Buoyancy enabled autonomous underwater construction with cement blocks

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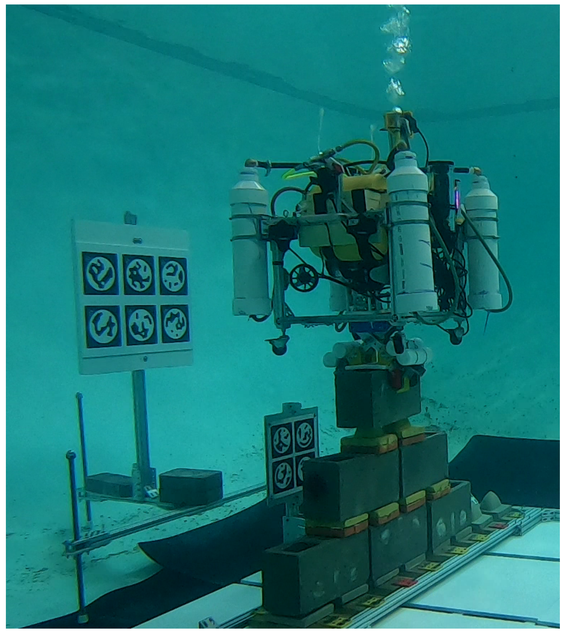
RLab Web

Overview



First free-floating autonomous underwater vehicle (AUV) construction system capable of using active ballasting to transport cement building blocks efficiently.

Inspiration

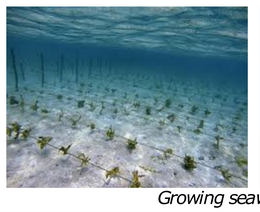
Reef restoration

Grande Anse Artificial Reef Project

Coast protection

Artificial harbors and jettys

Building for aquaculture



Growing seaweed and farming fish

Construction system

Error correcting cement blocks

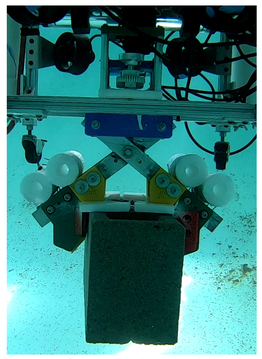
Noise in AUV's position is inevitable.

Cone inserts help guide the cinder blocks into alignment despite noise.

Cone inserts can correct up to 5cm in pre-drop error along block length and 2.5cm on width.

Two completed structures weighing 54Kg and 100Kg (41 and 75Kg in water)

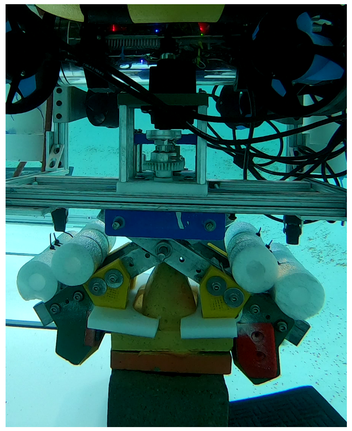
Error correcting manipulator

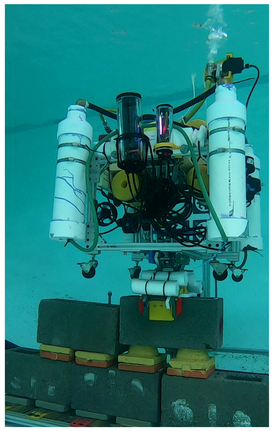


Passive strength limits energy use during transport blocks. Prevents accidental opening.

Allows compliant grasps which correct error.

Compliant grasp and drop





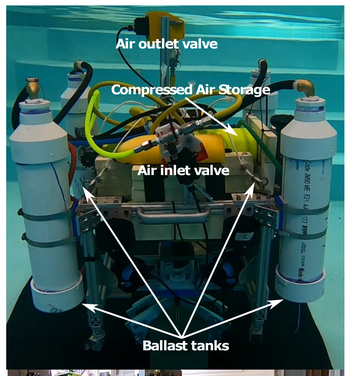
Plunging grasp (left): AUV pushes onto the top of the cone insert and disengages attitude control. Closing action of the manipulator aligns the AUV.

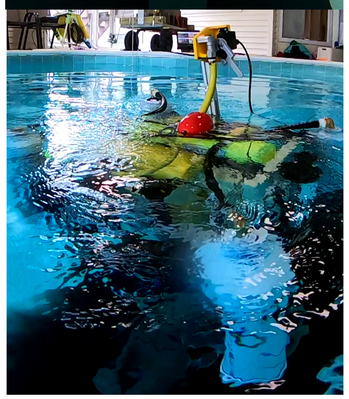
Bailing release (right): AUV releases excess air and disengages attitude / depth control. The block is gently placed.

Active ballasting system

Compressed air offsets the weight of the 9.5kg cement blocks the AUV lifts.

To set buoyancy, StoneClaw turns its thrusters on and slowly adds air to its ballast tanks.

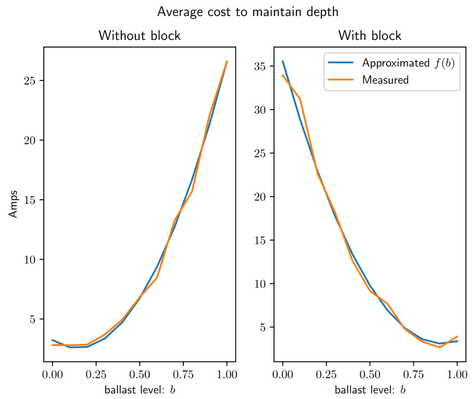




Adding air to lift a block

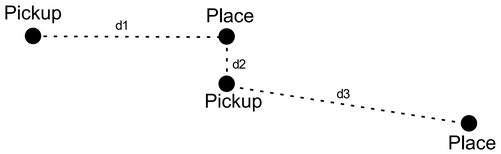
Releasing air after placing a block

Optimizing ballast



Polynomial model & experimental validation of power used to keep AUV at depth .

Goal: minimize battery use for AUV during construction process without using too much compressed air



$$\begin{aligned} \min_{\Delta} \quad & \mathbf{E}(\mathbf{M}\Delta) \\ \text{subject to} \quad & 0 \leq \Delta \leq 1 \\ & \mathbf{M}'\Delta \leq C \\ & 0 \leq \mathbf{M}\Delta \leq 1 \end{aligned}$$

Δ	Change in buoyancy after every hop
C	Maximum amount of air that can be added
$\mathbf{M}$	Converts from change in buoyancy to absolute buoyancy at every hop
$\mathbf{E}(\mathbf{M}\Delta)$	Convex approximation of energy used. Based on distance between hops and model of cost to hold AUV at depth

Next steps

More expressive building materials: allow 90 degree turns in the structure, add material heterogeneity.

Sense placement success: determine whether block is properly aligned based indirect AUV information.

Integrated construction planning: plan the order of the construction process using the convex program above as an objective function.