project could have implications that reach farther than the field of 3D printing for construction, Petricor is beginning by researching and developing the field of additive manufacturing. Petricor envisions that this is where they can make the biggest positive societal impact and that this lends to the most collaboration opportunities with the current community.

The OmniDidact version of Open House is an Open Source 3D printer, that can be built with materials and parts that are readily available in most parts of the world.

The Open Source approach is to incentivize the community to begin adopting these new methodologies and to begin printing outside the box. Allowing for a faster development of this technology and to expand its case uses to unforeseen avenues.

The ability to print large objects without size restriction it is a most appealing characteristic and is widened by the plethora of currently available materials which can be used to 3D print objects that were not possible before due to the inherent limitations of the 3D printers adopted by the market to this date.

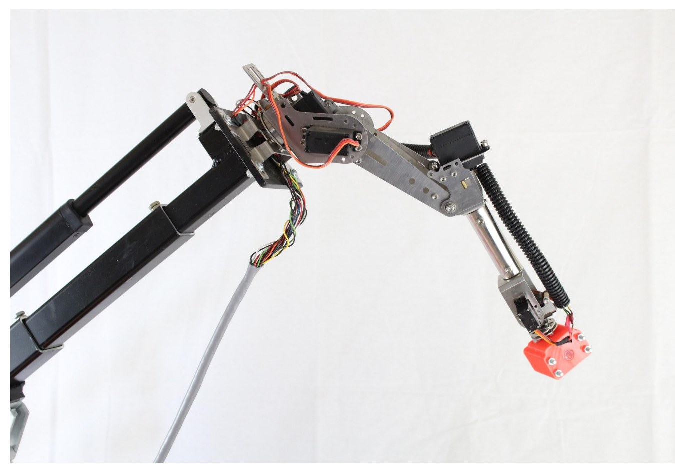
The goal of Open House is to eventually decrease the cost of building a home by at least 90% and the construction time by weeks or even days.

The Gantry dilemma

Additive manufacturing is typically performed by attaching one or more extruders to a three degree of freedom gantry system that either moves the extruder or the platform where the object is being created. The entire system is typically housed in a frame that dictates the maximum size of the object created. However, the proposed Open House technology concept is significantly different than the typical additive manufacturing process.

After the initial methodology has been established and adopted within the community, the planned future versions proposed will expand to many unforeseen and even unintended use-cases, this is due to the nature of the flexible hardware setup which differs in three ways from conventional 3D printing technology.

First, the extruder is attached to a six degree of freedom robotic arm that will allow optimization of the printing tool path, as well as providing flexibility in the interchangeability of the tools or end-effectors being wielded by the robot, which would define the capabilities of such configuration. [FIG.1].



[FIG.1]

Second, the robotic arm is attached to a telescoping lift that regulates the vertical and horizontal extension. Allowing for wider parts to be printed in a single pass, and to provide the vertical lift when needed.

Third, the lift is then attached to an omnidirectional mobile platform capable of changing directions in an instant, retaining the main functionality and manufacturing capabilities of a 3D printer. [FIG.2].

[FIG.2]

Introducing the Omnididact

The initial proposed working prototype is a simplified machine which purpose initially, is to create basic geometries to begin testing material recipe properties in lab environments while using different 3D printing logistics and employing conventional methodologies. The Omnididact **[FIG.3]** consists of an octagonal omnidirectional mobile platform with a mechanical paste extruder attachment, retaining the option to install conventional extruders for a variety of different materials, it boasts a z-axis max reach of 12” and a maximum part radius with solid infill of ~24”

This platform is designed with some limitations since making it accessible is Important due to the possible entrepreneurial use that the community can benefit from, this will enable more users with the resources needed to learn the technology and commit to use it for business and manufacturing purposes.

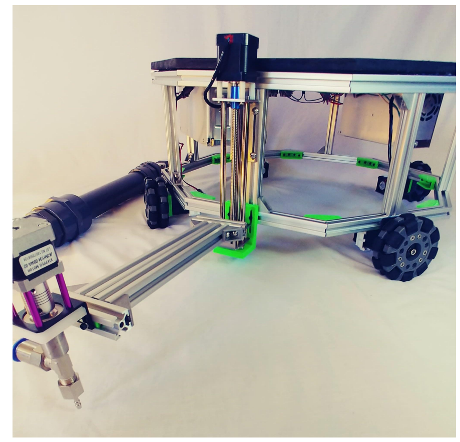


FIG.3

While several companies are currently working on the additive manufacturing of concrete, Petricor is also researching other avenues. They know that innovation doesn’t have to be a new product, that they can improve on something that is currently available. To do that they need to establish baseline performance data to assess how currently available materials will perform and how cost-effective they will be.

This research is important because if successful, the transformative impact would lead to novel 3D printing techniques and ultra-rapid construction times.

The goal of this effort is to begin introducing these new paradigms to the current additive manufacturing community as an affordable piece of equipment that is modular and that can be repurposed or upgraded. Tapping into the community’s resources and ideas is vital to accelerate the Open House adoption and increase its technological reach, plus the investigation of robot swarm techniques for collaborative 3D printing is an exciting emergent field eager to be explored.

Test software environment is currently being developed with the Robot Operating System (ROS) a robust Open Source platform for robot control. The sensor feedback is being obtained via Android cellphone built for Virtual Reality and Augmented Reality (VR/AR). Petricor is cleverly repurposing these common devices as the sole sensing device capable of tracking the motion of the machine, ensuring a standard quality assurance for a fraction of the cost while doubling as a personal phone for developers transitioning into this approach. The purpose of using these devices instead of dedicated sensor bundles is to grant an ease of replication for early adopters, but Petricor is pushing the envelope by integrating their own sensors to achieve greater accuracies.

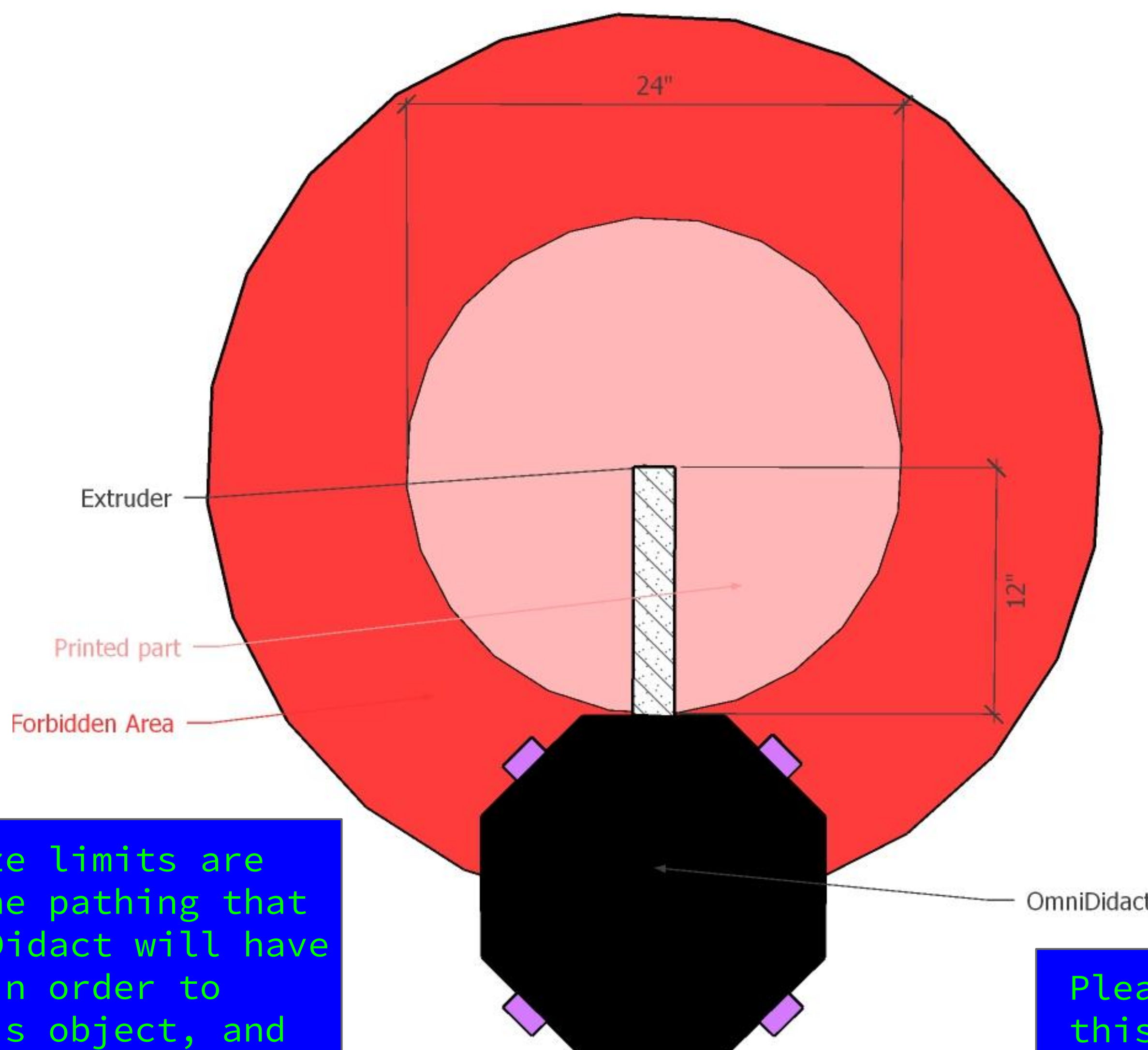
The materials currently being investigated for this use case are: Clays, cements, pastes, resins, polymers and recycled materials, such as cardboard, metal, glass, paper, plastic and biological materials like bacteria, plants or fungus. A secondary task is to further develop these materials and create standard recipes that can be used with this technology for different purposes and for the different climates of the world.

How omnidirectional printing works

Thanks to the omnidirectional wheels, the OmniPrinter can move in any direction at any moment, retaining the capabilities and functionality of a conventional Fused Deposition Modeling (FDM) 3D printer.

The OmniDidact isn't perfect however, it comes with some limitations that vary with the desired object to be printed, although most of these limitations are logistical in nature, they can be further analyzed in the following segments:

1. Solid Infill Objects

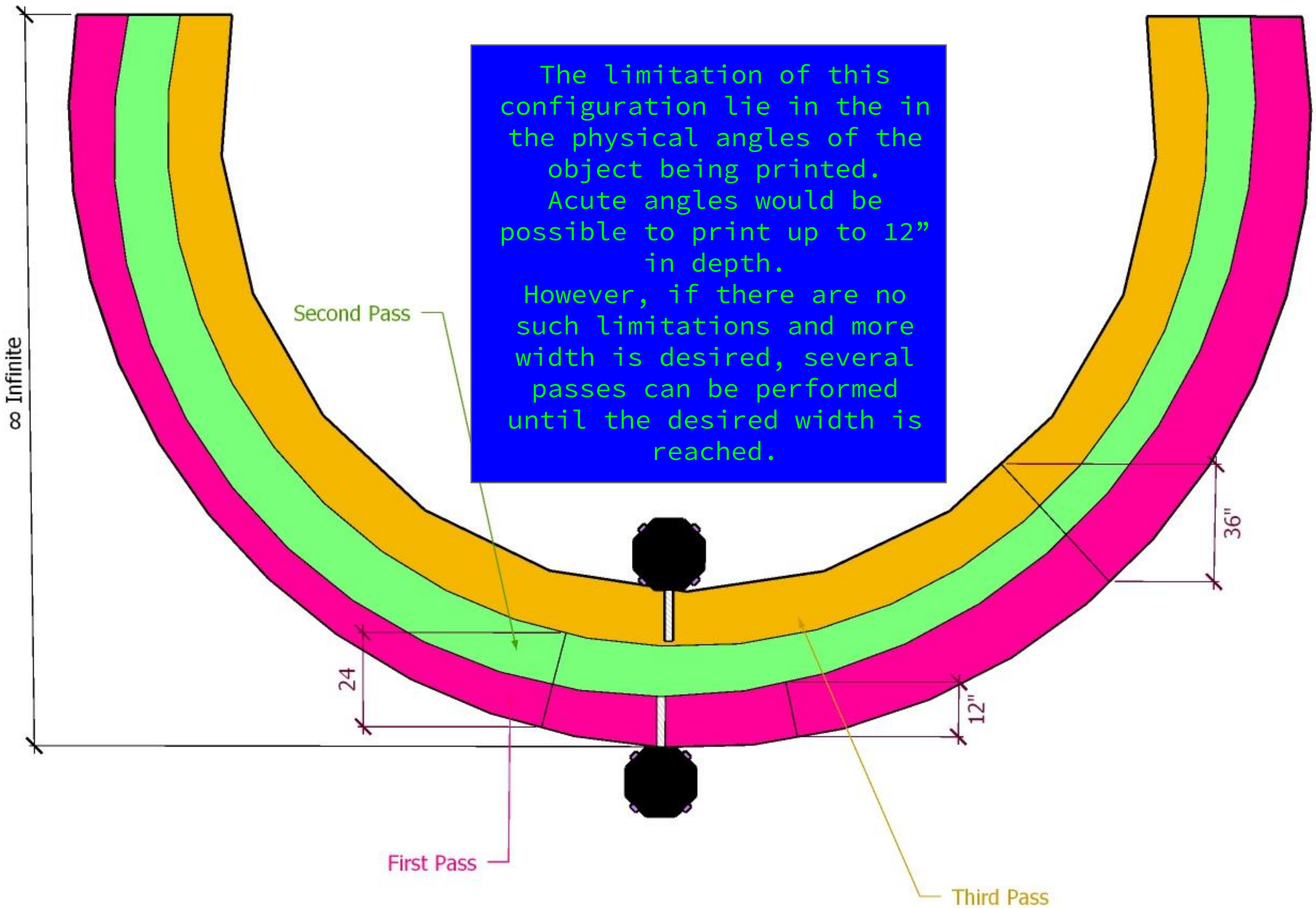


These size limits are due to the pathing that the OmniDidact will have to take in order to build this object, and mechanical collisions would prevent a larger solid circle to be printed at once.

Please note that this particular limitation can be rendered negligible as the print area can be further expanded by 12" every pass, as shown in the next segments.

2.Logistical Arrangement

Willfully Obtuse



The limitation of this configuration lie in the in the physical angles of the object being printed.
Acute angles would be possible to print up to 12" in depth.
However, if there are no such limitations and more width is desired, several passes can be performed until the desired width is reached.

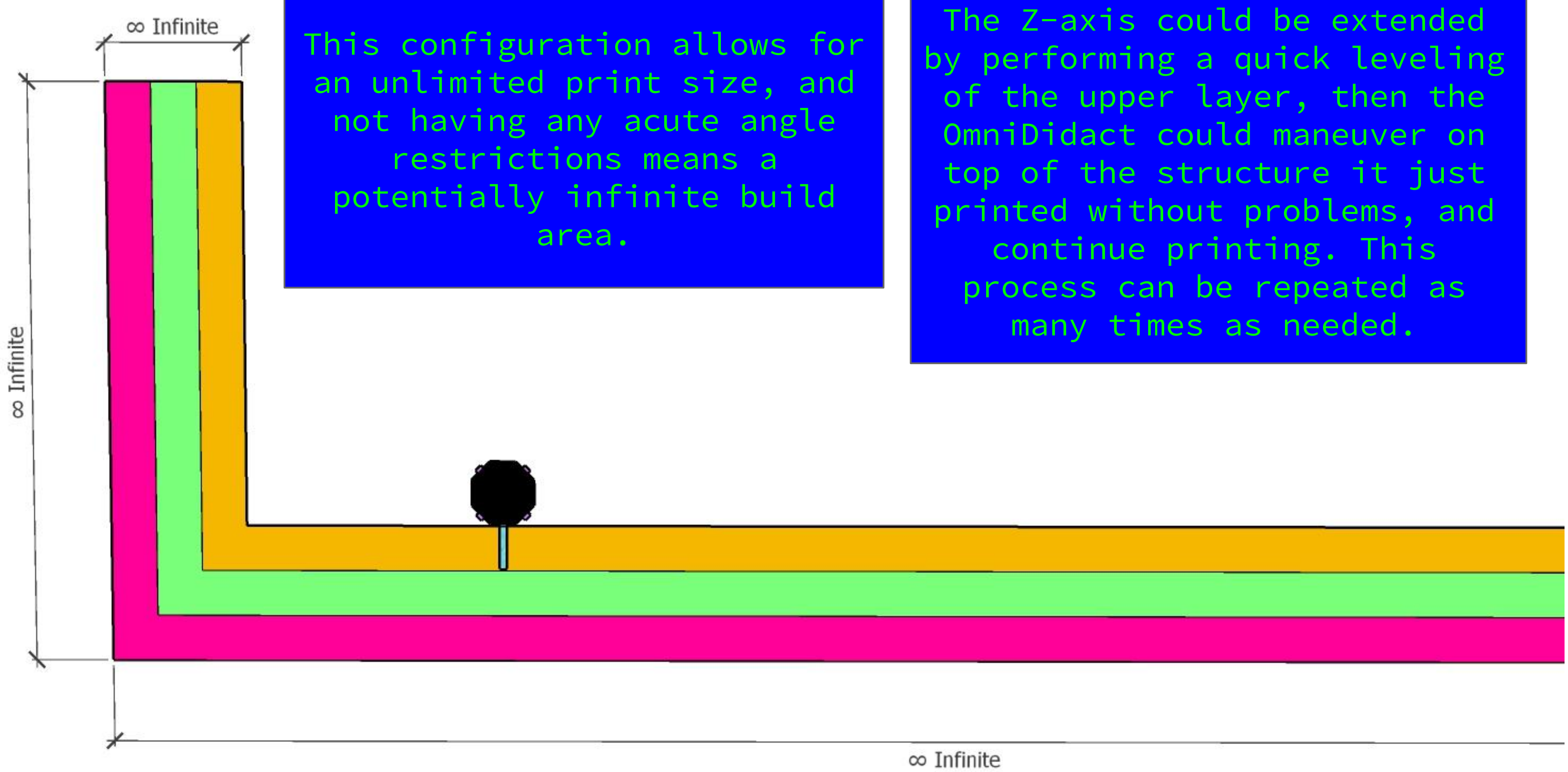
Each pass is 12" wide and tall, allowing unlimited expansion by applying several passes to the object being printed.

3.Ideal Use Case Scenario for Large Objects

Infinite range of X & Y axis + Width

This configuration allows for an unlimited print size, and not having any acute angle restrictions means a potentially infinite build area.

The Z-axis could be extended by performing a quick leveling of the upper layer, then the OmniDidact could maneuver on top of the structure it just printed without problems, and continue printing. This process can be repeated as many times as needed.



The only manual process involved in this scenario is the leveling of the upper layer, so the OmniDidact has no issues continuing printing. In some situations the OmniDidact could also print its own ramps to climb the print on its own.

Note: Future planned versions solve for this problem by increasing the vertical and horizontal reach of the extruder.

Technical Objectives

Technical Objectives to be Accomplished & some plans for next future versions

-Robotic arm implementation

The next generation of the OmniPrinter includes the use of an industrial robotic arm. This will empower the OmniPrinter to perform more than 3D printing, enabling the Open House OmniPrinter with a robot arm will turn this advance into a multi-functional tool. In the context of building a house, the robotic arm is used for post-processing. Once the walls are printed, the end effector can be interchanged to facilitate the automation of other tasks besides 3D printing, and the following efforts would be focused around developing the array of end effectors to endow the buildout of a house from the ground up, and with minimal human intervention.

-Machine Learning Design

Developing hardcoded software to execute these aforementioned tasks would be a daunting task. Every time a new end effector is developed, new software would also have to be established. In order to minimize these efforts and to minimize test and calibration times, a Machine Learning improvement is needed.

-Combine sensor arrays to achieve fine movements and quality assurance

In order to achieve the highest possible reliability for quality assurance, the OmniPrinters will be equipped with positioning sensor arrays to orchestrate the prescribed tool paths with the required accuracy.

-Use machine vision to create a persistent map for positioning, task performance, field and depth perception

To further increase the level of accuracy and quality assurance, a machine vision system is employed to create persistent maps for navigation and task tracking. As well as using the system for error detection, error correction, obstacle avoidance.

-All-Terrain Drives

The current proposed omnidirectional wheels have some disadvantages over other alternatives, due to the nature of this proposed case-use the stability of the platform is paramount. The current solution can present some vibration at high speeds, which is transferred from the wheels and amplified at the extruder. The wheels have roller bearings **[FIG.2]**that allow for the omnidirectional motion, once each roller makes contact with the ground this vibratory force causes unwanted movement at the extruder while it is moving, potentially causing small aberrations. A few observed approaches to solve this issue are to: redesign the drive system to absorb most of this vibration, to add or to change the wheel-type entirely to a different type of omnidirectional drive, to isolate the extruder from the platform completely by gyroscopic stabilization or to use a special surface material that will absorb this vibration. Future plans for more robust systems include the use of all terrain type of omnidirectional drives and a combination of stabilization approaches to achieve adequate working tolerances.

-Z axis lift extension

One envisioned idea is to add an extendable telescopic lift, capable of holding one or more robotic arms and their tools, away from the base platform, the goal is to obtain a larger reach. Which will solve some of the limitations posed by the initial prototype design, but also increases the challenges, one of them is the one of stabilization. As the weight of the arm is extended away from the platform, any vibration added to the system is multiplied in function of how much the load is extended away from the center of gravity to make this a viable solution more research is needed and, there are however, other alternatives which remain to be tested at the time of this writing.

-Material development

This technological approach enables an incredible expansion of material development & integration for different case uses yet to be explored. The saying goes: “If we can build a single machine that can make a house, we can make it do more”. The goal is to explore the possibilities in the micro-macro scale manufacturing with different materials and environments. I.e. Vacuum or gas chamber, how these environments can be utilized to catalyze chemical and electrical reactions in the printing process. For example: enabling the research for the multi-material manufacturing of elements that are unsafe for humans to labor with, creating chemical reactions to yield safe novel components, ionic or electromagnetic radiation,or to even utilize controlled electrical reactions for nano patterning and so on.
-The next space-age material will be manufactured under very controlled conditions undergoing complex chemical processes, and enabled by digital manufacturing.