Student Workshop on 3D Data Capture and Processing in Underwater Archaeology in Portorož, Slovenia

Delavnica za študente "Zajem in obdelava 3D podatkov v podvodni arheologiji", Portorož, Slovenija

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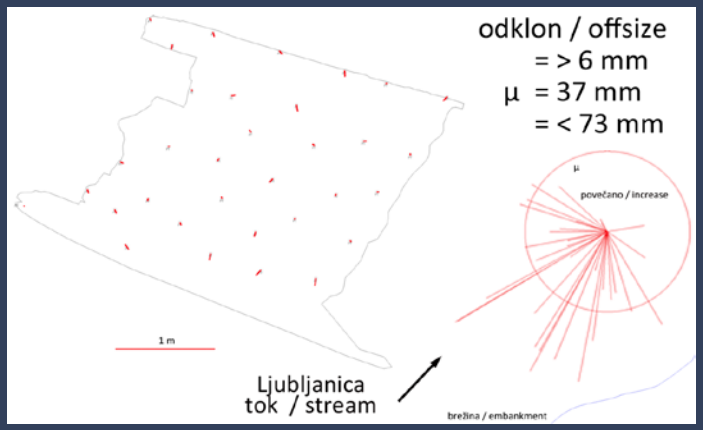
In early July, a student workshop on 3D Data Capture and Processing in Underwater Archaeology took place in Portorož, organised by the Institute for the Protection of Cultural Heritage of Slovenia (Miran Erič) and the University of Ljubljana's Faculties of Computer and Information Science (Franc Solina) and Maritime Studies and Transport (Marko Perkovič). Sixteen students and underwater archaeologists attended this international workshop from the Department of Archaeology, the Faculty of Arts, the Computer Vision Laboratory at the Faculty of Computer and Information Science, the Archaeology Department at the University of Zadar and the Archaeological Museum of Zadar.

The workshop programme was divided into morning field work at the site of sunken wooden cargo ships (Maona) in front of the Portorož salt warehouses, and afternoon lectures and workshops on archaeological methods and terminology, underwater archaeology, 3D data capture, photography, photogrammetry and 3D data processing, which all took place at the Faculty of Maritime Studies and Transport.

The workshop offered lectures and an introduction to various possibilities in documenting – over five days the authors presented the importance of documenting underwater heritage, methodology, techniques and the development of 3D tools and software, while Darja Grosman from the Department of Archaeology, Faculty of Arts gave a lecture on archaeological methodology, importance, remote data collection and prospects, and the difference between 2D > 3D > 4D.

2. a. 3D model constructed by photogrammetric processing, b. 3D model taken by Artec MHT scanner (photo and 3D models: R. Kovačič, processing with Autodesk 123D, 3D view with Meshlab).
a. 3D model narejen s fotogrametričnim procesiranjem, b. 3D model posnet s snemalnikom Artec MHT (photo in 3D modeli: R. Kovačič, procesiranje z Autodesk 123D, 3D ogled z Meshlab).

Marko Perkovič from the Faculty for Maritime Studies and Transport presented the Faculty's



1. The comparative analysis of 3D model and surveys conducted with tacheometer
Primerjalno analizo med 3D modelom in meritvami s tahimetrom

V začetku julija je bila v Portorožu organizirana delavnica za študente "Zajem in obdelava 3D podatkov v podvodni arheologiji" v organizaciji Zavoda za varstvo kulturne dediščine Slovenije (Miran Erič), Fakultete za računalništvo in informatiko UL (Franc Solina) ter Fakultete za pomorstvo in promet UL (Marko Perkovič). Mednarodne delavnice se je udeležilo 16 študentk in študentov ter podvodnih arheologov iz Oddelka za arheologijo Filozofske fakultete, Laboratorija za računalniški vid Fakultete za računalništvo in informatiko, Odjela za arheologiju Sveučilišta u Zadru ter Arheološkega muzeja iz Zadra.

Program delavnice je bil razdeljen na dopoldansko terensko delo na najdišču potopljenih lesenih tovornih ladij (maon) pred skladišči soli v Portorožu ter na popoldanska predavanja in delavnice o arheološki

3. Udeleženci delavnice
The workshop participants (photo: M. Perkovič)

nautical simulator and its importance for the protection of underwater cultural heritage. Rok Kovačič, Gregor Berginc and Žiga Stopinšek prepared seminars involving practical work: digital photography and cameras, the specific characteristics of underwater photography; lectures, workshops and exercises; programming tools for photogrammetry; lecture, workshops and exercises; 3D scanning, scanners, programming tools and prospects; lecture, workshop and exercises. Smiljan Glušević, the director of the Archaeological Museum of Zadar, presented insights into the contents of documenting and gave a lecture on the Apoxyomenos – from discovery to exhibition. Sebastijan Govorčin, a student at the University of Zadar, gave a lecture on shipbuilding terminology and on terminology pertaining to parts of a ship's structure.

One of the reasons for the good atmosphere and the high point of the introduction to the cultural heritage of Slovenian territorial waters was a meeting with the oldest living shipbuilder on the Slovenian coast, Mr Davide Filipas, who was presented at with the Shipbuilding Department of the Sergej Mašera Maritime Museum in Piran by curator Uroš Hribar. The Maritime Museum was presented by its director Franco Juri and its curator Snježana Karinja. The participants had the special honour of meeting Elica Boltin Tome, a pioneer in Slovenian coastal underwater site research, now retired. Curator Doris Delgiusto took us on a guided tour of the exhibition at the Piran Museum of Underwater Activities.

REASONS FOR HOLDING THE WORKSHOP

The development of hardware and programming solutions, the trend towards public access to common knowledge (a community that develops open-source systems) and the flexibility of the research community in the field of heritage research have in the past ten years changed the methodology of on-site heritage documentation. In just three steps, documenting has completely changed from first being done completely manually and

metodologiji in terminologiji, podvodni arheologiji, zajemu 3D podatkov, fotografiji, fotogrametriji in obdelavi 3D podatkov, ki so potekale v prostorih Fakultete za pomorstvo in promet.

Delavnica je ponudila predavanja in seznanjanje z različnimi možnostmi pri dokumentiranju, kjer sta avtorja v 5 dneh predstavila Pomen dokumentiranja podvodne dediščine, metodologija in tehnike ter razvoj 3D orodij in programske opreme, Darja Grosman iz oddelka za arheologijo Filozofske fakultete Arheo-

4. Curator Doris Delgiusto led the participants through the exhibitions at the Sergej Mašera Maritime Museum in Piran
Kustosinja Doris Delgiusto je udeležence vodila po razstavah Pomorskeg muzeja Sergej Mašera v Piranu (photo: F. Solina).

loško metodologijo, pomen, daljinsko zajemanje podatkov in perspektive ter razliko med 2D > 3D > 4D.
Marko Perkovič iz Fakultete za pomorstvo in promet je predstavil in demonstriral delovanje Navtičnega simulatorja FPP in njegov pomen za varstvo podvodne kulturne dediščine, Rok Kovačič, Gregor Berginc in Žiga Stopinšek pa so pripravili seminarje s praktičnim delom: Digitalna fotografija in fotoaparati, Posebnosti podvodne fotografije; predavanje, delavnica in vaje; Programska orodja za fotogrametrijo; predavanje, delavnica in

5. Davide Filipas, the legendary oldest living shipbuilder on the Slovenian coast
Legendarni, najstarejši še živeči ladjedelec na slovenski obali Davide Filipas (photo: F. Solina)

producing doubtful results in terms of accuracy – it was not in fact possible to detect and assess errors – to the digital recording of sites, and the final shift to entirely automated hardware and software documenting of sites, and will provide high-quality and scientifically verifiable documentation in the future.

An example of the progress made is the comparative analysis of a 3D model of the Roman ship from Sinja Gorica (Erič, Gaspari 2009; Erič et al. 2013) with simultaneously conducted geodetic surveys. These should be quite precise since the depth where the ship is located is only 3 m. Mistakes were detected in surveying conducted with a tacheometer (Figure 1), which pointed to the fact that they were connected to the flow of the Ljubljanica River. More important is the bitter realisation that to date faith in geodetic surveys was complete and the analogue documentation was drawn up in accordance with these surveys, which cannot be verified, and therefore the mistakes will remain unknown. Underwater heritage sites in deep waters are mostly shipwrecks and other sunken objects (aeroplanes, very rarely anything else), while in shallow coastal waters, due to geological changes such as erosion and tectonic shift, we encounter submerged architecture and other infrastructure. The increasingly better availability of 3D data collection devices and the quality of free 3D photogrammetric modelling software has completely changed the methodology of documenting underwater heritage.

Currently, new technologies for 3D data capturing and open-source solutions for the processing and modelling of such data are key to the development underwater cultural heritage

vaje; 3D snemanje, snemalniki, programska orodja in perspektive; predavanje, delavnica in vaje.
Vpogled v vsebino dokumentiranja sta predstavila direktor Arheološkega muzeja iz Zadra Smiljan Gluščevič, ki je predstavil Apoksiomen. Od odkritja do razstave ter študent Sveučilišta iz Zadra Sebastijan Govorčin, ki je spregovoril o Terminologiji v ladjedelništvu in delih ladijske konstrukcije.

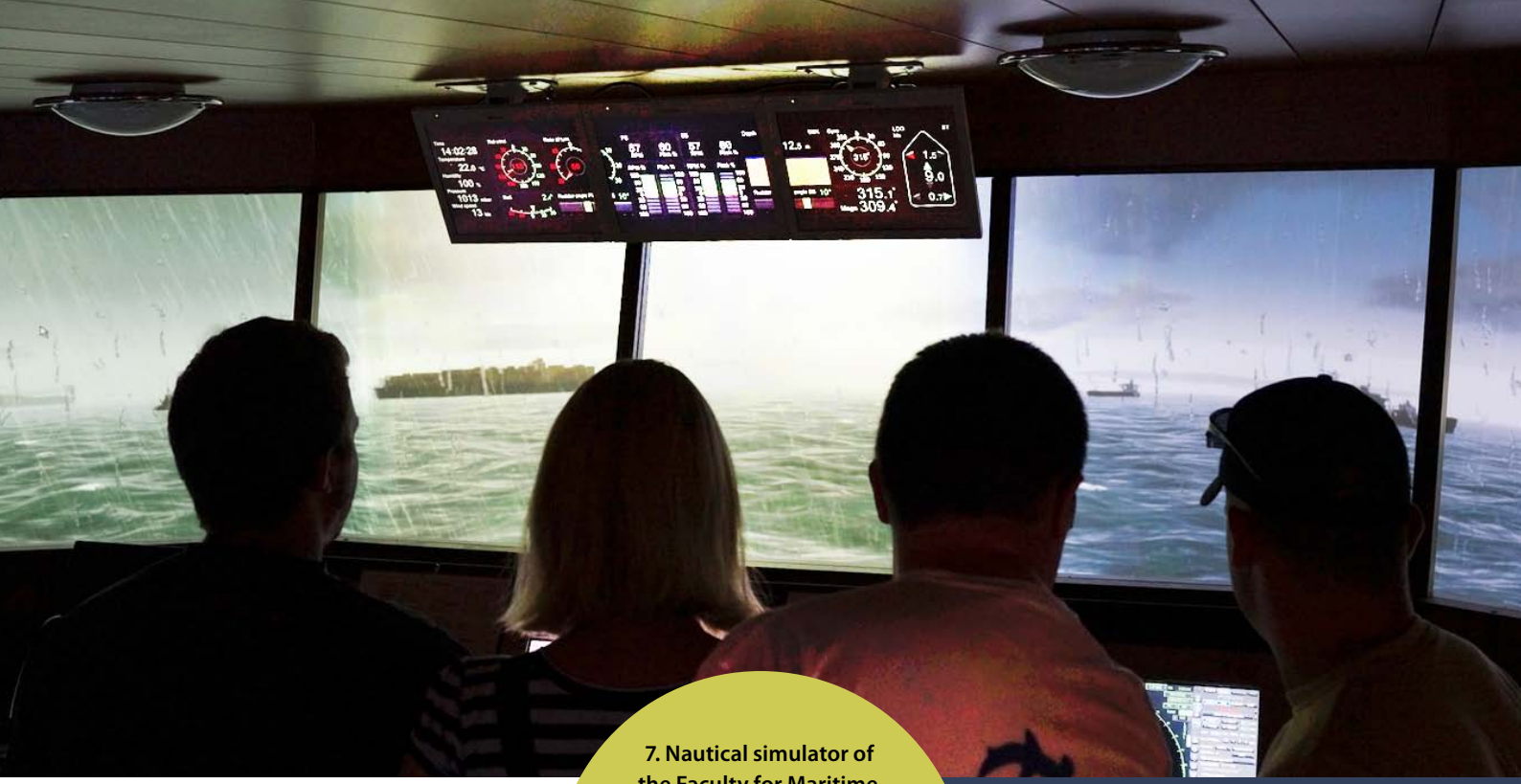
K dobremu počutju in seznanitvi s kulturno dediščino slovenskega teritorialnega morja pa so zaznamovala tudi srečanja z najstarešim živečim ladjedelcem na slovenski obali g. Davideom Filipasom, ki ga je hkrati z Oddelkom za ladjedelništvo Pomorskega muzeja "Sergej Mašera" iz Pirana predstavil kustos Uroš Hribar. Pomorski muzej so še posebej predstavili direktor muzeja Franco Juri, kustosinja Snježana Karinja, udeleženci delavnice pa so imeli posebno čast srečati tudi pionirko raziskav podvodnih najdišč v priobalnem morju Elico Boltin Tome, danes upokojenko. Po razstavi v Muzeju podvodnih dejavnosti Piran nas je popeljala kustosinja Doris Delgiusto.

RAZLOGI ZA PRIPRAVO DELAVNICE

Razvoj strojne opreme in programskih rešitev, trend javne dostopnosti do skupnega znanja (skupnost, ki razvija odprtokodne sisteme) in fleksibilnost raziskovalne skupnosti na področju raziskovanja dediščine je v 10 letih spremenil metodologije dokumentiranja dediščine in situ. V treh korakih se je dokumentiranje iz povsem ročnega in v smislu natančnosti - napak pravzaprav niti ni bilo mogoče prepoznati in oceniti - negotovega rezultata preko digitalnega snemanja najdišč prelevilo v povsem avtomatizirano strojno in programsko dokumentiranje najdišč, ki bo v bodoče zagotavljalo visokokvalitetno ter znanstveno preverljivo dokumentacijo.

Kot primer napredka si velja ogledati primerjalno analizo 3D modela rimske ladje iz Sinje Gorice (Erič, Gaspari 2009; Erič et al. 2013) z geodetskimi meritvami, ki so bile opravljene sočasno. Te bi morale biti dokaj precizne saj je globina na kateri se nahaja ladja zgolj 3 m. Ugotovljene so bile napake v meritvah s tahimetrom (Slika 1), ki so pokazale na dejstvo, da so bile povezane s tokom Ljubljanice. Pomembnejše je grenko spoznanje, da je bilo doslej zaupanje v geodetske meritve popolno in je bila risana analogna dokumentacija vezana na meritve, ki jih ni mogoče preverjati, prav tako pa ostaja neznana tudi napaka. Podvodna najdišča dediščine so v globjih vodah v veliki večini brodolomi in drugi potopljeni objekti (letala, zelo redko še kaj drugega), v plitvih priobalnih delih pa zaradi geoloških sprememb kot sta

6. Lecturer Gregor Berginc
Predavatelj Gregor Berginc (photo: F. Solina)



7. Nautical simulator of the Faculty for Maritime Studies and Transport, University of Ljubljana, presented by Marko Perkovič MSc
Navtični simulator Fakultete za pomorstvo in promet Univerze v Ljubljani vodi mag. Marko Perkovič (photo: F. Solina)

documentation. White light scanners (Stopinšek 2012), due to their technical limits (energy source, connection to computer, etc.) are not the best solution for documenting underwater heritage, but they can be useful under some conditions. Photogrammetry has completely changes due to the development of digital photography and, consequently, capturing image data. The devices are smaller, and the quality of the image is better. Because of the data processing difficulty and delays in documenting underwater heritage, photogrammetry was almost useless. However, in recent years, the research of photogrammetric procedures and computer processing of many images has seen rapid progress. Nowadays, due to the availability of open-source programmes and free access to programming tools – programming tools of the former generation were extremely expensive and therefore unavailable to a wider circle of researchers – the possibilities for accurate data capturing and quick on-site execution are great.

Comparative tests were conducted 3D point accuracy for the results obtained by a white light scanner and the photogrammetrically processed 3D model (Figure 2). The comparison showed that, in the majority of instances, 3D models obtained by photography and processed by photogrammetric software produced better results. The structured-light 3D scanner (< 0.1 mm) is more precise when it comes to the morphological features of an object's surface. In the case of capturing greater surfaces, where it is necessary to have several consecutive scanning cycles, the rate of error inevitably increases (Stopinšek 2012).

3D modelling software has to combine two elements: (1) groups of images for site analysis and (2) groups of images for depicting a 3D model.

The study procedures may be performed automatically or semi-automatically: (1) segmentation analysis, (2) 2D metric and volume metric analysis of 3D models, (3) orthographic analysis and conversion of 3D models into 2D basic plans, (4)

erozija in tektonski premiki, tudi potopljena arhitektura in druga infrastruktura. Čedalje boljša dostopnost do naprav za 3D zajemanje podatkov in kvaliteta prostodostopnih programov za 3D modeliranje s pomočjo fotogrametrije povsem spreminja metodologije dokumentiranja podvodne dediščine.

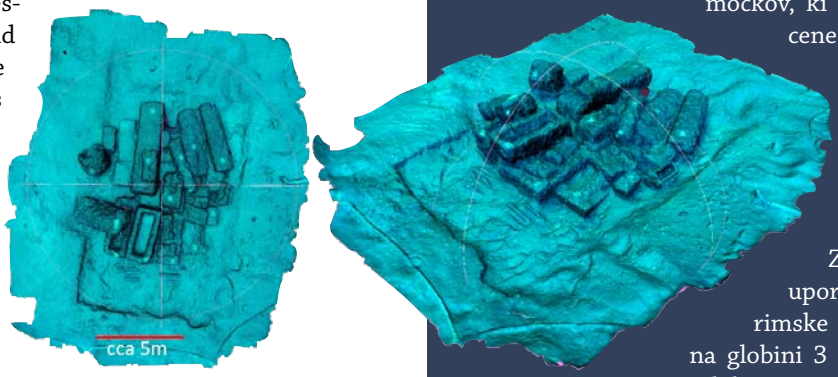
Ta hip so za razvoj dokumentiranja podvodne kulturne dediščine najpomembnejše nove tehnologije za zajem 3D podatkov in odprtokodne rešitve za predelavo in modeliranje takih podatkov. Snemalniki na belo svetlobo (Stopinšek 2012) zaradi tehničnih omejitev (vir energije, povezave z računalnikom itd.) niso najboljša rešitev za dokumenitranje podvodne dediščine, so pa pogojno uporabni. Fotogrametrija se je zaradi razvoja digitalne fotografije in s tem zajemanje slikovnih podatkov popolnoma spremenila. Aparati so manjši, kakovost slike pa boljša. Fotogrametrija je bila zaradi zahtevnosti in zamudnosti pri obdelavi podatkov pri dokumentiranju podvodne dediščine skorajda neuporabna. V zadnjih letih pa so raziskave fotogrametričnih postopkov in računalniške obdelave množice slik zelo napredovale. Zaradi dostopnosti do odprtokodnih programov in prostega dostopa do programskih orodij - programska orodja prejšnje generacije so bila izjemno draga in zato nedostopna širšemu krogu raziskovalcev - so danes možnosti za natančno zajemanje podatkov in hitro izvedbo na terenu povsem odprte.

Izvedeni so 3D natančnost bili primerjalni testi med rezultati snemalnika na belo svetlobo in fotogrametrično procesiranim 3D modelom (Slika 2). Primerjava je pokazala, da so v večini primerov 3D modeli dobljeni s fotografijo in procesirani s fotogrametrično programsko opremo bolje rezultirani. 3D snemalnik na strukturirano svetlobo (< 0,1 mm) je bolj natančen pri morfoloških zazavah površine predmeta. V primeru zajema večjih površin, kjer je potrebno sestavljati več zaporednih snemalnih ciklusov se začne napaka nenadzorovano večati (Stopinšek 2012).

Programska oprema za 3D modeliranje mora združiti dva

8. Lectures, demonstrations and exercises were held in the afternoon at the lecture hall of the University of Ljubljana's Faculty of Maritime Studies and Transport
Predavanja, demonstracije in vaje so se v popoldanskem času odvijale v predavalnicah Fakultete za pomorstvo in promet Univerze v Ljubljani (photo: F. Solina)

registration of the site in GIS, and (5) automatic classification by using open databases.
There are readily available advantages of using modern technology and surveying accessories, which are more and more affordable, while open-source software is literally improving on a daily basis. In the research of underwater heritage, the safety of divers comes first. For the sake of comparison, we can use the case of documenting the Roman vessel in Sinja Gorica at a depth of 3 m (Erič 2012). The drafting of manual documentation, covering 2D layout, 2-3 cross sections and 2-3 longitudinal sections, sketch and orthographic projection, would require 25 to 30 hours of diving. By using photographic sequences – with each sequence covering over 900 photographs – we needed a mere 3 to 4 hours of diving to conduct 3D photogrammetric modelling of the 3 phases of research of the layers of the vessel with the help of PHOV Mementify software.



9. A Roman period shipwreck with a cargo of sarcophagi at Sutivan on the island of Brač: a 3D model of the wreck
Antični brodolom s tovorom sarkofagov, Sutivan, Brač: 3D model brodoloma (photo: R. Kovačič, 3D model: G. Berginc, PHOV Mementifiy, Meshlab)

It is easy to understand and recognise from this that, with the latest 3D data capturing technologies, the availability of open-source programming tools and development of tools for the segmentation and processing of 3D data captured in underwater heritage research, we can obtain a previously unachievable accuracy of primary documentation, improve the safety of underwater work by reducing the time spent under

elementa: (1) skupino posnetkov za analizo najdišča in (2) skupino posnetkov za upodobitev 3D modela.
Postopki proučevanja so lahko izvedeni avtomatsko ali polavtomatsko: (1) segmentacijska analiza, (2) 2D merska ter volumenometrična analiza 3D modelov, (3) ortofotografska analiza in pretvorba 3D modela v 2D temeljne načrte, (4) vpenjanje najdišča v GIS, in (5) samodejno klasificiranje z uporabo odprtih podatkovnih zbirk.

Prednosti pri uporabi sodobne tehnologije in merilnih pripomočkov, ki dobivajo vse bolj dostopne cene in dobesedno vsakodnevnemu izboljševanju odprtokodne programske opreme so na dlani. Varnost potapljačev je na prvem mestu pri raziskavah podvodne dediščine. Za primerjavo je mogoče uporabiti dokumentiranje rimske tovorne ladje v Sinji Gorici na globini 3 m (Erič 2012). Za izdelavo ročne dokumentacije, ki bi obsegala 2D tloris, 2 - 3 prečne preseke in 2 -3 vzdolžne preseke, naris in ortografski tloris bi potrebovali 25 do 30 potapljaških ur. S pomočjo fotografskih nizov - vsak niz je obsegal preko 900 fotografij - za fotogrametrična 3D modeliranja 3 faz odkrivanja ladje po plasteh s pomočjo programske opreme PHOV Mementify smo potrebovali zgolj 3 - 4 potapljaške ure.

Iz naštetega je mogoče razumeti in prepoznati, da gre pri uporabi najnovejših tehnologij 3D zajemanja podatkov, dostopnosti prostokodnih programskih orodij in razvoj novih orodij za segmentacijo in obdelavo 3D zajetih podatkov pri raziskavah podvodne dediščine, za še nedosežene pridobitve pri natančnosti primarne dokumentacije, povečevanje varnosti pri podvodnem delu s skrajševanjem časa pod vodo in s tem povezan precej nižji strošek raziskav. Tako postajajo razmerja med kvaliteto podatkov in ceno za rezultate povsem neprimerljiva s tovrstnimi razmerji v preteklosti.

10. Manual data capture exercise at an archaeological site
Vaje iz ročnega zajema podatkov na arheološkem najdišču (photo: GoPro)

water and thus significantly reduce the costs of research. Therefore, the ratio between the quality and price of data has become entirely incomparable with this ratio in the past.

The pedagogical objectives of the student workshop on 3D Data Capture and Processing in Underwater Archaeology can be divided into short-term and long-term objectives.

SHORT-TERM OBJECTIVES:
(1) systematic observation of underwater cultural heritage, (2) documenting underwater heritage prior to the technological and computer development of surveying equipment and programming tools and the transition to the use of the latest tools, (4) awareness of the need for three important advantages when it comes to underwater heritage research; (a) the precision of documentation due to better interpretation possibilities, (b) increased safety due to the reduced time needed for documenting, and (c) the implementation of a better ratio between the lower price of underwater work and the higher quality of results, (5) self-evaluation, planning, performance of learning processes and continuous professional education and training, and (6) independent on-site research.

LONG-TERM OBJECTIVES:
(1) interdisciplinary participation in the field of underwater heritage research, (2) broadening the present multidisciplinary research of heritage, enabling inductive and deductive conclusions and understanding of underwater heritage, (3) evaluation and integration in international underwater heritage research, (4) the dissemination of research results to the professional and wider non-professional community, (5) improving the relations and understanding the importance of underwater heritage for the history of mankind, and (6) applying to tenders and acquiring funds for scientific and development research activities.

Pedagoške cilje Delavnice za študente "Zajem in obdelava 3D podatkov v podvodni arheologiji" lahko razdelimo na kratkoročne in dolgoročne.

KRATKOROČNI:
1. Sistematično opazovanje podvodne kulturne dediščine, 2. Dokumentiranje podvodne dediščine pred tehnološko -računalniškim razvojem merilne opreme in programskih orodij s prehodom na uporabo najnovejših orodij, 4. zavest o potrebi po treh pomembnih prednostih pri raziskavi podvodne dediščine; (a.) natančnost dokumentacije zaradi boljših možnosti interpretacije, (b,) povečana varnost zaradi skrajšanega časa za dokumentiranje in (c.) implementacija izboljšanega razmerja med nižjo ceno podvodnega dela in višji kvaliteti rezultatov, 5. ocena lastnega dela, načrtovanje, izvedba učnih procesov in stalno strokovno izpopolnjevanje, ter 6. samostojno raziskovalno delo na terenu.

11. The participants prepare for underwater work - dive leader R. Kovačić gives instructions
Priprava udeležencev na podvodno delo in napotki vodje potopov R. Kovačiča (photo: Ž. Stopinšek)

DOLGOROČNI:
1. Interdisciplinarno sodelovanje na področjih raziskovanja podvodne dediščine, 2. širjenje zastavljene multidiciplinarne raziskave dediščine, ki omogočajo induktivna in deduktivna sklepanja in razumevanja podvodne dediščine, 3. evalvacija in vključevanje v mednarodne raziskave podvodne dediščine, 4. diseminacija raziskovalnih rezultatov strokovni in širši laični javnosti, 5. poglabljanje odnosa in razumevanje pomena podvodne dediščine za skupno zgodovino človeštva in 6. aktivnosti prijavljanja na razpise in pridobivanja sredstev za znanstveno-raziskovalne in razvojno-raziskovalne naloge.

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