REAL TIME DIGITAL PHOTO SYSTEM FOR SEMI AUV TSL

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Abstract

One important task connected with marine ecosystems investigation consists in receiving of high resolution color photos of marine bottom in real time. The solution of this problem demands from one side of high stable platform for digital still camera, like AUV, and from other side of high speed communication channel for digital images translation to researcher on supporting ship for results estimation in real time.

The high resolution digital photo system and fiber optical communication system designed for semi AUV TSL are described in the paper. TSL is a self-propelled underwater vehicle equipped with data-command link to operator on the supporting ship by light one fiber optical cable.

Some results of bottom survey for diversity investigation and colony density estimation of bottom objects in Great Peter Bay of Japan Sea are supplemented.

1. Introduction

Evaluation of water environment condition, benthic animals and algae distribution density has great theoretical and practical value for ecosystem research. The underwater vehicle equipped with image and ecological sensors allows to obtain the objective and documented information about biocenosis in general and its plant component in particular. It makes possible to evaluate a character of bottom, a level of species dominance, evidence of their state and density of population. The information can be obtained on long lines in preset areas in the form of video record, photo images and sensor data with the positioning, current time and date. This allows to use it for multiple and comparative analysis, for studies of species density and population dynamics, and for data processing with different mathematical methods[1].

The maximum quality of digital photo and precision of program trajectory following needed for covering of preset areas can be received by use of AUV. From other side it is important for operator on supporting ship to estimate current received images and to have opportunity of manual control of AUV and process of photo. It allows to have guarantee result of photo when objects of interest are detected.

The semi autonomous AUV TSL [1] consists of on-board control system, supporting automatic and manual modes of operation, autonomous power system, propulsion system, providing the wide vehicle motion modes including the hovering, positioning system, allowing to determine the location and orientation, based on acoustic and on-board autonomous navigation systems.

One of IMTP projects is connected with investigation of structures and functioning of marine ecosystems on the shelf. Based on images and data from sensors installed on TSL the database is accumulated for integrated analysis and study of dynamic of ecosystem elements functioning. Important here is the fact that aggregation search and colony density estimation of bottom objects using AUV do not disturb the conditions and biosphere of inquiry subjects.

IMTP and TINRO-centre in 2001- 2002 years fulfilled conjoint research for diversity investigation and colony density estimation of bottom objects in Great Peter Bay using semi autonomous underwater vehicle TSL. Operations were conducted on depth up to 90 meters.

In the second section of the paper the TSL characteristics are supplemented, the digital photo and fiber optical communication systems between TSL and operator console on supporting ship are described. Some details of digital photo system operation parameters adjustment are discussed in the section three. Approach to ecology monitoring of marine shelf by semi AUV TSL use and some survey results during Great Peter Bay bottom investigation in 2002 year are described in the section four of the paper.

2. Semi AUV TSL structure

Semi AUV TSL (fig.1.) is a specialized self-propelled underwater vehicle with data-command link to operator on supporting ship by fiber-optical cable of 2 mm in diameter. The vehicle is rigged with color video and digital photo cameras. Video camera is

Fig.1 Semi AUV TSL.

installed on pan and tilt platform and allows a forward vision in wide angle. Photo camera is arranged on the vehicle's bottom and oriented vertically down.

Vehicle propulsion system consists of six thrusters (two in the nose and four in the stern TSL sections). It provides wide number of motion modes including hovering. Cable freely winds off from the reel when TSL is moving. Dimensions and specifications of TSL are shown in table 1.

Table 1

Dimensions and specifications of TSL

Length	3030 mm
Diameter	533 mm
Dry weight	320 kg
Max speed	2 m/s
Max depth	200 m
Batteries	24 V/70 Ah
Endurance (v=1.2 m/s)	10 hours
Max length of fiber optical cable	5 km

TSL control system is distributed and consists of on board control system or autopilot on the vehicle and operator console on the supporting ship. Operator console based on PC is intended for input of control information and TSL operation mode by multi windows graphic user interface /GUI/ in real time and also for accumulation and visualization of TSL sensor data.

The manual and automatic modes of TSL control system operation are possible for region inspection. In the manual mode an operator organizes TSL trajectory for region covering by setting of TSL motion parameters (height or depth, velocity and heading) from console. For trajectory covering of region in automatic mode the operator initializes one of the standard missions, corresponding to the predefined trajectory. In this case an operator can stop the mission execution at any time, investigate the detected target in manual mode and then continue mission fulfilling.

TSL control system automatically stabilizes mission height or depth, head and motion velocity. On base of down, forward and slope echo sounders on board control system allows automatic obstacle avoidance in vertical plane.

Transmission of current video and photo images and sensors measurements to operator console through the fiber optical cable provides the real time search and inspection of objects on the bottom and in water column.

Positioning of TSL and supporting ship trajectories is fulfilled on base of joint data processing from GPS, USBL positioning system and TSL on-board autonomous navigation system. It enables to calculate the TSL trajectory coordinates and detected object positions in geographical coordinate system with error about 10 meters.

The map with TSL and supporting ship trajectories is visualized in one of graphic windows of operator graphic user interface.

2.1. Color digital photo system

The TSL digital photo system operates under control of on-board computer of TSL technical vision system /TVS/. The photo system consists of digital CCD camera, flashbulb and framegrabber that connected to TVS computer by PCI channel. Digital CCD camera and framegrabber were produced by VIDEOSCAN (RUSSIA). The structure of digital photo system as a part of TSL is shown on fig. 2.

The digital photo camera produces image size of 1280*1024 pixels. The camera has resolution of image intensity in each pixel of 10 bits. Exposition time

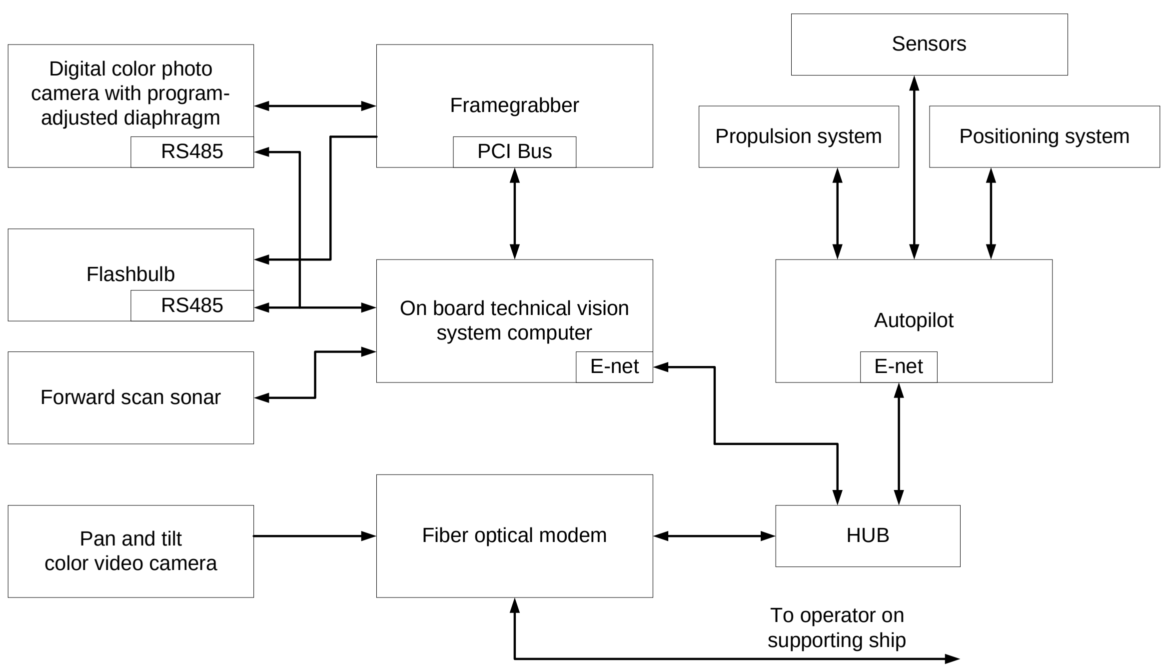

Fig.2. The structure of digital photo system as a part of TSL.

can be changed from 56 mks to 110 seconds from operator console or by TSL mission program. The maximum of frame frequency is 7.5 Hz. The camera has a progressive scanning and can to operate as automatically with preset period of time as episodically from operator or TSL mission program commands. For receiving of needed image quality as for day time as for night time just from flashbulb the camera has adjusted diaphragm that is controlled on base of commands from TVS computer using microcontroller connected to TVS computer by RS-485 interface.

Color decoding is fulfilled for receiving of color images. Color matrix of the camera has painting of pixels as shown on fig. 3. Resultant image is formed

R11	G12	R13	G14	R15	G16	...
G21	B22	G23	B24	G25	B26	...
R31	G32	R33	G34	R35	G36	...
G41	B42	G43	B44	G45	B46	...
R51	G52	R53	G54	R55	G56	...
G61	B62	G63	B64	G65	B66	...
...	...	...	...	...	...	...

Fig.3. The painting of color matrix pixels of the CCD camera.

by interpolation of image intensity of identical color pixels. For example, even diagonal elements are calculated using next expressions:

$$r_{ii}= (R_{i-1i-1}+R_{i-1i+1}+R_{i+1i-1}+R_{i+1i+1})/4,$$
$$g_{ii}= (G_{i-1i}+ G_{ii-1}+ G_{ii+1}+ G_{i+1i})/4,$$
$$b_{ii}= B_{ii}.$$

Framegrabber drives of digital camera functioning and sets its operation modes based on commands from TVS computer. Framegrabber allows a synchronous operation of digital camera and flashbulb by generation of program delay between signal for flashbulb and signal for image capture. It contains two memory banks of one digital image size each. When current image is stored in one of the memory bank the previous image can be translated from other memory bank to TVS computer by PCI channel.

The flashbulb allows needed illumination in survey region. The energy of flash is assigned on base of commands from TVS computer using flashbulb microcontroller that connected to TVS computer by RS-485 interface. Maximum of flash energy of the flashbulb is 120 joule.

The photo system software consists of two parts. One of the part is installed on TVS computer of TSL and allows mode adjustment and operation of framegrabber, flashbulb and digital camera. During operation captured digital images are stored in the memory of TVS computer. The second part of photo system software is installed on computer of operator console and intended for images preprocessing, making incuts of sensors data to images and its representation on operator monitor in preset format.

2.2. TSL fiber optical communication system

TSL fiber optical communication system includes on ship fiber optical communication module installed in operator console and TSL fiber optical communication module. Both modules allow one optical line for one side translation of standard color TV signal (PAL, SECAM, NTSC) and one Ethernet 10 Mbit channel by one standard single mode optical fiber. The structure of the system is shown on fig.4.

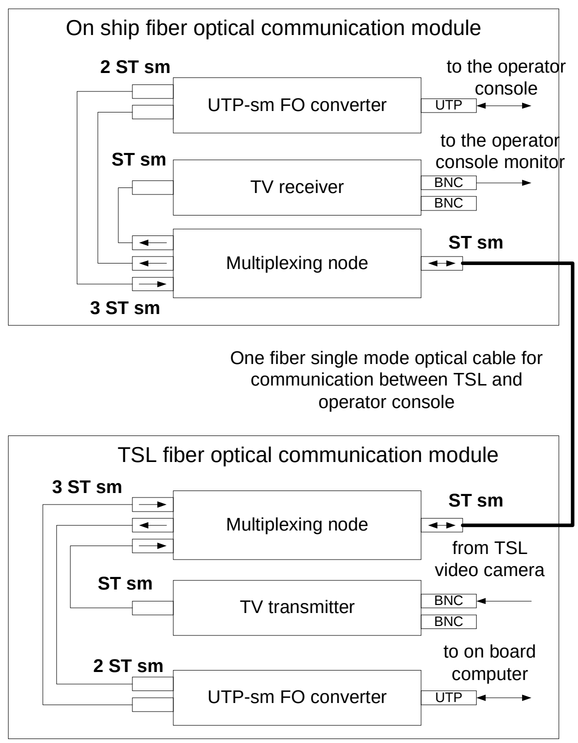

Fig.4. TSL fiber optical communication system.

TSL fiber optical communication module consists of UTP – sm FO converter intended for conversion of electrical signals of E-net interface to optical and vice-versa (wave length is 1.31), BNS – sm FO converter intended for conversion of standard TV electrical signal to optical signal (wave length is 1.55) and multiplexing node that mixes mentioned above optical lines to one optical fiber.

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FO converter intended for conversion of optical signal (wave length is 1.55) to standard TV electrical signal and multiplexing node that allows detection of optical lines from one optical fiber.

3. Method of bottom objects survey using semi AUV TSL

Bottom survey on base of TSL use was fulfilled by next way. Before shallow water operation the survey area is divided into regions. The supporting ship is anchored in the center of each region for inspection. Region size depends on fiber optical cable length that TSL reel was equipped. Then regions are inspected using sensors and TV system. Operational distance of TV system depends on water transparency and ranges from 0.5 to 8 m on the shelf. For probability restriction of AUV fiber optical cable tangling around bottom objects (rocks, grass and industrial targets) two shifted opposite tacks trajectories were used.

After run into hydrobionts aggregation, digital photo system is switching on by command from on ship operator. In this mode the AUV moves by fixed tack and catches still photo images with programmed period. The data received during AUV operation (bottom color video and still photos, sensor measurements and motion parameters) are stored for next analysis.

Let estimate the maximum AUV velocity when can be received sharp images of bottom. It can be chosen from condition that for exposition time the displacement of the AUV must not exceed the distance equal to the length between neighbor strings of the image.

Suppose that camera is oriented vertically down and has vision angles $\phi=28°$ in longitudinal direction and $\varphi=35°$ in transversal direction respective to AUV motion. In this case the region of shooting is rectangle the transversal side H of which equals:

$$H = 2h*tg(\phi/2),$$

where h – height of survey.

Let assume that the exposition time equals τ second and the image size in the direction of AUV motion is m pixels. The expression for maximum AUV velocity v_{max}, when can be received sharp images, has view:

$$v_{max} = 2h*tg(\phi/2) /(m*\tau).$$

When h = 1 meter, m = 1020 pixels and $\tau = 10^{-3}$ seconds it can be calculated that $v_{max} \approx 0.5$ m/s.

The optimal period of shooting T, when there are no overlapping frames and gaps are absent, can be found from:

$$T = H/ v_{max} = m*\tau,$$

From this expression it follows that optimal period of shooting is independent from height of AUV over bottom and motion velocity – the bigger height corresponds to the higher velocity. It can be calculated for given above parameters of shooting that T = 1.02 seconds.

For calculation of covered square by video survey without overlapping frames and gaps suppose that height of motion over bottom is 1 meter and running way – L = 350 meters. The size of visible region in transversal direction is calculated in accordance with expression $L = 2*h*tg(\varphi/2) \approx 0.63$ m and the square covered by digital shooting of high precision equals to $S = 0.63*350 \approx 220$ m^2.

The real size d of object in image frame is defined from expression:

$$d = L*k/R,$$

where k and R are measured on photo image the object size and frame horizontal size.

The digital images of the bottom received by TSL photo system are supplemented with two strings of data that consist of geographical coordinates (latitude and longitude) of image position, height over the bottom and depth of vehicle motion, current date and time, the temperature and horizontal size of bottom region reflected on still photo.

4. Some marine operation results

Bottom survey for hydrobionts population investigation was fulfilled in 2001 – 2002 using semi autonomous underwater vehicle TSL. The investigation results of 2001 year were published in [3] and data received in 2002 year were described in [4]. In this part we describe some results, received during joint expedition of IMTP and TINRO from 31 of August to 17 of October in 2002. Scientific ships “Impulse” and “Gastello” took part in the operations.

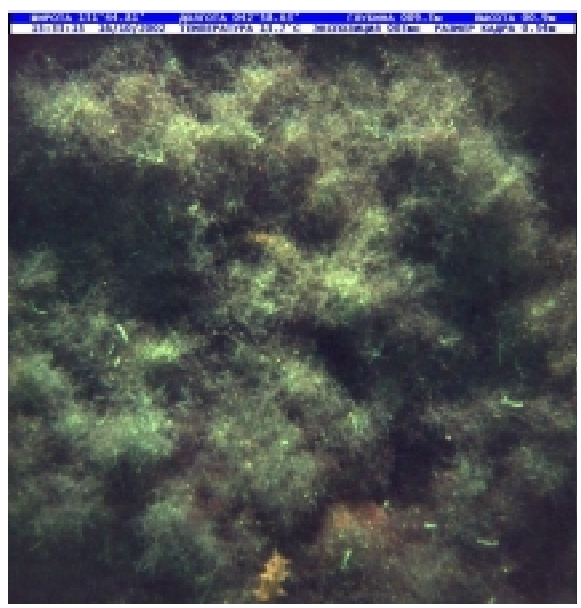

Fig.5. *Stichopus japonicus on Ahnfeltia tobuchiensis* field.

Fig.6. Image of *Cucumaria japonica*.

Bottom hydrobiont population in the Great Peter Bay consists of algae, sea-water grass, echinoderms, shellfish and crayfish.

One of objects for survey was aggregation of *Stichopus japonicus on Ahnfeltia tobuchiensis* in the Stark strait and near Ivantsev cape. Survey in August – September let to detect just some alone representatives of *Stichopus japonicus* on the layer of *Ahnfeltia tobuchiensis.* In the middle of October survey reveals considerable increasing of *Stichopus japonicus* on the layer of *Ahnfeltia tobuchiensis.* It proves the fact of observation that in warm summer period of time *Stichopus japonicus* located inside of layer of *Ahnfeltia tobuchiensis* but in cold late autumn period it goes up to the surface of *Ahnfeltia tobuchiensis* layer. Digital image with *Stichopus japonicus on Ahnfeltia tobuchiensis* field on depth of 10 meters is shown on Fig.5.

Other object of investigation was aggregation of *Cucumaria japonica.* The survey results prove the fact of *Cucumaria japonica* migration during seasons. Photo image with *Cucumaria japonica* on depth of 43 meters is shown on Fig.6.

Also there were visually detected some anomalies in evolution of *Asterias amurensis* (number of rays is more than five) and of *Patiria pectinifera*. Bottom images with marine stars and hedgehogs on depth of 12 and 43 meters are shown on fig. 7 – 8.

5. Conclusions

Quality video data become more and more significant in underwater scientific research. Marine biologists and ecologists need in color images of high resolution that complete the sensors information.

Video images and still photos received using TSL let to recognize the bottom hydrobionts species, to recognize their square density and size of objects, to define the bottom soil type. Bottom hydrobionts behavior observation in natural conditions by video is more ecologically safe and opens prospect for environmental protecting actions fulfilling.

Video information can be used for ecological monitoring, checking of water quality in lakes and bays with mapping of essential parameters, for aquaculture tasks, and also for bottom hydrobiont reserves evaluation with production estimation and ecosystem condition identification. Use of AUV gives an opportunity of bottom hydrobionts efficient utilization by making choice of more appropriate regions for fishing operations.

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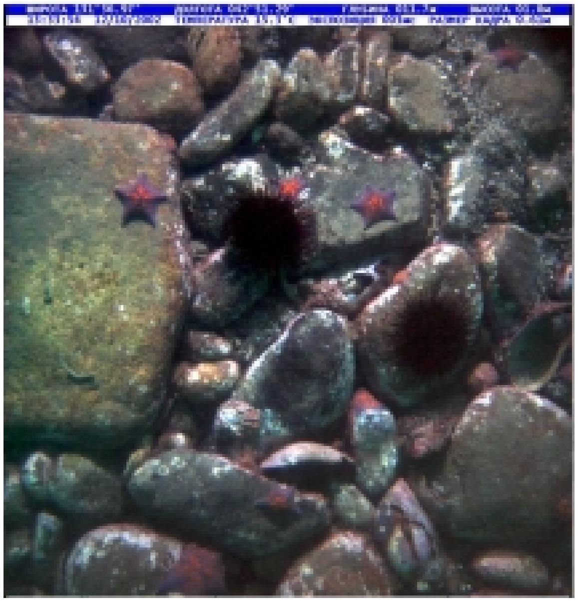

Fig.7 Marine stars and hedgehogs on depth of 12 meters.

Fig.8. Marine stars on depth of 43 meters.