Design and Use of Portable 3D Printers for Emergencies

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Abstract. In emergency response, the ability to adapt rapidly is the key to mitigating the impact of disasters and saving lives. 3D printers have emerged as a groundbreaking technology that is revolutionizing emergency preparedness and relief efforts. In this paper, the focus is on how the 3D printing technology can be adjusted and used in actual rescue environments. Research and exploration are done in the fields of emergency situations and 3D printer technology. In addition to the literature research, primary data for real case situations are gathered from interviewing the Hellenic Rescue Team and a portable 3D printer system is designed based on their needs to service the main fields of action. The design concept takes into consideration not only the possible objects to be 3D printed, but all the processes to practically include this portable 3D printing system in the rescue team's operations.

Keywords: 3D printing, emergency, design, crisis

1.Introduction

The first known use of the term emergency was circa 1631, according to the Merriam-webster Dictionary, with the definition of it being: "an unforeseen combination of circumstances or the resulting state that calls for immediate action". To deal with crisis like medical emergencies, natural or human disasters or acts of violence, adaptability, customization and fast response are the basic characteristics any provided solution should include. People can never be fully prepared for what is needed in terms of equipment, tools or other fixing or supporting objects. Additive manufacturing or 3D printing, a rapidly growing technology based on these characteristics, is able to create all kinds of objects with a solid material, complex geometries and less connection points, saving material and time comparing to traditional manufacturing.

Hence, it has already started to act like a tool in emergencies, providing practical solutions on-site to produce supplies in demand in multiple situations. The main reasons for this are: the fast production on demand, customization in products like in medical surgical operations where doctors create personalized organ samples (Whelan, 2023), remote production on site-important in unreachable areas like in Nepal after the earthquake in 2015 where the area was unreachable for supplies, and they created small spare and medical parts in the rescue area (Medling,2018) and cost-effective production. Other applications of 3D printing in emergencies includes the production prosthetic parts for underdeveloped countries in very low prices (Choi,2021), medical situations like the COVID-19 where many medical items where printed due to lack of time for traditional ways (Warkiani et al., 2021) and spare or replacement parts in damaged hard to reach areas (Owen,2019). Despite all the advantages and benefits gained from 3D printing used in emergencies, challenges that the newly developed technology needs to face, are there too. Such as the lack of quality control, which according to Minshall can affect the safety and quality that are crucial to avoid more harmful situations (Minshall,2016), material limitations, printing time, training, cost equipment portability and in some cases even property protection.

3D printing as a technology has started to being used as an experimental way of dealing with crisis situations, exploring its possibilities in providing humanitarian aid. The current work focuses on building an organized working 3D printing system, that rescue teams can count on using on field with specifications based on each rescue field's qualifications.

2. Why and how 3D printing can be used in emergencies

During the Covid-19 pandemic, we saw how using 3d printing technology was helpful as the industrial production companies couldn't keep up with the fast consumption of medical consumables. The way the consumable parts were 3d-printed and distributed to the hospitals in need, felt that an upcoming technology like that can be widely used in such meaningful ways, other than monetarily profiting. In emergencies that happen in different and unpredicted types of environments every time, such as rescue operations in remote or hazardous location, equipment can't be easily transferred. Most importantly ii isn't possible to predict the required equipment or materials with the specific needed characteristics and carry them wherever needs with no granted access. Here the 3D printing technology excels among others because of the ability to print on demand. Combining that with the feature of portability the rescue teams can gain access to many equipment parts with only carrying one toolkit for many uses and departments, minimizing the carried equipment and time for planning and setting up.

3. Methodology

Designing for emergency situations requires understanding them. Hence, the work started from research in literature and online in the fields of emergencies and how the emerging 3D printing technology is involved in them. Second and essential step is gathering raw data, straight from interviews of people with experience in rescue missions. The first interview reviewed as a case study was from the Born to Design – SOLIDWORKS podcast from Dara Dotz, a pioneer in 3D printing in austere environments who started 3D printing as a way of addressing immediate needs two years after the Haiti earthquake and has had a lot of experience since then (Medling,2018). The second interview is a semi-structured live one, with Miltiades Meliadis (Special HRT Secretary & volunteer 12 years in the Water Search and Rescue), Zafiris Trompakas (Training Manager & volunteer 43 years in the Mountain Search and Rescue), Athanasios Moutsiopoulos (IT& European Programs & volunteer for 20 years) experienced members of the Hellenic Rescue Team that gave the main guidelines for the 3D printer system specifications. Data gathered and analyzed from the main interview about objects that are mostly in need and possible to 3D print for each HRT's field of action shown in Table 1. Highlighted importance during the interview is given in the Urban Search & Rescue department for immediate on-site production of unexpected amounts of durable sub-column parts in need for ruin support while carrying humans, in the Water Search and Rescue for flexible patches for inflatable boats damages between the missions and in the Mountain Search and Rescue for climbing equipment replacements during missions in refugee bases. Challenges and problems with potential solutions if using a 3D printing system in their missions can be seen in Table 2. After extracting the data for basic object to be print and the 3D printer needs and challenges from all sources, they are combined giving the 3D printer's specifications, as showcased in Table 3. Interpretation of needs and requirements into solutions and choice of 3D printer type through benchmarking lead to the concept generation. The basis for the design of a Portable 3D Printer System for Emergencies, was to design both for the situations it will be needed and the parts in should produce on each field but at the same time, design it to fit the needs of the user, the Hellenic Rescue Team, a non-governmental organization, whose members participate in Search and Rescue missions in Greece and abroad through the Team's branches on a voluntary basis since 1994.

Table 1. Objects/ Parts to be 3D printed for each department according to needs

	1.	2.	3.	4.	5.
-	**Mountain Search and Rescue**	**Water Search and Rescue**	**Urban Search and Rescue**	**First Aid**	**Research and Technology**
A	Shovel with attachment for piolet	Patches for inflatable boat balloons	Sub-columns for ruin support	Human body proplasm	Drone model or parts
B	Rope pulleys	-	Pipe/Cable replacement parts	Organs proplasm	Transponders vaulted coverings
C	Rock climbing piton	-	Thermal camera extension	Bones problems	Box handles & lids
D	Climbing nuts	-	Whistle	-	Protective cases
E	Torch of parts of torches	-	Helmets	-	Tools: screwdrivers, wrenches

Table 2. Challenges and problem solutions within HRT potential

Challenge/Problem	HRT Solution
Power Supply	Bringing power generator in all missions In refugee and bases solar panels Power inverter devices existing
Portability with safety	Strong & durable waterproof protective cases
Dust full or humid environments	Protection of the printing area
Low or high temperatures	Device and printing area insulation
No internet or cloud connection	Offline standard database for print with no connection or laptop
No quality testing available on site	Predesigning, Preplanning for testing
Different devices available, brands or types	Connectivity with all kinds of devices
No time for design on spot	Predesigning, Preplanning, connecting on cloud /offline database
No user training	Preplanning: training, friendly user interface
Need to work with many foreigners	Friendly user interface with not difficult words

Table 3. 3D printer's specifications

3D printer's specs
Portability
Strong protective waterproof cases for transfer
Size that fits in helicopters, SUVs cars
Weight carriable by vehicles or 1 or 2 individuals (not more than a person's weight)
Everything needs to be printed fast due to emergencies
Cost-effective with recycling material ability after single use or part break or failing
Connectivity with internet & offline printing
Autonomous printing for enough time until re-supply
Easy use from everybody available

4. Design-final product

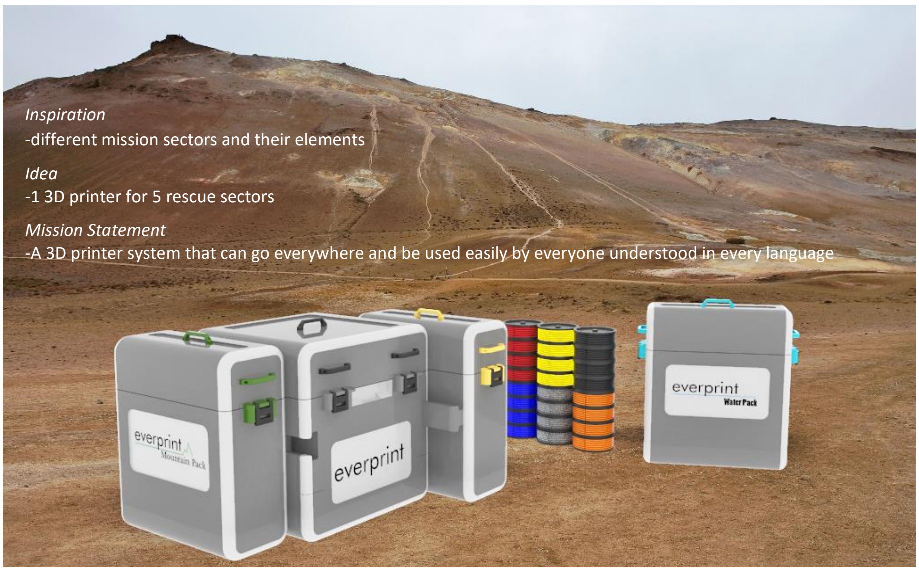


Figure 1. The full 3D printer system "everprint"

The design aim is creating a 3D printing system to be used in rescue missions. It is called a system because it consists of the physical parts, but also of the plan on how to fit it into the rescue team's operations and an online/offline database with pre-tested models ready to print that can be seen in Figure 1.

Figure 2. Main pack & 3 packs according to each sector

The main physical parts are a. the main unit, being a hard case pack with handles, containing a 3D printer, a toolkit and free space for a laptop and connectivity devices, and b. urban, mountain & water pack units containing material filaments according to the mostly needed parts for every sector for easy categorization. The main unit case has 2 horizontal insets on the right and left sides for the side parts to slide into and connect together for easier carrying by 2 people, Figure 4 and a shallower inset on the cap for placing the 3d printer and using the unit as a desktop creating a workspace for every environment seen in Figure 2.

The 3D printer to be used needs to be a Fused Filament Fabrication (FFF) technology model, fulfilling all the specifications shown in Table 3. Since the mechanical design of the printer is outside the scope of this paper, an existing model fitting the qualifications is used with. 495 x 585 x 520mm dimensions, 20,6 kg weight with protected printed area and build size 330 x 240 x 300mm, Wi-Fi, Ethernet & USB connectivity, supporting all OS systems and multiple file types like STL, OBJ, X3D, 3MF, BMP, GIF, JPG, PNG and compatible with a wide range of materials including strong plastics, nylon, carbon fiber for tough use and TPUs for flexible parts.

Organizing and preplanning is a vital need to be ready to act in emergencies. The identity of the system is created with the name ''everprint'' and simple indications of color and graphics are designed for each department to be easily understood internationally. Separation of material packs with materials mostly needed in each sector are prepared with the according signs and handle colors for easy separation. Green for the mountain pack with more strong plastics and carbon fiber material, blue for the water pack with big flexible TPU amounts and yellow for the general disasters with multiple materials but mostly carbon fiber for durable parts, Figure 3. Designing for realistic use, and given the money insecurity the HRT faces, the main 3D printer unit is proposed for training causes, research and testing in the team's headquarters, where the First Aid & Research and Technology operations take place and create tested models to fill the database. The unit is fully packed with its transfer case and full material stock for each department, ready for whenever an emergency occurs. The aim is to start like this with the customizable 3D printer set parts prepared for every occasion and once it starts working as a trustworthy method of dealing with emergencies place main units in the team's bases like the mountain refugee to assist each areas needs but also for faster delivery of produced parts on the field. The main and side unit case parts are made from strong durable plastic for protection of the 3D printer and are designed so that they can be carries from one or two people, fitting into SUVs and helicopters for delivery on the field of action. Each side pack provides enough capacity for continues printing when in rescue, until the refilling of the pack, with 24pcs filament capacity each.

everprint
Mountain Pack

Mountain Search and Rescue

everprint
Water Pack

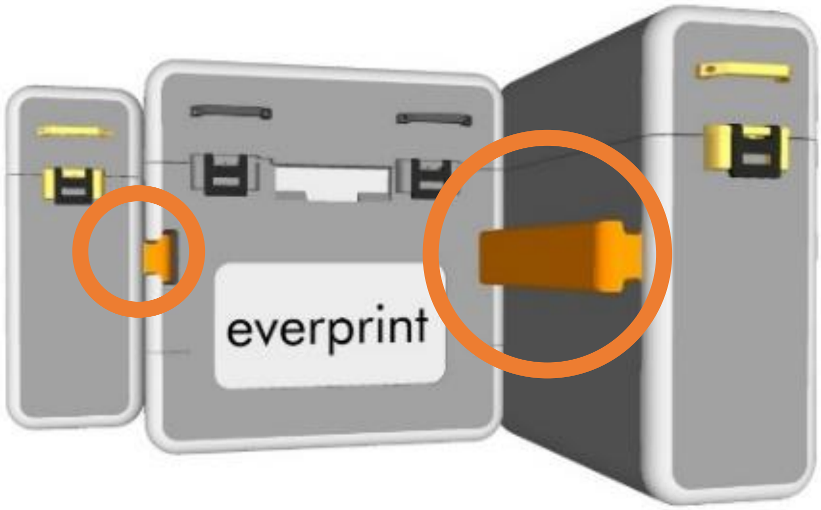
Water Search and Rescue

everprint
CRISIS PACK

Urban Search and Rescue

Figure 3. Mountain, Water & Urban rescue packs identity design

The online and offline database is built for the everprint system to include all tested and prepared to print models categorized by missions' field of action. The interface is designed having in mind to be user friendly, easy to explain what and where for easy decisions during emergencies. Images and color separations are used instead of words for minimizing international communications. Word indications are kept the minimum possible amount to assist and not steal observing or questioning time, Figure 5.
Possible future additions to the portable 3D printer system to adapt to even more circumstances can be an extra nozzle to 3D print also metallic objects, additional battery kit and an online featured collection of tested models with their material specifications to be sold and bring the organization some income back for supporting the operations. A groundbreaking addition would be the ability to swift the geometry of the pre-tested models and based on their evaluation predict their new qualifications the new model will have so no time is lost in failed trials on field use.



Main unit (690 x 690 x 720 mm)

3D printer:	20.6 kg
Transfer Case & tools:	10 kg max
Total:	30kg

Side part units

Full material load:	18-24kg
Transfer Case & tools:	5 kg max
Total:	23 – 29 kg

Main unit + one side part: 53 - 59 kg
Main unit + two side parts: 76 – 82 kg

Side unit (690 x 340 x 720 mm)
Maximum Diameter 203mm
Maximum height 70mm

Weight minimum 750g
Weight maximum 1000g

Figure 4. Connection parts detail& specifications

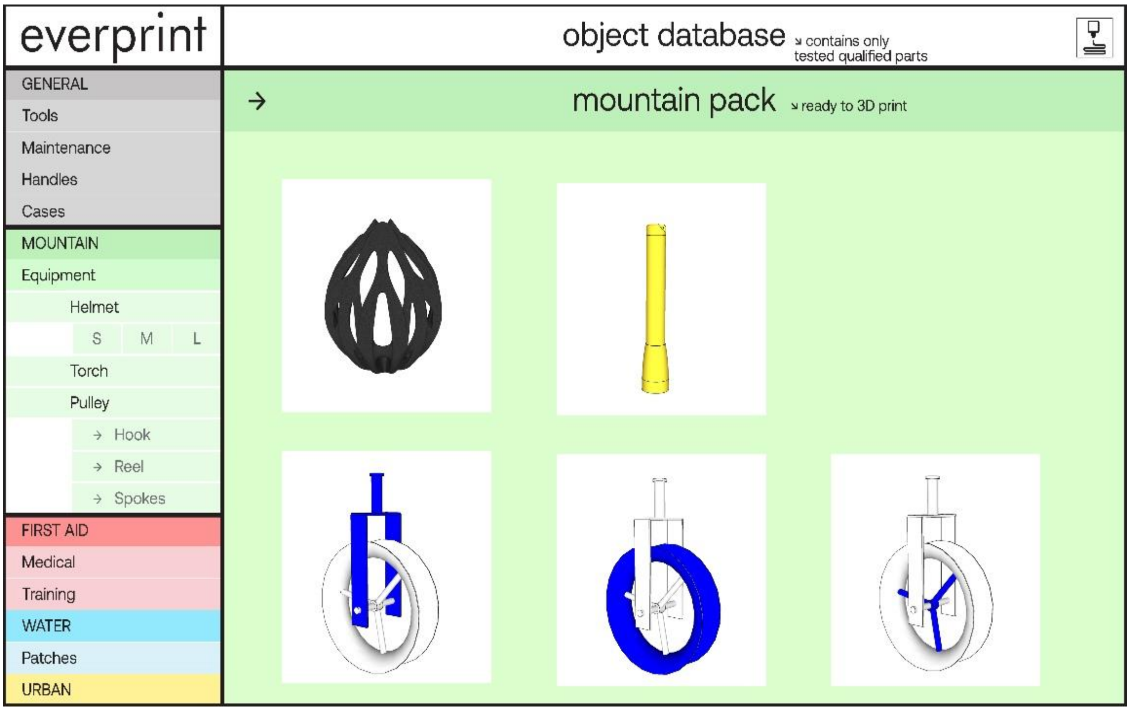


Figure 5. Application/database user Interface

5. Conclusions

The emergence and integration of portable 3D printers into the sector of emergency response mark a transformative leap forward in our ability to adapt and innovate in times of humanitarian crisis. Aiming to adapt a portable 3D printer into a rescue team's operations to deal better and faster with unpredictable situations, a holistic system concept was planned, designed and presented taking into consideration the most important reasons to do it as long as the challenges it faces. This technology has the potential to bridge the gap between limited resources and immediate demands, offering better solutions to those affected by disasters but needs good pre-planning, organizing, testing and evaluating before missions to make the most effective use when in need. In circumstances that unpredictable as in crises, a toolkit like that which can provide the adjustment to print in place whatever is needed can be liberating as it provides immediate and customizable coverage of multiple needs. Even though this technology is still under development the help it can provide in emergencies is worth the effort because the possibilities are endless for 3d printing to evolve and assist humanitarian aid. There is willingness to do it and so much potential to aiming the multiple needs required very frequently n almost all kinds of emergencies, and It is a promising way to make all these happen so any possible means of supporting the portable 3D printer and the organizing system to be used crisis situations is needed as soon as possible.

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