Graduation Topic Ideas

Graduation Studio Extraterrestrial Architecture MSc 3 | Maria Dumitrache

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Topics in Robotics for Disaster Relief

INTERVENTION CLEANUP + CONSTRUCTION OF SHELTERS

- workflow for operating robots remotely
- intervention > lidar scanning/photographs
    - Drones can take a series of photos > generate orthomozaics.
    - Point cloud scanning
- debris collection grippers > separation of materials and producing primary matter for 3d printing mix
- Optimization algorithms + ML ANN for determining correct ratios between materials
- Set premade plans for diff types of debris (timber/ metal - steel+ aluminum - / plastics/ concrete/stone, etc.)
- Creation of mix
- Printing /assembly of shelters/ new buildings from debris based primary matter
- Design of the shelter and execution human - robot collab

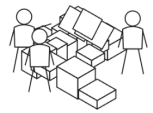
Potential for development:

- ML for determining mix ratio based on debris material properties and on-site environmental factors.
- Human-robot collaboration for assembly process

Current versus proposed approach

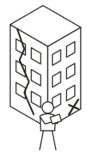
A - CURRENT APPROACH

Excavators, trucks and manual labour. Linear: debris leaves the site, shelter arrives from outside.



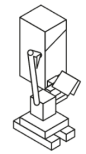
01 Search & rescue

Rescue teams search the rubble by hand; drones map the site from above.



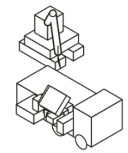
02 Damage assessment

Engineers inspect buildings one by one and mark them for repair or demolition.



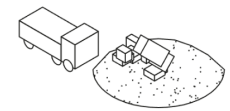
03 Demolition

Excavators pull down unsafe structures, with operators close to unstable debris.



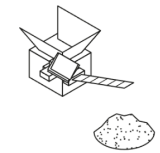
04 Loading

Mixed rubble is loaded onto trucks, mostly unsorted.



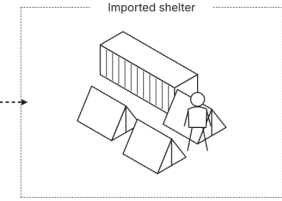
05 Hauling

Trucks haul the rubble to temporary debris sites or landfill.



06 Partial recycling

Where programmes exist, part of it is crushed for reuse (e.g. UNDP in Türkiye, 2023).



07 Temporary shelter

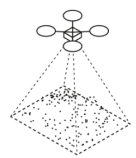
Displaced people move into tents and containers brought in from outside.

Material flow: site → landfill · Shelter flow: from outside → site

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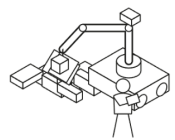
B - PROPOSED ROBOTIC WORKFLOW

Debris is sorted on site. The mineral fraction becomes the base, local bamboo the woven envelope. Humans stay in the loop.



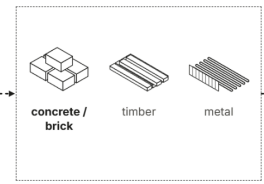
01 Drone scan

Drones scan the site; a point cloud maps debris volume and type.



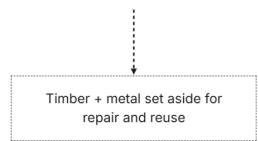
02 Robotic sorting

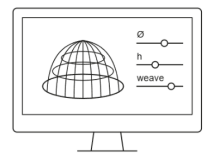
A mobile robot picks and sorts debris; a human confirms pieces the robot is unsure about.



03 Material fractions

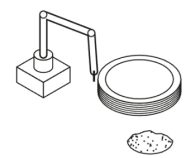
Concrete and brick go on to the base; timber and metal are set aside.





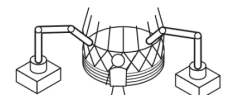
04 Parametric design

Diameter, height and weave density follow from occupants, material tests and robot reach.



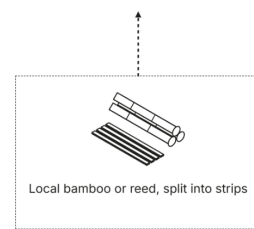
05 Printed base ring

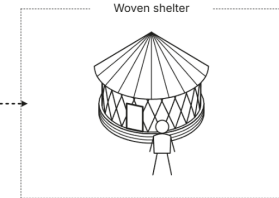
Crushed concrete and brick become aggregate; a robot prints the base ring.



06 Robotic weaving

Robots bend and weave strips onto the ring; a human guides joints that need judgement.





07 Round woven shelter

Built on site from local material; strips and base can be taken apart and reused.

Material flow: stays on site · Shelter built where people are, from debris and local fibre

Topics in Robotics for Disaster Relief

POTENTIAL QUESTIONS DERIVED FROM THE BROAD TOPIC

Draft from the workflow to narrow down to one as the project goes for a final design

Material

- Which sorted debris fractions (crushed concrete, brick, stone) can replace natural aggregate in a printable mix, and up to what replacement level?

Mix ratio / ML

- Can a model train on published mix data plus own lab tests predict the printability of a debris-based mix from measured debris properties, and so cut trial batches?

Sorting

- Which sorting decisions can the robot take alone, and when does a human need to confirm (mixed or contaminated pieces)?

Design per debris type

- How should the shelter design change with the debris type available on site (your 'premade plans per debris type')?

Human–robot assembly

- Which printing / assembly tasks go to the robot and which to the human, measured by time, accuracy and workload?

DESIGN POSIBILITIES DERIVED FROM THEME

- Automated assembly shelter design using 3d printing from debris material, collaborative robots that make, supply and print materials

- *Parametric implementation* based on:
    - flood risk, design changes with changing factors
    - recycled aggregate level! Depending on predicted material properties, design changes: maximum wall height, maximum overhang
    - aftershock forces needed: Interlocking or dry joints, light parts, raised floor

Options for site location

NATURAL DISASTERS

Türkiye - Kahramanmaraş earthquakes, 6 Feb 2023
- 156,000 buildings collapsed or need demolition (507,000 homes and offices)
- 116–210 million t of rubble (UNDP early estimate); 1999 Marmara earthquake: ~13 million
- Debris: mainly **concrete and masonry** → mineral aggregate source

UNDP, 24 Feb 2023

Nepal | China - flash flood, Rasuwa / Nuwakot, 26 Aug 2026
- Flood entered Nepal via the Bhote Koshi River from the Tibetan side of the border
- Districts hit: Rasuwa, Nuwakot, Dhading, Gorkha, Chitwan
- Early casualty figures conflict (95–162 dead, ~400 missing on day 1)
- Debris: structures buried in **mud and sediment**

World Vision International, 26 Aug 2026

Philippines - informal-settlement fires, Quezon City, Feb 2023
- Several separate QC fires in Feb 2023
- Ex: Tatalon fire 18–19 Feb 2023: 35 houses, 310 families / 1,323 people; houses of **plywood and lumber**
- Debris: charred timber and sheet metal → little mineral content for a mix

Philippine Daily Inquirer, Feb 2023

WAR ZONES

Ukraine - since 24 Feb 2022
- 13% of total housing stock damaged or destroyed (24 Feb 2022 – 31 Dec 2024)
- Debris clearance and management: ~US$13 bn; housing recovery need: ~US$84 bn
- Active conflict: on-site access not guaranteed

RDNA4 (World Bank, Govt. of Ukraine, EU, UN), Feb 2025

Armenia | Azerbaijan - Aghdam
- Captured July 1993; town sacked, almost entirely ruined and uninhabited until 2020
- Returned to Azerbaijani control 20 Nov 2020
- Debris = ~27-year-old ruins, not fresh disaster debris → reconstruction, not relief

NATURAL DISASTERS

Nepal Flash Floods



A drone view shows rescue workers inspecting damaged structures following flash flooding along the Trishuli River in the Devighat area of Nuwakot district, Nepal, on August 29, 2026

NATURAL DISASTERS

Turkey Earthquakes



Collapsed buildings in Kahramanmaras, Turkey on
February 17, 2023

NATURAL DISASTERS

Philippines Fires



Charred houses after a fire at a slum area in Quezon City, the Philippines.
February 2, 2023

WAR DISASTERS

Ukraine



An aerial view shows a residential building destroyed by shelling, as Russia's invasion of Ukraine continues, in the settlement of Borodyanka in the Kyiv region, Ukraine, March 3, 2022. (Reuters Photo)

WAR DISASTERS

Armenia-Azerbaijan



Areas of debris in Aghdam, Azerbaijan after being returned to Azerbaijani control following the end of the second conflict
Early December, 2020.

Location Choice Criteria

Accessibility
physical access is relevant for mapping the area, fragmented landscapes require a differentiated modelling technique, based on point-cloud data

Data availability
data about building construction materials and techniques, recently recorded maps

Intervention Possibilities
by event type

- **Earthquake (Türkiye)**
  - Large volume of mineral rubble → crush and sort into recycled aggregate for a printable mix
  - UNDP already plans to recycle the rubble rather than dump it
- **Flood (Nepal)**
  - Clearance of mud-covered structures comes first
  - Whether flood sediment can be printed like raw earth (cf. WASP TECLA, 2021) is untested → soil tests needed
- **Fire (Philippines)**
  - Little mineral debris to reuse → new shelter from local earth rather than from debris
- **War (Ukraine, Aghdam)**
  - Access and safety limit on-site work; long-term reconstruction rather than relief

Status Quo

INTERVENTION
TLP autonomous robots

autonomous excavator by ETH - **HEAP** (Johns et al., 2023)

Foster + Partners turns to **robot "swarms"** for construction (SWIFT-BUILD, Oct 2026 – Sep 2029)

EPFL work (Grangeot et al., Rob|Arch 2024) builds **walls from concrete rubble** using digitally augmented cranes and drills.

INTERVENTION CLEANUP + RECONSTRUCTION

- **Sorting**
  - AI + robotic sorting of construction and demolition waste reviewed by Dodampegama et al. (2024) - recycling plants, not disaster sites
- **Debris-based mix for 3D printing**
  - Maroszek et al. (2025) review: 50–100% recycled concrete aggregate tested in printed concrete → buildability up, flowability down, strength drops as replacement rises; test protocols inconsistent between studies
- **ML for mix ratios**
  - Marcucci et al. (2023): ANN predicts whether a mix design meets printability requirements
  - Malik et al. (2024): 5 ML models on 21 mix features; GPR best (R^2 > 0.91 for printed strength); checked on 4 printed mixes
- **Rubble → printed components**
  - Ruggiero et al. (2026), TRAP project: extrusion of dry-assembled wall components from rubble-derived aggregates; reports technical and regulatory limits
- **Practice**
  - UNDP Türkiye (2023): recycle rubble instead of dumping; in Nepal UNDP recycled 90% of the rubble in the areas it managed

Status Quo: to further investigate

Maxence Grangeot, Qianqing Wang, Katrin Beyer, Corentin Fivet, Stefana Parascho. 2026. “Rising from Rubble: Leveraging Existing Construction Tools for Upcycling Concrete Waste into Slender Walls.” Robotic Fabrication in Architecture, Art and Design 2024 (ROB|ARCH 2024), pp. 253–265, Springer, Cham. https://doi.org/10.1007/978-3-032-22607-5_16

Slender walls are built from large concrete rubble pieces using a drill and a digitally guided crane, with gravity orienting each piece as it is lifted. Two full-scale walls were built to test the method.

Eleni Skevaki, Marirena Kladeftira, Ziqi Wang, Sihui Wu, Gudela Grote, Stefana Parascho. 2025. “TimberProxy: A Tangible Human–Robot Interface for Incremental Design and Fabrication of Timber Structures.” ACADIA 2025: Computing for Resilience, Proceedings of the Annual Conference of the Association for Computer Aided Design in Architecture, pp. 786–795. https://doi.org/10.52842/conf.acadia.2025.2.786

A theory paper on what reused rubble walls should look like architecturally, compared with cast concrete and stone masonry. It proposes four premises: brutalism, rustication, spoliation and “concrete made from concrete”.

Maxence Grangeot, Tanguy Auffret-Postel, Stefana Parascho, Corentin Fivet. 2025. “New Tectonics of Concrete through Rubble Reuse.” Structures and Architecture: REstructure REmaterialize REthink REuse, edited by Mario Rinke and Marie Frier Hvejsel, pp. 1185–1192, CRC Press. https://doi.org/10.1201/9781003658641-141

A Tangible Human-Robot Interface for Incremental Design and Fabrication of Timber Structures

Marirena Kladeftira, Corentin Fivet, Stefana Parascho. 2025. “Re:Config: A Human–Robot Collaborative Process for the Reuse and Reconfiguration of Existing Timber Structures in the European Building Stock.” Structures and Architecture: REstructure REmaterialize REthink REuse, edited by Mario Rinke and Marie Frier Hvejsel, CRC Press.



TimberProxy

A Tangible Human-Robot Interface for Incremental Design and Fabrication of Timber Structures

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ABSTRACT

Despite advancements in autonomous robotics, their application in construction remains constrained to executing predefined instructions. Construction sites, however, are inherently unpredictable and demand real-time adjustments that current robotic systems cannot handle independently. While human–robot collaboration offers potential, most existing interaction modalities depend on digital interfaces that often fail to convey spatial intent or support hands-on engagement with materials. Meanwhile, direct human presence on active construction sites, especially with large-scale components and dynamic robotic movements, raises safety and practical concerns. To address these challenges, we introduce TimberProxy, a physical interface enabling remote and tangible interaction with robotic agents during timber assemblies. Users guide fabrication by manipulating a scaled physical model of the structure composed of simplified props. Changes to the scaled model are digitally captured and translated into actionable instructions for a hybrid construction team of two robotic arms and a human. Validated through experiments and co-design workshops, TimberProxy demonstrates intuitive interaction, supports collaborative design, and shows potential for lowering barriers to entry for robotic construction. By enabling tangible, hands-on engagement, our framework reimagines how human intent can shape fabrication processes—incrementally, collaboratively, and from a distance.

1 A human designer uses TimberProxy to guide the fabrication process. The resulting inputs are translated into instructions executed by two robotic arms at full scale.

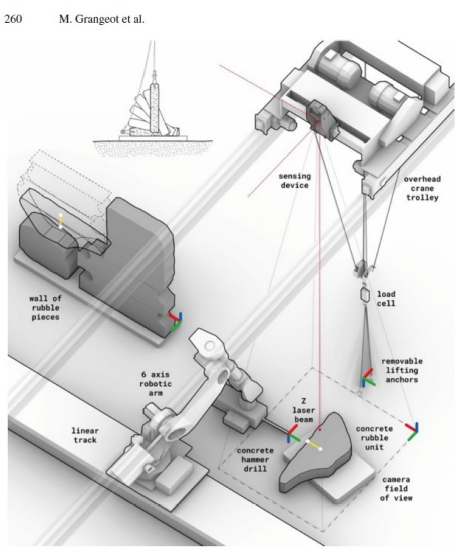


Fig. 7. Tool augmentations and relevant planes used for calibration and operation. The Z laser beam of the sensing unit of the overhead crane acts as a reference for calibrating the camera, the concrete hammer drill end-effector, the wall base, and the lifting hooks.

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