Underwater Glider Embedded Control System Design Based on QNX Real-time Kernel

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***Abstract*—Underwater glider, being a new kind of underwater autonomous robot which has no external propulsion system equipped on it, is driven depending on buoyancy adjustment of itself. In development of underwater glider, its control system design plays an important role. The paper put forward the design approach to build embedded control system based on a real-time kernel in underwater glider. Hardware configuration of the control system is designed, in which SysCentreModuleTM-7108B main-board and M-System DOC2000 flash memory serve as core. The methods that drive DiskOnChip under QNX as well as QNX kernel migration to M-System DOC2000 are given. Main content and fundamental frame of system boot file-BuildFile which suitable for the embedded control system is created. Control system software modules applied in underwater glide is described and some of them were developed. All application software is supported by QNX real-time kernel and ultimately resided on DOC together with QNX. Theoretical analysis and some simulation experiments prove that the design idea is correct and the implementation approach is feasible.**

***Key words*— underwater Glider, QNX real-time kernel, embedded Software design, OS migration, simulation**

I. Introduction

Initially conceived by Henry Stommel[1], autonomous underwater gliders has attracted strongly research interests in ocean exploring and monitoring field. Underwater glider is a new kind of underwater autonomous robot which has no external propulsion system equipped on it. Underwater glider is driven depending on buoyancy adjustment system of itself. Adjustment system change barycenter of the carrier and gravity changes its gesture. Therefore, underwater glider can navigate along periodical zigzag track in water. Sailing sketch map of underwater glider is shown in Fig 1.

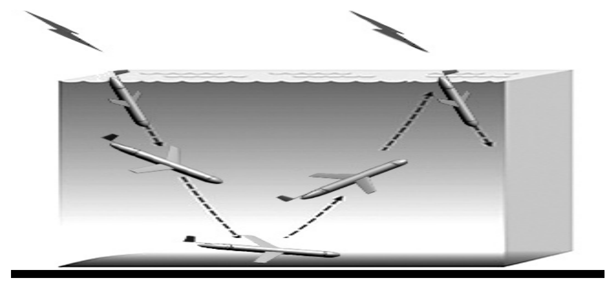

Figure 1. Sailing sketch map of underwater glider

Generally speaking, underwater glider has approximately 5 KG load capability. Except navigation control system absolutely necessary hardware, various appropriative sensors can be mounted on underwater glider to satisfy task need of ocean exploring and monitoring. Considering spatiotemporal density and operational flexibility on ocean monitoring, underwater glider shows prominence application future. U.S Office of Naval Research provided financial support for Autonomous Oceanographic Sampling Network (AOSN) project, several seaworthy gliders which named Sea-glider[2], Spray[3] and SLOCUM [4] were developed respectively.

Underwater glider have distinct propulsion and navigation system comparing with traditional underwater robot, therefore, it's controller design and navigation as well as sailing programming are different and novel. In order to develop underwater glider, it is critical to design its control system. Considering restriction of carrier space and load capacity, submarine control system of underwater glider should be embedded system so as to achieve high mobility and the robustness. Embedded application under supported by

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real-time operating system kernel represents embedded system development direction. Under real-time kernel, flexibility and extensibility of software module designing can be realized. Oriented to underwater glider, the paper design and implement embedded control system based on QNX real-time kernel.

II. EMBEDDED CONTROL SYSTEM HARDWARE DESIGN

Underwater glider is comprised of submarine control computer, gravity adjustment system, buoyancy adjusting system, energy system, sensors system etc. Control computer responsible for navigating data collection, glider's position prediction, motion control algorithm implementation, failure diagnosis as well as communication with surface mainframe. Communication subsystem of the submarine control computer realize the function of download navigating plan from surface mainframe, upload glider navigation state to surface mainframe. Hardware configuration of the underwater glider control system is shown in Fig. 2.

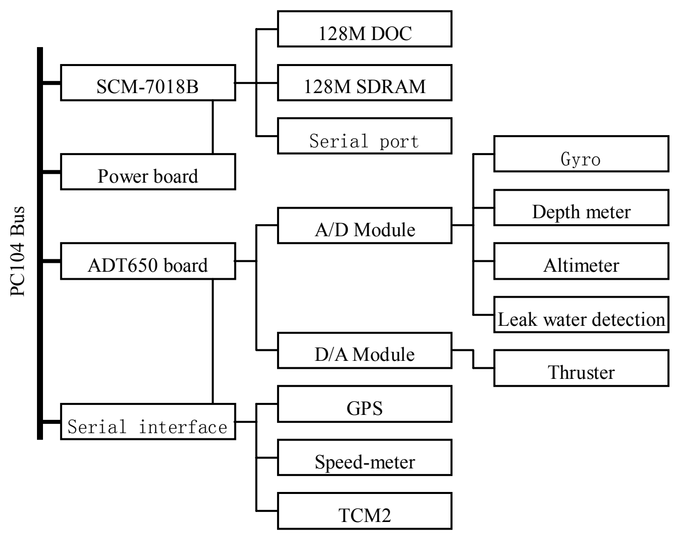

Figure 2. Underwater glider embedded control system hardware configuration

In hardware design, SysCentreModule™-7108B main-board bases on PC104 bus standard was selected, in which X86 processor is core. M-System DOC2000 flash memory was choose and equipped on SCM-7018B to provide DiskOnChip memory. QNX kernel and all control system software module supported by QNX are resident on this DOC. ADT650 Extension board provided A/D, D/A modules. A/D module is responsible for detecting underwater glider navigating information which needed for motion control algorithm calculation. D/A module provide control pulse output for step motors of buoyancy, gravity and pitching adjustment system. Serial interface board used to connect navigation positioning system. It transmits navigating positioning data information of GPS, Speed-meter and TCM2-50 electrical compass to embedded control system. The navigating positioning data is ultimately important for glider's position prediction and control. Power transmission board is a self-make board. The function is obtains embedded computer working power by inverted supply equipped on glider.

III. EMBEDDED SOFTWARE DEVELOPING PLATFORM

Underwater glider executes ocean monitoring tasks at submarine special environment. Real-time and security of the software is required mostly. Comprehensive considering factors of running speed, kernel size, scheduling strategy, security and power consumption, QNX Neutrino real-time operating system is employed in the underwater glider control system development. The inherent reliability and excellent performance have proved that QNX RTOS is a optimal real-time embedded to support X86 series microprocessor[5].

A. QNX microkernel architecture and it's security guarantee

QNX microkernel adopts optional priority preemptive scheduling strategy. The main function of the kernel are processes scheduling and processes communication as well as interrupt handle, other services are provided by optional processes. The QNX Neutrino OS microkernel structure illustrate in Fig.3.

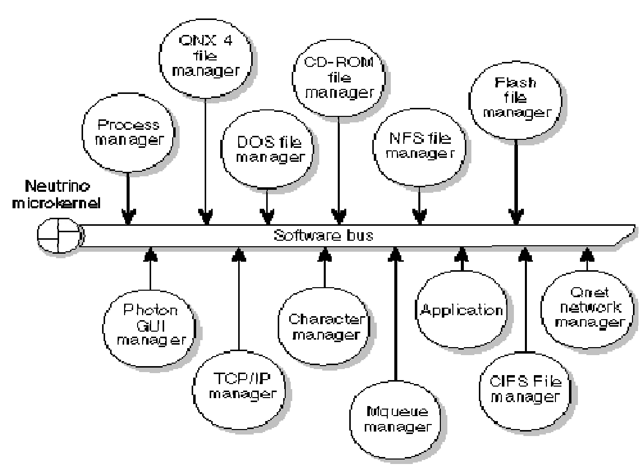

Figure 3. Architecture of The QNX Neutrino RTOS

From the architecture, it can be seen that QNX Neutrino acts as a kind of software bus. OS modules can plug in/out dynamically whenever needed. Except kernel, all processes have equal rank to interact with each other through the coordinating kernel [6].

The kernel is cabinet and run fast, can satisfy the need of underwater glider correct motion controlling with period of 16ms.

QNX microkernel OS also offers complete memory protection, It provides protection not only to OS components (device drivers, file systems, etc.), but also to user applications processes. That means all process is decoupling with kernel and running in a protected memory address space. In case a module failure, OS system can not crash. This feature guarantees the security of underwater glider embedded control system.

A. DOC driven procedure and QNX migration method

QNX kernel and all control software module running on QNX will eventually resident on DiskOnChip flash memory which mounted on embedded processor main-board SCM-7108B in form of OS image [7]. OS image is a file that contains OS kernel, executable application module, and any data files related to user's programs. In the development of underwater glider control system, OS image must be created and transferred to DOC. The first step of establishment development environment is DOC driving. The DOC driven procedure and QNX migration on DOC are as follow:

- Load QNX6.0 and DOC device driver on mainframe
- Drive DOC under mainframe
- Format DOC, do corresponding configuration, restart QNX and run DOC device driver, then mainframe can aware DOC. At this time, DOC can be found by QNX running on mainframe
- Create partition for DOC and write to QNX Loader
- Drive DOC physically and initiate QNX file system on DOC partition, and then, Drive QNX file system physically on DOC partition
- Copy QNX system files to corresponding address on DOC partition
- Create a start image file named buildfile which consists of a boot-file, a script, a list of links. Compile buildfile to form .boot file and transfer to DOC

Now, QNX operating system platform is migrated on DOC in X86 embedded main-board.

Main content and frame of buildfile is shown as follow:

```
{
[virtual=x86,bios +compress] .bootstrap = {
    startup-bios -Nmachine-name
    PATH=/proc/boot:/bin:/sbin
    LD_LIBRARY_PATH=/proc/boot:/dev/shmem:/lib:/lib
    /dll procnto
}
[+script].script={
devc-con -n4 &
reopen /dev/con3
    devb-doc blk automount=hd0t77:/ &
     pipe &
  [+session] sh &
            reopen /dev/con1
            …
  [+session] sh
}
[search=${MKIFS_PATH}:/root]
[type=link] /tmp=/dev/shmem
[type=link] /usr/lib/ldqnx.so.2=/proc/boot/libc.so
libc.so
devb-doc
```

IV. EMBEDDED CONTROL SYSTEM SOFTWARE DESIGN

A. Software general structure design

Software can be divided into two parts: surface software system running on mainframe and submarine software system running on underwater glider embedded system. Surface software system is responsible of task planning, data receiving, mission commands sending and motion trace displaying etc. Submarine software system realizes navigation control of underwater glider. Communication subsystem is the bridge of surface and submarine system. The software general structure is shown in Fig.4.

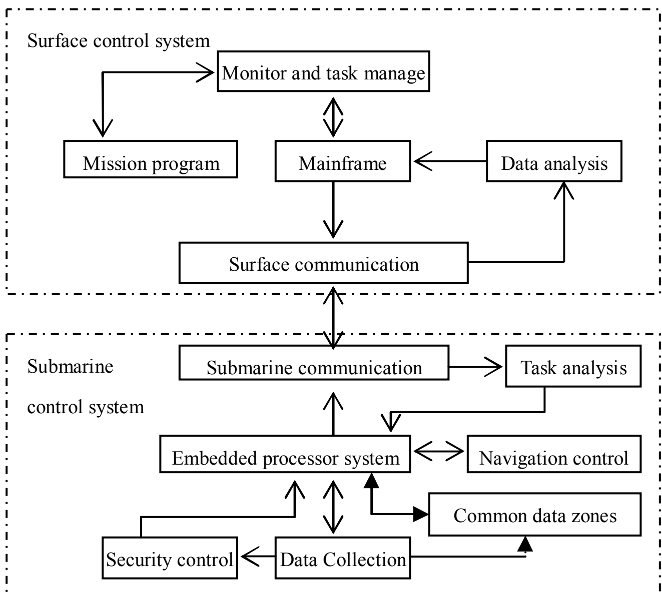

Figure 4. Sketch map of the software general structure

B. *Communication software design*

Before underwater glider diving, it can connect to mainframe via serial cable and download navigation plan, while the carrier diving, wireless radio station is utilized to transmit data between surface and submarine.

Underwater glider receive commands from surface mainframe occasionally, interrupt style is adopted in reception module of submarine communication subsystem of the carrier, while query style is used in reception module of surface communication subsystem for receiving data from carrier frequently. Transmission module of surface and submarine communication subsystem use query style.

Surface communication subsystem should running on PC, it just needs serial port communication functions driven by QNX. By simply set the parameters such as the baud rate, the verification position, the data length, etc, communication can be realized by read(write) data from(to) serial port. While on subsystem of the carrier, serial ports driver being customized and ported from QNX, it has to load OS image file, register hardware resource of serial port, make configuration for serial controller driver parameters in order to implement serial communication.

The reception module program flowchart of submarine communication system is shown in Fig.5.

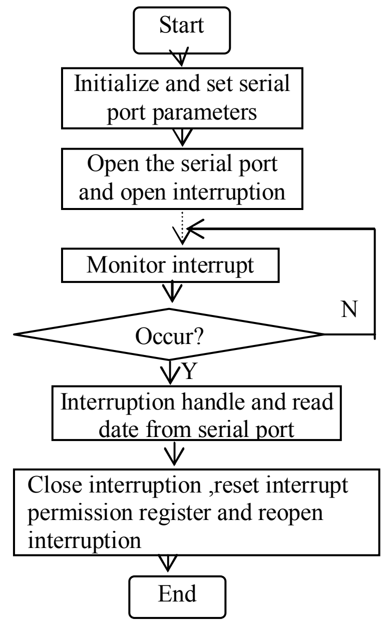

Figure 5. Flowchart of receive module of submarine carrier

Brief frame of submarine communication subsystem illustrate as follow:

```
*Include files*
main(){
OpenPort();//open serial port
ClosePort();//close serial port
}
void OpenPort(){
InitCOM();//initialize serial port
*Initialize internal register
 set interruption vector and interruption processing function, interruption number 4*
InterruptAttach(4,asyncint,NULL, 0, 0);
InterruptEnable();//open interrtuption
}
const struct sigevent *asyncint (void *arg, int id)
```

```
{
out8(0x20,0x20);
}
void ClosePort(void) {
*close interruption and reset interrupt permission register, reopen interrupt*
}
void InitCOM(){
ThreadCtl(_NTO_TCTL_IO, NULL);
*Initialize the internal register and set serial communication parameters*
}
unsigned char read_char(){
*read data from buffer*
}
void send_char(unsigned char *unch){
*detect circuitry state register and when it is 1, then send data to send data register*
}
```

The communication programs have been debugged in experiment environment and already successfully used in serial communication of underwater glider.

C. *Approach for increase detect and control precision*

Underwater glider navigating state information can collect by multi-sensors equipped on it. For instance, data can obtain from DVL speed-meter, TCM2 electrical compass, as well as information from A/D converter. One navigation parameter may come from different sensor. Single sensor has the characteristic of imperfection and uncertainties because of measuring data affected by environment and carrier motion state. So multi-sensor data fusion approach has been proposed for increase detect precision. Meanwhile, some sensor's detecting data is affected by corresponding factors, dynamic correction is needed according to state changing of carrier. Considering various factors, reliable data acquisition approach is proposed and shown in Fig.6.

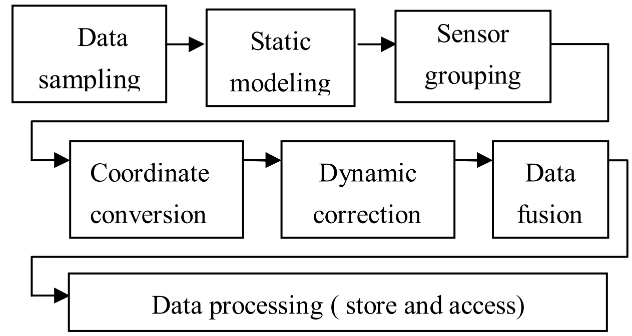

Figure 6. Approach of increase detecting precision

On the basis of the processed data, precision of ship' position prediction algorithm as well as control algorithm will be higher.

V. CONCLUSION

Special navigation style of underwater glider decide that it's navigation control system should be embedded. Real-time application supported by real-time operating system represent embedded system development trend. The proposed scheme of underwater glider embedded control system based on QNX real-time operating system is advanced and rational in technology. Designing technique analysis and some simulation experiments prove that the design idea is correct and the implementation approach is feasible. The proposed technology scheme and technology implementation approach will be able to have good model function and guiding sense in relevant research.

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