Team LEBOB’s

Innovations

2025 Unearthed

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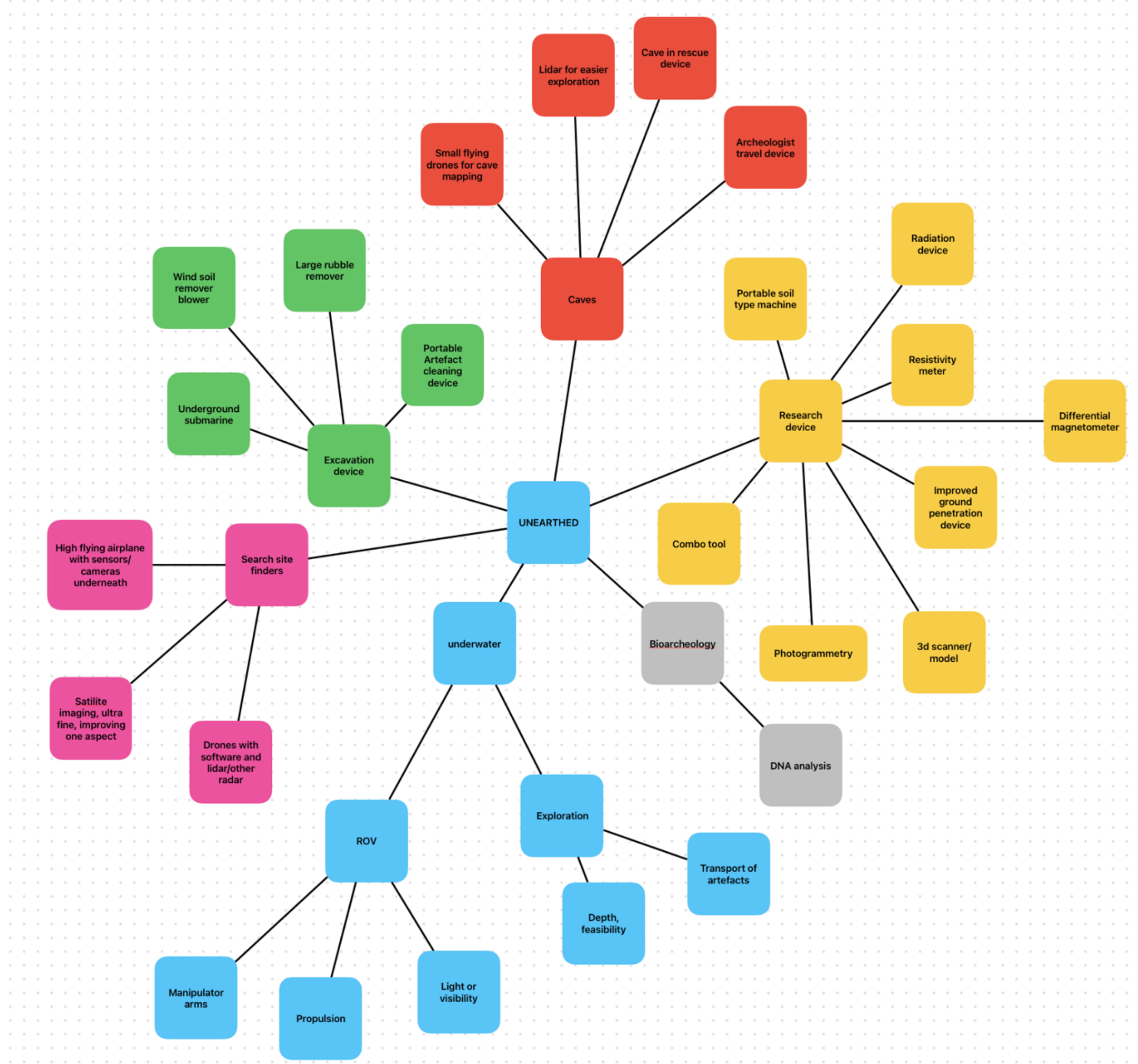
Brainstorm



As a team, we had a couple of different preferences. We would have liked to do something that was coding related as well as mechanical, and which involved electronics. However, as a team we were flexible and didn't really mind what we did. We ultimately decided upon manipulator arms, as they are a rapidly improving field, that was doable to a group of school students that had at their disposal 3D printers and basic electronic parts.

Problem

Archaeologists are facing hard times trying to recover fragile, broken or small shards from the sea floor, relying on cheap, two finger manipulator hands on ROV arms, that were originally intended for oil, mechanical or industrial use. These clumsy setups could lead to the inability to recover artefacts, or even worse, the destruction of those artefacts. They also have severe and hard limits on the size and shape of objects they can carry.

Research

Websites to visit

Assessing damage and predicting future risks: A study of the Schilling manufactured Titan 4 seven function manipulator during 2017 - 2022 – DONE
https://www.sciencedirect.com/science/article/pii/S002980182302666

Collision Detection for Underwater ROV Manipulator Systems -
https://pdfs.semanticscholar.org/2327/89da0cdc7c8ff9b114b9383fc5ce8a49956a.pdf

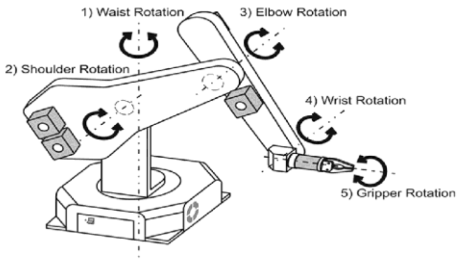
Underwater manipulators: A review – DONE
https://www.sciencedirect.com/science/article/pii/S002980181831030

Lightweight underwater robot developed for archaeological surveys and excavations -
https://robomechjournal.springeropen.com/articles/10.1186/s40648-023-00240-4

https://www.imca-int.com/resources/safety/safety-flashes/0301-rov-personnel-injury/
Sivčev et al., 2018a; Bogue, 2015; Petillot et al., 2019; Antonelli, 2014

Notes

Underwater manipulators: A review
Notes: - Underwater manipulators are used in many ways: grasping, lifting, handling objects underwater - Factors that affect the performance of these include hydrodynamic effects (drag, added mass), buoyancy, structural stiffness, joint design, reach, torque, capability - Reach is also important - Manipulator arms are considered the most suitable tool for executing sub-sea operations - Majority of existing arms are anthropomorphic - Most arms are designed for a single purpose, ie lifting large, heavy objects, or attaching a gripper to an underwater object - Most working class ROVs have two manipulator arms, one simple, strong one to hold onto the object, and a smaller one to do the actual job - Most common materials used are metal alloys, including titanium Ti 6-4, anodized aluminum alloys (5083, 6082 T6, 6061 T6, 7075 T6, A356), stainless steel alloys (316, 630, 660), as well as some plastics (Polyethylene)

- Key factors in those materials include high corrosion resistance, relatively high strength and ease of manufacturing
- To reduce weight and actuator burden, buoyant materials have been tried
- Commercially available arms typically are rated at 3000m to 6500m of sea water, however some can reach 7000m
- Some have been developed for full ocean depths 11000 msw
- size of underwater manipulators is described as a parameter called “reach”
- represents the length of the whole manipulator kinematic chain
- reach of existing underwater manipulators from 0.5 m up to 2.4 m
- max wrist torque ranges from 8Nm to 250Nm
- listing and carrying vary from 5 kg to 500 kg
- rotary low torque rated for max of 75 Nm
- manipulator arm weight in air varies from 6kg to 150kg
- commercial arms come with interchangeable grippers with specific purpose
- common gripper type is parallel acting jaws that has a slot for a standard T-bar handle
- primary function to grip a variety of different objects and tools
- different grippers include three/four finger intermeshing jaws, two/three finger floating jaws, scissor jaws, suction foots
- grippers are usually hydraulic
- grip strength range from 35 kgf to 652 kgf
- both experimental and commercial arms have between 3 to 6 degree of freedom (DOF)
- 

  Example of a 5 DOF manipulator arm
- reason for this is that 3 DOF is sufficient for achieving arbitrary position and 6 is sufficient for achieving both arbitrary position and orientation of the end effector
- term “n-function” generally used to describe number of actuators used, one for the gripper and the rest for arm movement
- underwater arms with 7 or more DOFs, not including gripper actuator, are not very common, but do exist
- True 7 DOF manipulator arms are said to be inherently redundant from a kinetic standpoint
- This can be used later for redundancy or to achieve secondary objectives

- Benefits of sea water hydraulic operated manipulator arms include : low viscosity, high power density, non-flammable properties and zero environmental impact
- Disadvantages: corrosive and abrasive properties, lubrication and sealing issues, unsuitable working temperature range, etc
- All existing manipulator arms now either use oil hydraulic or electricity, both of which have advantages and disadvantages
- Proposed dual, both oil and electricity, however not commercially viable yet
- Biodegradable oil has now minimized the impact of fluid leaks
- Generally, hydraulic actuators can produce an output force/torque much larger than the force applied on the input without the use of mechanical components such as gears and levers (direct drive)
- They are a necessity for the implementation with electric actuators
- Thus, hydraulic systems have higher power to weight ratio (payload capability) which goes up to the order of three for the existing commercial hydraulic underwater manipulators
- Whereas ratio is one or less for the electrical ones
- Hydraulic benefits lead to majority of commercial arms being hydraulic
- Actuators with limited motion e.g. piston cylinders and rotary vane actuators are used to drive manipulator joints
- Some cases gearmotors, type of hydraulic motor with continuous motion are used for wrist joint actuation
- Hydraulic manipulator arms suffer from poor positional accuracy compared to electric arms, and are not suited for fine control of the interaction force with the environment during contact tasks
- Another problem is fluid leaks, which is almost impossible to solve, which brings demand for higher quality material and construction, resulting in higher prices
- Also, hydraulic arms require additional infrastructure, like pumps and tanks, while electric don't, requiring only electricity which can already be found
- Electric arms are less frequent in commercial use, however are often used for experimental or custom made arms
- Actuators commonly use brushless DC motors, with large reduction ratios
- To stop water ingress, oil is used, which also helps with lubrication and cooling
- To prevent using external wires that could result in possible entanglement, power and signal cables are fed through the same hoses used for pressure compensation
- Main advantage of electric arms are its precision and force/torque control

- Most aren't used in operations as they lack the speed, reliability and strength requirements
- Different types of operating systems
- One which has each actuator/joint as a different input-output system, which combined to control the entire arm, this is known as a decentralized control scheme
- The second type is the opposite, a centralized control scheme, which takes dynamic interactions between the joints into account
- When designing a control system, you need to take into consideration the specifics of your ROV as your drive system, different actuators, etc can impact the control system, if you're using a hydraulic system, the viscosity of the oil and its pressure and flow can
- It is extremely difficult to model and control a manipulator arm, as hydrodynamic effects such as buoyancy, drag and lift forces as well as external forces like waves, currents etc all can affect manipulator arms. The temperature, depth, salinity, etc can also affect the hydrodynamic affects as well as the arm itself
- Control schemes which integrate proportional (P), integral (I) and derivative (D) terms in different variations offer simplicity of implementation and low software costs

Reference https://www.sciencedirect.com/science/article/pii/S0029801818310308

Assessing damage and predicting future risks: A study of the Schilling manufactured Titan 4 seven function manipulator during 2017 - 2022

Notes:

- Leaks or damage to the seals of the manipulators arms are the most common cause of damage
- The jaws or fingers of the manipulator arms are the element most exposed to damage
- There is a correlation between operator errors and manipulator damage
- It is possible to identify possible preventative measures against future failures
- The Titan 4 is the most widely employed equipment on work class ROVs world wide
- Depth for scientific work can go between a few meters underwater to 10,000 m (Cochran, 2019; Kennish, 2019).
- only around 5% of ROV shares are used for scientific research
- Underwater Vehicle Manipulator Systems (UVMS) typically resemble human arms and have interconnected rigid arms with revolute joints and end-effectors like grippers and tools
- Often also have cameras or lights

- designed for different purposes, such as lifting heavy objects, attaching detachable grippers to sunken objects, fixing underwater vehicles to structures or walls, inspection tasks, dexterous intervention operations, and more
- Work class ROVs typically have two manipulators, with one serving to hold the ROV near the structure while the other performs the actual intervention task (Sivčev et al., 2018a)
- Tasks executed by underwater manipulators include .... biological and geological sampling, archeological work, and more
- Most manipulator arms are located at the front, but some can be found located in the back
- Most are operated by pilots and co-pilots, however limited visibility in murky waters and poor camera angles can lead to collisions and significant damage
- A collision detection mechanism has already been developed
- Titan 4 has good corrosion resistance, a key factor for underwater mechanical mechanisms
- Key parts of the Titan 4 include azimuth, shoulder, upper arm, elbow, forearm, pitch & yaw, wrist, and jaw

Reference: https://www.sciencedirect.com/science/article/pii/S00298018230266

Analysis of Lightweight Materials for Robot Manipulators

Notes:
- Aluminum is widely used for manipulators, because of its good mechanical properties
- For industrial robot designs, a material with low density and high rigidity is preferred
- Composite materials often can perform better than aluminum, however, are more expensive and difficult to manufacture
- Comparison between aluminum and a carbon fiber composite

Table 1: Material comparison

Material	Mechanical properties	
	Density (kg/m3)	*Elastic Modulus (GPa)*
Aluminum 6063 – T6	2700	70
Carbon Fiber (70%) Composite	1600	140

-
- Traditional heavy rigid arms are designed with stiff links, so the links dynamics can be ignored, and the position of the entire arm can be found through the positions of the actuators

- In flexible robots the links are no longer assumed to be rigid, so when there is movement, unwanted vibrations may change the position of the arm and tip, making positional errors more likely
Reference: https://www.ajbasweb.com/old/ajbas/2015/May/877-882.pdf

Materials for ROVs – Top 5

Notes:

- **Anodized aluminum**
- **Benefits**: corrosion resistance, durability, relatively light,
- **Drawbacks**: may not be suitable to deep-sea applications where more durable materials like titanium would be preferred, coating may rub off in abrasive conditions
- **Titanium**
- **Benefits:** exceptionally strong, low weight, corrosion resistance, excellent fatigue resistance, can withstand high pressure and aggressive fluids
- **Drawbacks:** much more expensive than aluminum, fabrication can be more complex, large carbon and environmental footprint
- **Stainless steel**
- **Benefits:** corrosion resistant, good strength
- **Drawbacks:** much heavier than other options, may require additional treatments to make for optimal corrosion resistance
- **Plastics and composites**
- **Benefits:** good balance of weight, strength and corrosion resistance, can insulate against electricity, good seals
- **Drawbacks:** limited high temperature resistance, limited depth capacity, not suitable for deep sea applications
- **Ceramics**
- **Benefits:** excellent corrosion resistance, wear resistance and thermal stability
- **Drawbacks:** brittle and require careful engineering to prevent failure under mechanical stress or impacts, least versatile and very rare to see ceramics in main body of ROV, more in specialized applications like sensors
- **In General:**
- Materials that are needed in ROVs typically require three main properties:
- Corrosion resistance, the sea is extremely salty and can rust or damage materials if submerged for enough time
- Strength, deep sea pressures or impacts with creatures or rocks can damage structural elements, which can lead to malfunctions or at worse, water leaking into the electronics, resulting in an unusable ROV

- Low weight, less weight requires less energy to move in water, making the ROV more energy efficient, and reducing the amount of power the movement motors require, giving more to the main manipulator arms.
Reference: https://seamor.com/materials-for-rovs-top-5/

Specifications of existing manipulator arm models:

Table 1
Specifications of existing commercial underwater manipulators.

Manufacturer	Model	Actuation	DOF	Weight in air [kg]	Weight in water [kg]	Lift capacity max nom. (full ext.) [kg]	Wrist torque [Nm]	Grip force [kgf]	Depth rating [m]	Max. reach [m]	Power Source	Material	Actuators	Sensors	Control	Price [$]
Ansaldo	MARIS 7080	Electric	7	65	45	8 (/)	/	20.4	6000	1.4	72VDC	Al	BLDC	Resolvers, F/T	Semi Automatic	/
Cybernetix	Maestro	Hydraulic	6	85	65	100 (96)	190	150	6000	2.4	50 Hz 220VAC 210bar 18lpm	Ti	Rot. vane & gerotor	Resolvers	Pos. & force fb.	~1m
Eca Hytec	Arm 7E	Electric	6	69	49.2	40 (40)	25	80	6000	1.79	24-36VDC	Al 6082 T6	BLDC in oil	/	Prop. & torque	~110k
Eca Hytec	Arm 7E Mini	Electric	6	51	30	25 (25)	25	50	3000	1.44	24-36VDC	Al 6082 T6	BLDC in oil	/	Prop. & torque	~110k
Eca Hytec	Arm 5E	Electric	4	27	18.5	25 (25)	25	60	6000	1	24-30VDC	Al 6082 T6	BLDC in oil	/	Prop.	~40k
Eca Hytec	Arm 5E Mini	Electric	4	23	15	25 (25)	25	50	6000	0.85	24-40VDC	Al 6082 T6	BLDC in oil	/	Prop.	~40k
Eca Hytec	Arm 5E Micro	Electric	4	10	2.7	10 (10)	10	50	6000	0.64	24-30VDC/240VAC	Al 6082 T6	BLDC in oil	/	Prop.	~25k
Forum Perry	TA40	Hydraulic	6	98	65	125 (210)	150	509	11000	2	No electrical 210bar 9lpm	Al, SS	Cylinders, rot. vane & gerotor	No	Pos./Rate/ Hybrid fb.	/
Forum Perry	TA60	Hydraulic	4	82	60	380 (300)	250	509	11000	1.44	No electrical 210bar 9lpm	Al, SS	Cylinders, rot. vane & gerotor	No	Rate/Hybrid fb.	/
Forum Perry	TA60J	Hydraulic	4	76	51	380 (300)	250	509	11000	1.38	No electrical 210bar 9lpm	Al, SS	Cylinders, rot. vane & gerotor	No	Rate/Hybrid fb.	/
Forum Perry	TA16	Hydraulic	4	50	40	147 (102)	108	226	11000	1.06	No electrical 210bar 9lpm	Al, SS	Cylinders, rot. vane & gerotor	No	Rate/Hybrid fb.	/
Graal Tech	UMA	Electric	6 (7)	28	14	10 (/)	/	/	100	1	24VDC	Al	BLDC	Yes	Position	~75k
Hydro-Lek	40400	Hydraulic	4	45	30	150 (210)	75	/	11000	1.42	210 bar	SS 316, Al HE30, PE	Cylinders & gerotor	No	Rate	~16k
Hydro-Lek	40500(R)	Hydraulic	6	59	40	150 (210)	75	/	11000	1.5	210 bar	SS 316, Al HE30, PE	Cylinders & gerotor	No	Rate	~30k
Hydro-Lek	43000	Hydraulic	4	6	4	10 (20)	8	/	11000	0.53	160 bar	SS 316, PE	Cylinders & gerotor	No	Rate	~4k
Hydro-Lek	CRA6	Hydraulic	5	28	14.5	32 (32)	38	/	11000	1.5	140 bar	SS 316, Al HE30, PE	Cylinders & gerotor	No	Rate	~12k
Hydro-Lek	EH5	Hydraulic	4	12	9.5	25 (25)	14	/	11000	0.8	140 bar	Al E30, SS 316	Cylinders & gerotor	No	Rate	~7k
Hydro-Lek	HD5	Hydraulic	4	21.5	16.5	40 (40)	38	/	11000	0.819	140 bar	SS 316, Al HE 30, PE	Cylinders & gerotor	No	Rate	~9k
Hydro-Lek	HD6W HD6R	Hydraulic	5	29	21	40 (40)	38	/	11000	1.12	140 bar	SS 316, Al HE30, PE	Cylinders & gerotor	No	Rate	~12k
Hydro-Lek	MB4	Hydraulic	3	13.3	11	40 (40)	40	/	11000	0.63	140 bar	SS 316, Al HE30, PE	Cylinders & gerotor	No	Rate	~5k
Hydro-Lek	RHD5(W)	Hydraulic	4	30	20	80 (80)	38	/	11000	0.95	210 bar	SS 316, Al HE30, PE	Cylinders & gerotor	No	Rate	~11k
ISE Ltd.	Magnum 7	Hydraulic	6	63.5	30	454 (295)	108	205	11000	1.5	70bar 19lpm	Al, SS	Cylinders	Potentio-meters	Pos./Rate	~59k
ISE Ltd.	Magnum 5	Hydraulic	4	50	27	454 (295)	108	160	5000	1.16	70bar 19lpm	Al, SS	Cylinders	Yes	Pos./Rate	~52k
ISE Ltd.	Magnum 6 Mini	Hydraulic	5	57	30.6	454 (317)	108	160	5000	0.96	70bar 19lpm	Al, SS	Cylinders	No	Rate	~56k
ISE Ltd.	Magnum 5 Mini	Hydraulic	4	34	24	68 (23)	14	35	5000	0.71	35bar 19lpm	Al, SS	Cylinders	No	Rate	~46k

Table 1 (*continued*)

Manufacturer	Model	Actuation	DOF	Weight in air [kg]	Weight in water [kg]	Lift capacity max nom. (full ext.) [kg]	Wrist torque [Nm]	Grip force [kgf]	Depth rating [m]	Max. reach [m]	Power Source	Material	Actuators	Sensors	Control	Price [$]
KNR Systems Inc.	HYDRA UW3	Hydraulic	6	130	/	300 (121)	350	300	500	2.035	210bar 19lpm	Al, SS, Ti	Cylinders & rotary vane	Encoders	Position	~175k
Kraft	Predator	Hydraulic	6	80	51	227 (91)	135	135	6500	1.64	50 Hz 220VAC 210bar 19lpm	Al, SS	Cylinders, rot. vane & gerotor	Yes	Pos. & force fb.	~200k
Kraft	Raptor	Hydraulic	6	75	44	227 (91)	135	135	6500	1.52	50 Hz 220VAC 210bar 19lpm	Al, SS	Cylinders, rot. vane & gerotor	Yes	Pos. & force fb.	~200k
Kraft	Grips	Hydraulic	6	59	41	82 (45)	20	90	3000	1.556	50 Hz 220VAC 210bar 11lpm	Al, SS	Cylinders, rot. vane & gerotor	Yes	Pos. & force fb.	~200k
Ocean Innovation System	BE5-500	Electric	4	15	8	/(16)	1.6	100	500	0.7	24 VDC	Al 5083, PE	BLDC	Hall	Rate	~30k
Oceaneering	Atlas Hybrid	Hydraulic	6	73	50	454 (250)	205	454	6500	1.66	90-260VAC 206bar 19lpm	Al 6061 T6, SS	Cylinders, rot. vane & gerotor	Solid State Pos.	Hybrid Pos./ Rate	/
Profound Technology	M1P	Hydraulic	6	115	77	275 (250)	175	652	4000	2.1	/	Al, SS	Cylinders & rotary	Yes	Pos./Rate	/
Schilling	Titan 2	Hydraulic	6	80	61	/(109)	68	136	6500	1.92	90-260VAC 210bar 19lpm	Ti	Cylinders, rot. vane & gerotor	Resolvers	Pos. & force fb.	/
Schilling	Titan 3	Hydraulic	6	/	/	/(/)	/	/	6500	1.92	90-260VAC 210bar 19lpm	Ti	Cylinders, rot. vane & gerotor	Resolvers	Pos. & force fb.	/
Schilling	Titan 4	Hydraulic	6	100	78	454 (122)	170	417	7000	1.92	90-260VAC 210bar 19lpm	Ti	Cylinders, rot. vane & gerotor	Resolvers	Pos. & force fb.	/
Schilling	Conan 7P	Hydraulic	6	107	73	273 (159)	205	454	3000	1.8	90-260VAC 210bar 19lpm	Al 6061, SS	Cylinders, rot. vane & gerotor	Potentio-meters	Pos.	/
Schilling	Orion 7P/ 7R	Hydraulic	6	54	38	250 (68)	205	454	6500	1.85	90-260VAC 210bar 19lpm	Al, SS	Cylinders, rot. vane & gerotor	Potentio-meters	Pos./Rate	/
Schilling	Atlas 7R	Hydraulic	6	73	50	500 (250)	205	454	6500	1.66	90-260VAC 210bar 19lpm	Al 6061 T6, SS	Cylinders, rot. vane & gerotor	No	Rate	/
Schilling	RigMaster	Hydraulic	4	64	48	270 (181)	205	454	6500	1.37	No electrical 210bar 19lpm	Ti, Al, SS 630	Cylinders, rot. vane & gerotor	No	Rate	/
Schilling	Orion 4R	Hydraulic	3	30	21	136 (/)	205	454	6500	0.68	No electrical 210bar 19lpm	Al, SS	Cylinders rot. vane & gerotor	No	Rate	/
Seamor	7F-H-ARM	Hydraulic	6	32	/	/(5)	/	/	300	1.07	300V 35bar 4.5lpm	SS 316, Al 6061 T6	/	/	/	/
TitanRob	M700	Hydraulic	6	30	20	50 (40)	45	80	3000	1.05	140 bar min 1.5lpm	Ti, SS 316	Cylinders, rot. vane & gerotor	No	Rate	~45k
TitanRob	G500	Hydraulic	4	20	15	100 (80)	80	250	3000	0.8	140 bar min 1.5lpm	Ti, SS 316	Cylinders & rotary	No	Rate	~40k
TitanRob	M501	Hydraulic	4	14	11	50 (40)	45	80	3000	0.95	140 bar min 1.5lpm	Ti, SS 316	Cylinders & rotary	No	Rate	~35k

Solution

Our solution is to use a combination of existing technologies, applied in creative ways. Firstly, we use soft foam pads on the tips of the fingers on the gripper to help reduce the chances of breaking delicate artefacts. Secondly, we apply pressure sensors beneath the pads. This gives a readback to the operators, as well as give ROV operators the option of running our code, which stops the actuator when the pressure value reaches a certain threshold. Thirdly, we attach all of the pads and the pressure sensors to a rotating surface. This allows the pads to always have decent contact on the object, making awkward positions more feasible. They can also set presets for different objects, like one for a soft object like coral or one for a harder object like limestone.

Testing and Results

We used a set of 4 objects, a pot, a treasure chest, a bone and an anchor.

We chose this set of items because they are a diverse range of items, with different shapes and features. For example, the bone and the anchor are both quite long items, however one has two sets of holds that could provide grip for a manipulator arm, however the bone has little places to grip, besides the two ends. The chest and the vase are also quite similar, as they are both quite stout objects, however the chest is a rectangular object, with grooves in the side for quite easy grip, while the vase is a smooth, circular object, and only has the head portion to grip for the arm.

Object	Number of attempts (4 fingers)	Number of attempts (2 fingers)	Pressure values to grip
Bone	2	4	26 g f
Anchor	5	4	96 g f
Vase	3	5	411 g f
Chest	3	3	288 g f

Feedback

Experts emailed

Dr John McCarthy
Associate Professor Jonathan Benjamin
Chelsea Wiseman
Michael O'Leary (UWA)
Jerem Leach
Ingrid Ward
Hiro Yoshida

Institutions emails

Australasian Institute for Maritime Archaeology
Minderoo UWA Deep sea Research Centre
Western Australian Museum, Maritime Archaeology Department

Emails

Hi Chris,

Thanks for reaching out. Yes I have used ROV's to collect stone artefacts from the sea floor, as well as small geological specimens to better understand the primary source rocks the artefacts originate from.

I have the Chasing 2 ROV and we have used a grabber arm https://www.chasing.com/en/grabber-arm-2.html to collect these specimens. The main challenge in doing this is that you have to position your drone in the right position before closing the grabber claw onto the rock sample but this becomes difficult were there are strong currents which make holding the grabber arm in the right position and angle to the sample challenging.

I have been thinking the better option might be a bucket style sediment sampler to scoop up the rocks rather then try and grab them https://www.chasing.com/en/sediment-sampler.html

Happy to answer any other questions you might have

Cheers

Mick

Hi Chris,

Thanks for writing. I'm a maritime archaeologist here at the museum.

- Any issues you have experienced with ROV manipulator arms, and more specifically collecting artefacts underwater
    - We have only used ROVs for image capture, and haven't used one with a manipulator arm
- How these issues affected your archaeological operations
    - Many artefacts are incredibly delicate and often need to be excavated (sediment removed around them).
    - Bottles and pottery can also be full of sediment, so they can be very heavy - which is a challenge for some robotic actuators
    - Many WA sites are in shallow waters, and where waves break - so robots could be used on deeper sites only, or would have to be able to controlled in the waves.

Cheers,

Patrick Morrison he/him
Assistant Curator Maritime Heritage

Hi Chris,

Thanks for reaching out and tackling a difficult problem the subsea world has had for a long time.
I am not an archaeologist, but I can comment on the challenges of using ROVs for science.

ROVs are great tools but they have some limitations. When we collect small animals, like corals, which are very delicate, we run the risk of crushing the animal and its structure. As sad as it is killing an animal for a specific question, if we crush the structure and cannot use it, then we always have another individual from that species which we can find and use. If this is a delicate artifact, it is rare and unlikely to have a replicate therefore it is very high risk picking up delicate artefacts in case we crush it. It is difficult for ROV pilots to feel how much pressure they are putting on the thing they are collecting. There is some work in the medical industry that provides pressure feedback to operator which provides a sense of how much to push. The manip arm is very strong and can easily crush samples.

ROV also create turbulence when they move which can create a cloud of sediment in silty environments. Skilled pilots are very good at reducing this, but it still a problem.
ROV are also tethered to the main vessel which means we need a lot of cable if we want to work in very deep environments. We also have to drag that tether around which can be difficult and dangerous.
The payload of an ROV isn't huge which means they cannot lift heavy things. Some small artefacts can be collected with the arm, but anything larger would need to be lifted using alternative means.

I hope this gives you some ideas about the difficulties working with ROV at depth.

Good luck.
Todd.

Dr Todd Bond
Deputy Director

Innovations Play

Roles:

- Presenter 1 and 2 (main talker x 2) – medium parts, 1 is slightly more than 2
- Scientist (gives critical info like stats and other things) – long part, facts
- Questionnaires 1, 2 and 3(ask questions x 3) – short parts, ask questions
- Customer 1 and 2 (person who gives feedback x 2) - 1 part, medium parts

Presenter 1 – [Chris] – school formal uniform, MEMORISE

Presenter 2 – [Kingsley] – school formal uniform, MEMORISE
Scientist – [Subesh] – lab coat, you can bring a clipboard for reading off
Questionnaire 1 – [Leven] - casual clothe, MEMORISE
Questionnaire 2 – [Andre] – casual clothe, MEMORISE
Questionnaire 3 – [Aaron] – casual clothe, MEMORISE
Customer 1 – [Oliver] – Construction vest, MEMORISE
Customer 2 – [Sean] – lab coat, MEMORISE
Total: 8
1st Scene – first advertisement:

Presenter 1: have you been having issues with your manipulator arms?

Presenter 2: been unable to hold onto fragile artefacts that you cannot, for the life of you, destroy?

Presenter 1: can't even pick up a large treasure chest and have been forced to wait costly months while a larger, more advanced and more expensive ROV arrives?

Presenter 2: well, we have the perfect solution for you! Introducing our new, amazing, spectacular manipulator arm!

Presenter 1: with all new adaptable foam to help cushion delicate vases and pottery, and a large grasping area, the Claw Testing Design 4000, or CTD, is the perfect addition to any ROV collection, for the wealthy or the curious.

Presenter 2: And that's not all. Our arm has been engineered with highly experimental, rotating pads to grip any surface, and to make sure you don't mess up your next big job.

Presenter 1: but you don't need to just trust us!

Presenter 2: we've brought in our very own scientist to explain to you how important, and feature packed our arm is.

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2nd scene – scientist and facts:

Scientist: Thank you. Our CTD is made up of multiple different materials. For the main structural components and frame, we would prefer to use titanium, due to its high strength and high corrosion resistance, however for a cheaper option we can go with anodized aluminium, which provides many of the same advantages as titanium, however with a cheaper material and production cost. For the manipulator fingers, internal structural supports and filler material, we would use plastics and composites to hold electronics and sensors in place. They are a great deal lighter than the structural materials, however, are still quite strong and are corrosion resistant. It also reduces the weight of our arm by around 20% compared to similar sized and spec-ed commercial arms like the Titan 4, which also has the same 6 Degrees of Freedom as our designed arm.

Presenter 1: but what about delicate artefacts?

Scientist: well, I'm glad you asked! Our arm has soft expanded polyethylene foam, that can compress up to, while also providing good grip on objects. Coupled with our adaptable arms, which allow us to always maintain good connection with artefacts by having the grippers rotate to the direction of the object.

show grippers and how they work

Presenter 2: (look impressed) wow! That's a lot of features to help keep artefacts safe and together.

3rd scene – Questionnaires:

Questionnaire 1: Hmm. I'm sceptical. What facts are we talking here?

Scientist: We have a couple predicted facts that are based on existing models. Unfortunately, we have been unable to create a perfect commercial arm and haven't been able to test them in real world conditions. However, based on our testing and research, we believe our arm will be able to reach depths of over 6,000 meters under the water, have a reach of 2 meters

Questionnaire 2: So, you're saying your arm is mainly theoretical. Well, what research can you give us to back your claims?

Presenter 1: Well, if you flip to page 4 of our innovation document, you will find all our listed research, as well as a large table of common commercially available arms, with their different specifications. As you can see, we have quite a lot of research to base our claims on.

Questionnaire 3: Well, how does it compare to those models? Wouldn't it be better to buy an existing, tested model?

Scientist: Of course, our model is an experiment prototype. However, with our testing and new innovations, we are confident that our model we be able to make a sect in the market.

Questionnaire 1: what are those innovations you speak of?

Presenter 2: I'm glad you asked! Firstly, we have the rotating grippers. This allows us to always have most, if not all our gripping surface on the object, allowing for more grip than a standard setup. Secondly, we have removable fingers, allowing users to quickly change out the length and shape of the fingers. Finally, we have installed pressure pads to the grippers, which can give information back to ROV pilots and help with collecting delicate artefacts. These three innovations will be able to compete with more established brands.

Questionnaire 2: what about the long-term use and reliability?

Presenter 1: well, a common manipulator arm is the Schilling Titan 4, which has been tested under full load for 250,000 underwater cycles with minimal wear. However, part changes between years are common, especially for the high friction or wear parts like the O-rings or actuator bushings. Our prototype should have a life span of around 7 years, with major part replacements like actuators and structural components every 2 year, thanks to our corrosion resistant materials and good structural design.

4th scene – customer reviews:

Questionnaire 3: do we have any real customer experience?

Presenter 2: Yes!

Customer 1: Hi! I'm an archaeologist who specialises in recovering artefacts from within shipwrecks. Recently, we had issues with trying to pick up loose rocks from the seabed, especially with the currents making it difficult to position the gripper so that we wouldn't lose it. In this case, the CTD would have been a great help, as the adjustable fingers would have made errors in positioning have a lesser impact on the chance of picking up the rock sample.

Customer 2: Nice to meet you! I'm a scientist who uses ROV manipulator arms to pick up small animals, like coral. However, when we do try and pick them up, we run the risk of damaging them or even killing them, as the arms are very strong. It is very difficult to know how much force to use when trying to pick them up, as there is no direct form of pressure sensor or similar. However, if we were using the CTD, then we would be able to know how much pressure we are exerting and be able to test how much pressure would damage a coral sample, making it easier to not damage samples.

5th Scene – final advertisement:

Presenter 1: well, as you can now see, our CTD] will revolutionise the ROV manipulator arm scene, with our new innovations-

Scientist: -engineered with innovation and adaptability in mind-

Presenter 2: so, whether your exploring ancient underwater ruins or hauling up century old treasure chests –

Presenter 1: - the CTD will adapt to your mission, task, and environment!