INSA Toulouse

Project Release Report

Autonomous Drone Guide

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Autonomous target-guided navigation in low obstacle enviroment

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Abstract

Being fifth year students at INSA Toulouse, we saw that many visitors had difficulties to find the Electrical and Computer Engineering Department (DGEI) and they were late for the meeting. At the end of our study in Critical and Embedded System, we have an opportunity to work with a drone so we decided to make our project more useful. Our Pink team is working on developing a UAV that can go to DGEI wherever it was by searching a signal power of an Xbee emitter (or a GPS).

Contents

1 Introduction

Introduction

2 General project presentation

2.1 Goal of our project

Our project, proposed by our tutor D. Le Botlan is titled “Adptove Flight”. It is composed of two main parts.

The first one is about target detection and autonomous flight.
The other one is obstacle avoidance.

Actually, our UAV must be able to detect a target, flight to this point and above all, avoid the human obstacles.

2.2 Documentation & deliverables

In the beginning of the project we have created a website on our project. It can be accessed at :

`https://sites.google.com/site/projetsecinsa/projets-2012-2013/projet-de-la-mission-pink`

We have also written technical documentation : PMP, SRS and STD. They can be downloaded in the “Sources” section of our website.

Regarding software production, we have used the versionning manager git. Our code is hosted at this url :

`https://github.com/insadrone/InsaQuadDrone`

Finally, various documents, unsorted, like mid-term presentations, hardware benchmarks can be seen in the included folder named “google_drive_dump”

3 Hardware considerations

3.1 Bluetooth

This part explains how to connect and read data from an android smartphone that sends information via bluetooth. ShareGPS, an application running on the phone is sending its GPS coordinate to the computer. The aim of the document is to give the process to get this coordinate.

First step: with the smartphone

- Turn on the bluetooth and the GPS
- Launch ShareGPS and share coordinate via bluetooth
- Make the bluetooth visible by other devices

Second step: with the computer on Linux

- Turn on the bluetooth and open a terminal (you may need to be root) Scan devices with: "hcitool scan" -> Write down the MAC address of the corresponding device
- Find the good channel which gives GPS coordinate with: "sdptool records MAC_ADDR" -> This command displays all channels and their functions -> Look for the one called "ShareGPS" and write down the corresponding channel
- Create the connection with: "rfcomm bind X MAC_ADDR CH" -> X: positive integer corresponding to the rfcomm you want to bind -> MAC_ADDR: MAC address of the smartphone -> CH: channel of the ShareGPS application

You can now check that /dev/rfcommX exists. The last step is to read data. To kill it use the command "rfcomm release rfcommX" or "rfcomm release all".

Third step: read data

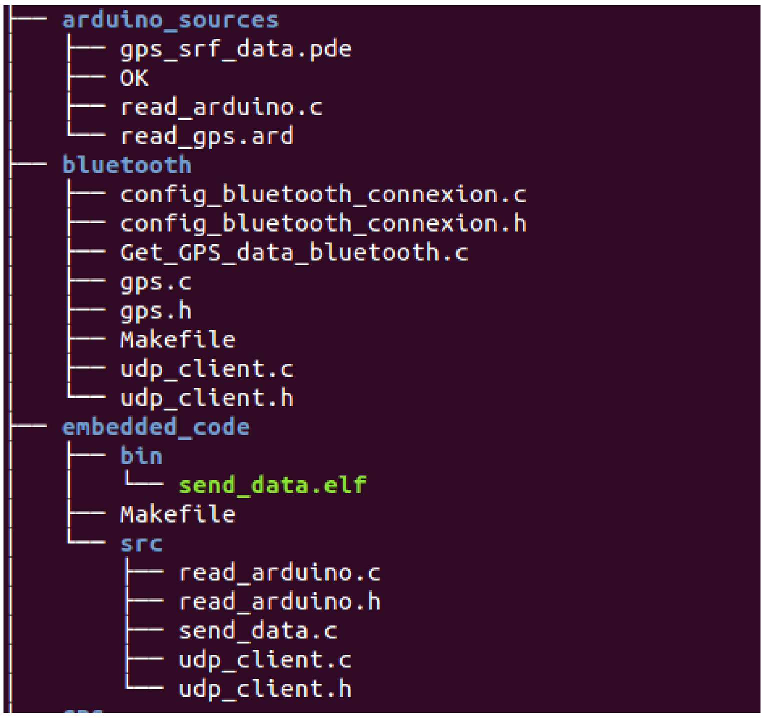
- Using PuTTY: connect via serial to /dev/rfcommX with a 9600 baudrate
- You can also use a self-made program

Source: `http://www.thinkwiki.org/wiki/How_to_setup_Bluetooth`

4 Software producted

4.1 Repository architecture

The general architecture of our code repository is explained in this tree :



```
├── arduino_sources
│   ├── gps_srf_data.pde
│   ├── OK
│   ├── read_arduino.c
│   └── read_gps.ard
├── bluetooth
│   ├── config_bluetooth_connexion.c
│   ├── config_bluetooth_connexion.h
│   ├── Get_GPS_data_bluetooth.c
│   ├── gps.c
│   ├── gps.h
│   ├── Makefile
│   ├── udp_client.c
│   └── udp_client.h
├── embedded_code
│   ├── bin
│   │   └── send_data.elf
│   ├── Makefile
│   └── src
│       ├── read_arduino.c
│       ├── read_arduino.h
│       ├── send_data.c
│       ├── udp_client.c
│       └── udp_client.h
```

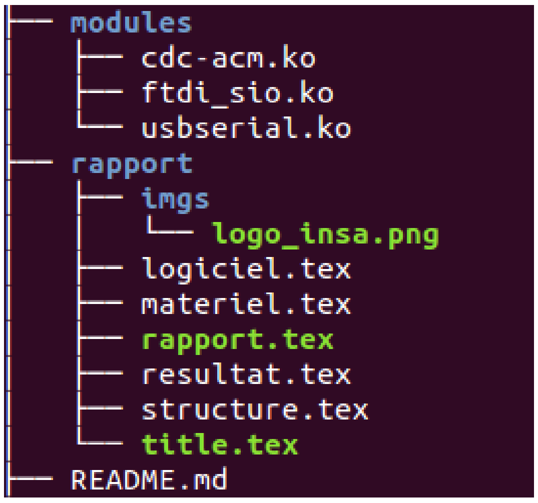
Figure 4.1: 1st part of the repository

In arduino_sources folder, all the code related to the arduino board can be found. The software used to program the arduino is expecting .pde or .ard files.

In the following parts, we will provide more details for each files.

The bluetooth folder contains C sources et headers used on the target to catch informations sent by the smartphone.

The embedded code section includes all the programs we created to run on the UAV embedded linux.



```
├── modules
│   ├── cdc-acm.ko
│   ├── ftdi_sio.ko
│   └── usbserial.ko
├── rapport
│   ├── imgs
│   │   └── logo_insa.png
│   ├── logiciel.tex
│   ├── materiel.tex
│   ├── rapport.tex
│   ├── resultat.tex
│   ├── structure.tex
│   └── title.tex
├── README.md
```

Figure 4.2: 2nd part of the repository

All the compiled modules we added on the embedded linux can be found in the module folder.

The “rapport” directory contains the sources of the documentation you are reading !

Finally, the most important folder is the one named sdk_apps. It contains one application named auto_flight. Like most of the c projects, you can find a Makefile, a bin/ and a src/ folder. The Makefile is configurated to create the application binary and to move it to the bin/ folder. You can find additionnal informations about the Makefile in the appedices.

About the src/ folder :

The most important C file is named ardrone_testing_tool.c. This file is making the link between our application and the ARdrone library. Moreover, it is launching and joining all our threads.

The Auto/ folder contains code related to the auto_control thread.

The Avoidance/ folder contains code related to the avoidance thread.

The Comm/ folder contains code related to the receive_gps thread.

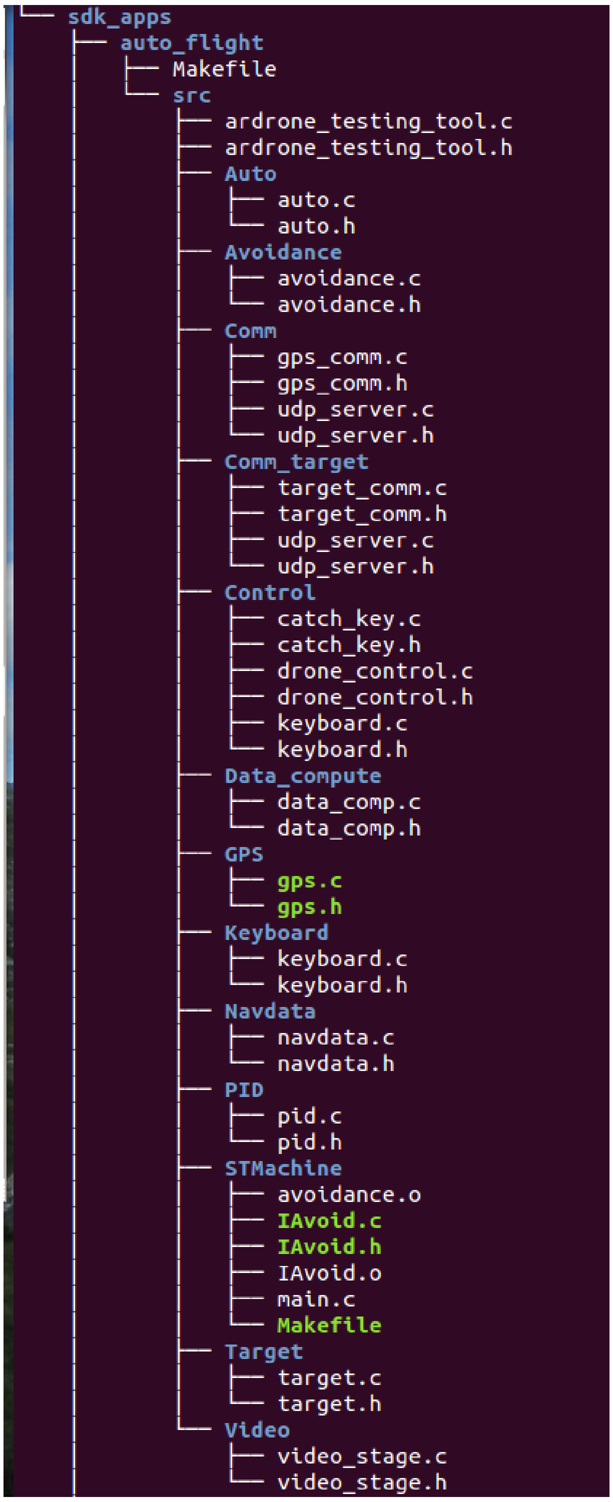
The Comm_target/ folder contains code related to the gps_target thread.

The Control/ folder contains an small library we wrote to handle UAV travelling.

The GPS/ folder contains algorithms used to manipulate GPS strings and make distance and angle calculation.
The Navdata/ folder contains the fonctions used to read and store navdata sent by the UAV.

The STMachine/ folder contains the fonctions generated by SCADE KCG compiler.

The Target/ folder contains code related to the target thread.



```
└── sdk_apps
    ├── auto_flight
    │   ├── Makefile
    │   └── src
    │       ├── ardrone_testing_tool.c
    │       ├── ardrone_testing_tool.h
    │       ├── Auto
    │       │   ├── auto.c
    │       │   └── auto.h
    │       ├── Avoidance
    │       │   ├── avoidance.c
    │       │   └── avoidance.h
    │       ├── Comm
    │       │   ├── gps_comm.c
    │       │   ├── gps_comm.h
    │       │   ├── udp_server.c
    │       │   └── udp_server.h
    │       ├── Comm_target
    │       │   ├── target_comm.c
    │       │   ├── target_comm.h
    │       │   ├── udp_server.c
    │       │   └── udp_server.h
    │       ├── Control
    │       │   ├── catch_key.c
    │       │   ├── catch_key.h
    │       │   ├── drone_control.c
    │       │   ├── drone_control.h
    │       │   ├── keyboard.c
    │       │   └── keyboard.h
    │       ├── Data_compute
    │       │   ├── data_comp.c
    │       │   └── data_comp.h
    │       ├── GPS
    │       │   ├── gps.c
    │       │   └── gps.h
    │       ├── Keyboard
    │       │   ├── keyboard.c
    │       │   └── keyboard.h
    │       ├── Navdata
    │       │   ├── navdata.c
    │       │   └── navdata.h
    │       ├── PID
    │       │   ├── pid.c
    │       │   └── pid.h
    │       ├── STMachine
    │       │   ├── avoidance.o
    │       │   ├── IAvoid.c
    │       │   ├── IAvoid.h
    │       │   ├── IAvoid.o
    │       │   ├── main.c
    │       │   └── Makefile
    │       ├── Target
    │       │   ├── target.c
    │       │   └── target.h
    │       └── Video
    │           ├── video_stage.c
    │           └── video_stage.h
```

Figure 4.3: 3rd part of the repository

Thread name	Period	Description
ardrone_control	2	Library related thread
navdata_update	20	Library related thread
auto_control	20	Thread allowing manual command of the UAV
receive_gps	50	Thread used to received gps coordinated sent by the UAV
avoidance	60	Thread used to perform autonomous obstacle avoidance
gps_target	50	Thread used to received gps coordinated sent by the target
gps_target	50	Thread used to perform autonomous convergence to the target

This table summarizes all the thread launched in our application. In the following sections, we will detail the operations of each threads.

4.2 The auto thread

The auto thread is mainly based on the movement API we developped with the Brown team.

4.2.1 Movement API

This API is an overlay of the Parrot API, it allows more intuitive UAV control. It also provide movement quatification, which means you can quantify an order by speed, distance or duration. For example, you can emit orders like “go forward on 300 cm”.

Les mouvements élémentaires

Les commandes de déplacement sont définis dans le fichier Control/drone_control.c, elles ont toutes le même format :

The travelling commands are all defined in the file Control/drone_control.c, they have the same format :

```
C_RESULT ordre (void *arg)
```

The list of available travellings :

- turn_left
- turn_right
- forward
- backward
- up
- down
- right
- left
- stop

4.2.2 Send an order

The above order can be passed to both functions depending on whether you want to make a move that will be termed “elementary”, or a longer trip by specifying the distance.

Elementary move

An elementary movement allows for a sudden displacement of around 10 cm. You must use the following function:

```
C_RESULT small_move(ORDER* order)
```

Sample code :

```
small_move(turn_right);
```

Long move

All orders to send move commands accept an argument of type void *. This argument must be cast to void * but available commands manage only the type arguments mov_t which includes different arguments :

```
typedef struct mov_t{
  int32_t power;      //engine power between 0 and 100
  int32_t distance;   //distance in cm
  int32_t time;       //time in usec
}mov;
```

Before sending orders, it's important to fill correctly this structure. Unused fields must be initialized to -1. To send an order, this function must be used :

```
C_RESULT send_order(ORDER* order, void *arg)
```

Sample code :

```
/* 30% on 70 cm*/
mov mv = {30, 70, -1};
send_order(backward, &mv);
```

4.2.3 Using of this API

In the auto thread, we need to control the UAV with the keyboard of the station. This automatic control is really useful in case of problems occuring during the automatic control.

Basically, we are just running a scanf in an infinite loop. Depeding on the key pressed, we just have to call the wright function of the API.

```
  while (1) {
    usleep(100000);
    scanf("%c", &c);
    printf("%c\n",c);
    switch(c){
    case 'f':
      small_move(forward);
      break;
    case 'b':
      small_move(backward);
      break;
    case 'u':
      small_move(up);
      break;
    case 'd':
      small_move(down);
      break;
    case 'o':
      //small_move(left);
      printf("Batt␣:%d\n",sauv_ndata.bat_level_current);
      break;
```

Very helpful functionalities are battery control, by pressing the "o" key, and recover from emergency m ode by pressing "x". All the other command are pretty basic ("land", "go up", "go down").

4.2.4 Storing navdatas

We also use this thread to store the navdata received. To achieve this goal, it is necessary to declare three functions, defined in the ARDrone library :

```
/* Initialization local variables before event loop  */
inline C_RESULT auto_navdata_client_init( void* data )

/* Receving navdata during the event loop */
inline C_RESULT auto_navdata_client_process( const navdata_unpacked_t*
    const navdata )

/* Relinquish the local resources after the event loop exit */
inline C_RESULT auto_navdata_client_release( void )
```

We just keep the informations we have to use later, like battery level, control state, altitude or psi angle.

```
sauv_ndata.psi_current = nd->psi / 1000;
sauv_ndata.bat_level_current = nd->vbat_flying_percentage;
sauv_ndata.ctrl_state_current = nd->ctrl_state;
sauv_ndata.tag_detected = nv->nb_detected;
sauv_ndata.tag_tab = nv->camera_source;
sauv_ndata.alt = nd->altitude / 1000.0;
```

We store all these informations in a global structure that will be accessed by the other threads.

4.3 The avoidance thread

This thread is mainly based on SCADE generated code. The statechart modeling the avoidance is printed below :

Then, the KCG compiler gave us some independent code, that we included in our project.

```
switch (AvoidMachine_state_sel) {
    case SSM_st_Travelling_AvoidMachine :
      outC->AvoidMachine_reset_act = inC->obstacle_detected;
      break;
    case SSM_st_Hovering_AvoidMachine :
      if (br_1_guard_AvoidMachine_Hovering) {
        outC->AvoidMachine_reset_act = 1;
      }
      else {
        outC->AvoidMachine_reset_act = br_2_guard_AvoidMachine_Hovering;
      }
      outC->init = 0;
      break;
    case SSM_st_Avoidance_up_AvoidMachine :
      if (inC->obstacle_detected) {
        outC->AvoidMachine_reset_act = 1;
      }
      else {
        outC->AvoidMachine_reset_act = br_2_guard_AvoidMachine_Avoidance_up
            ;
      }
      outC->init2 = 0;
      break;
```

The top-level function is defined in the file IAvoid.h.

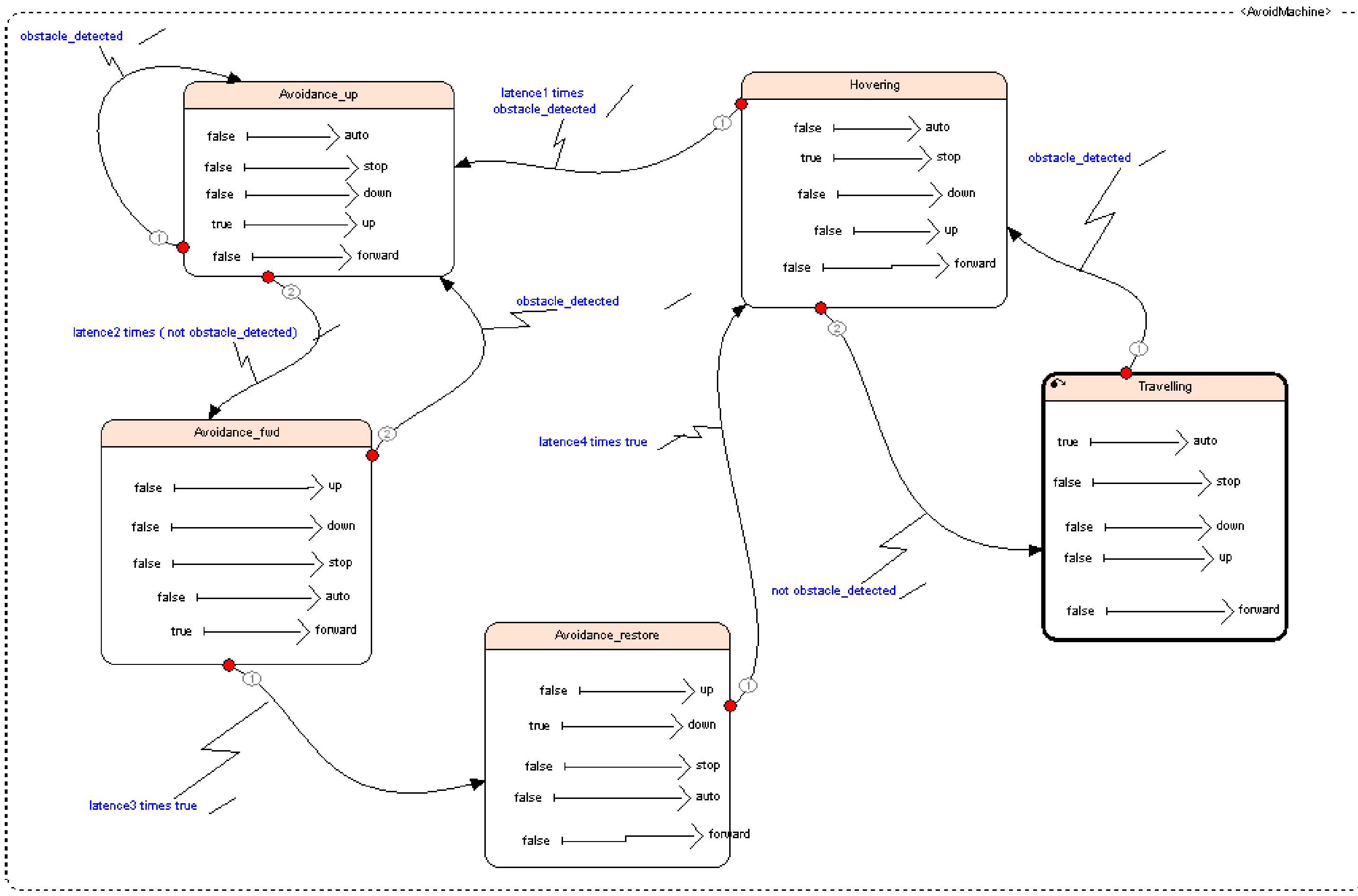


Figure 4.4: SCADE statechart

```
extern void IAvoid(inC_IAvoid *inC, outC_IAvoid *outC);
```

The inputs of this statechart are a boolean named "obstacle_detected" (its value is 1 if there is an obstacle and 0 otherwise) and 4 integers describing latencies between transitions.

The outputs are 5 booleans : 4 orders (up, down, stop, forward) and a neutral order (if there is nothing to do).

Each call to the function represent a cycle. We have planned to execute a cycle each 10ms. The following code is illustrating the use of the auto-generated function :

```
DEFINE_THREAD_ROUTINE(avoidance, data) {

  comm_datas datas;
  double dangerThreshold=100;
  int detection;
  double average_left;
  int ret;

  init_array_obstacle_pos2();

  IAvoid_reset(&output);
  input.obstacle_detected = 0;
  input.latence1 = 100;
  input.latence2 = 100;
  input.latence3 = 300;
  input.latence4 = 100;

 while (1) {
   usleep(10);
   if (auto_ready) {
     //get srf datas
     datas = get_comm_datas();

     ret = average_obstacle_pos2(&datas.srfr, &average_left);
     printf("Moyenne␣capteur(%d)␣:␣%f\n", ret, average_left);

     //check threshold
     if (average_left < dangerThreshold) {
       detection = 1;
     } else {
       detection = 0;
     }

     input.obstacle_detected = detection;
     IAvoid(&input,&output);
     command(output);
     usleep(10000);
   }
 }

  return (THREAD_RET) 0;
}
```

And the command function is :

```
void command(outC_IAvoid comm) {
  mov speed;

  if (comm.up) {
    speed.power = 8;
    send_fast_order(up,(void *)&speed);
  } else if (comm.down) {
    speed.power = 3;
    send_fast_order(down,(void *)&speed);
  } else if (comm.stop) {
    send_fast_order(stop,NULL);
  } else if (comm.auto1) {
    speed.power = 1;
    printf("avance\n");
    send_fast_order(forward,(void *)&speed);
  } else if (comm.forward) {
    speed.power = 1;
    printf("avance\n");
    send_fast_order(forward,(void *)&speed);
  }

}
```

4.4 The receive_gps & gps_target threads

Those threads are designed to receive and store the GPS strings sent by UAV and Target. The receive_gps thread also handle SRF datas sent by the ultrasonic sensor.

We have created a small library with functions to receive udp datas. This library is described in the udp_server.h file.

This function is reading udp datas on port 6444 (sent by the UAV).

```
/*
   Start listening the buffers sent from uav
*/
int start_comm(void)
{
    udp_struct udp_uav;
    int msglen_uav;

    if(udpserver_init(&udp_uav,UDP_UAV,1)) diep("udp_UAV␣init");


    while (start_listen) {

        do {
            msglen_uav = udpserver_receive(&udp_uav, buf_uav, 512);
        } while(msglen_uav<=0);

       record_data(buf_uav);

    }

    udpserver_close(&udp_uav);
    return 0;
}
```

Then, depending on whether it is a sensor or GPS data, we fill a structure.

```
int record_data(char *buf) {
  char *gprmc_begin = "$GPRMC";
  char *gpgga_begin = "$GPGGA";
  char *srfl_begin = "$SRFL";
  char *srfr_begin = "$SRFR";

  int ret_val = 0;

  if (!strncmp(gprmc_begin,buf,6)) {
    strncpy(ret_datas.gprmc_string,buf_uav,sizeof(ret_datas.gprmc_string));
    ret_val = 1;
  } else if (!strncmp(gpgga_begin,buf,6)) {
    strncpy(ret_datas.gpgga_string,buf_uav,sizeof(ret_datas.gpgga_string));
  } else if (!strncmp(srfl_begin,buf,5)) {
    ret_datas.srfl = atof(buf+6*sizeof(char));
  } else if (!strncmp(srfr_begin,buf,5)) {
    ret_datas.srfr = atof(buf+6*sizeof(char));
  } else {
    printf("ERROR␣NO␣STRING␣DETECTED\n");
  }
  return ret_val;
}
```

The other thread (receiving from target), uses similar functions.

4.5 The target thread

This thread contains functions related to auto-convergence. We have impleted different algorithms, described thereafter.

4.5.1 Turn angle algorithm

When it converges to the target, the UAV need to turn to an absolute angle between 0 et 360 from north. Depending on the UAV angle, it can be better to turn right, or to turn left, to reduce the turning duration.

The UAV will turn to reach the angle given as an argument. We have defined a tolerance. Indeed, because of transmission delays, the UAV can keep turning even if the angle is ok. A tolerance of 5.0 degrees is acceptable and always working.

```
/*
  INPUT: angle   (float)
  tolerance (float)
  This function will make uav turn to the direction of target with an error
      of +- tolerance
*/
void turn_angle2(float target_angle, float tol) {

  fdata sauv_ndata = get_ndata();
  float angle_360 = sauv_ndata.psi_current;
  float angle_inf, angle_sup;

  angle_inf = target_angle - tol;
  angle_sup = target_angle + tol;

  if (sauv_ndata.psi_current < 0) angle_360 = 360 + sauv_ndata.psi_current;
  if (target_angle < 0) target_angle += 360;

  if (target_angle > angle_360) {
     (target_angle - angle_360) < 180 ? send_order(turn_left,NULL) :
        send_order(turn_right,NULL);
  } else {
    (angle_360 - target_angle) < 180 ? send_order(turn_right,NULL) :
       send_order(turn_left,NULL);
  }

  while (!(sauv_ndata.psi_current > angle_inf && sauv_ndata.psi_current <
     angle_sup)) {
    sauv_ndata = get_ndata();
    usleep(100);
  }

  send_order(stop,NULL);
  sleep(1);
}
```

4.5.2 Convergence algorithm 1

Let's describe the first algorithm :

1. Magneto calibration (the UAV has to be flying)
2. Receive GPS datas
3. Turn to wright angle
4. Go forward 2 seconds
5. If target reached, land otherwise, jump to step 3.

```
if ( (landed == 1) && (calibration == 0) ){
  printf("start␣calibration\n");
  calibrate_magneto(NULL);
  sleep(4);
  calibration = 1;
  printf("Calibration␣done\n");
}

if ( (landed == 1) && (calibration == 1) && (mission == 0) ) {
  datas = get_comm_datas();
  extract_coord(datas.gprmc_string,&depart);

  datas_target = get_comm_datas_target();

  if ((check_gps_coord_struc(&depart) > 0) && (check_gps_coord_struc(&
     datas_target.dest) > 0)) {
    navigation(&depart, &datas_target.dest, &distance, &angle, NULL); //&
       relatif_error

    turn_angle2(angle ,5.0);

    if (distance > 5.0){
      fprintf(redir_sortie,"La␣distance␣restante␣est␣%f\n",distance);
      fflush(redir_sortie);
      speed.power = 3;
      send_order(forward,(void *)&speed);
      sleep(3);
    } else {
      send_order(land,NULL);
      printf("LANDING␣\n");
      mission = 1;
    }
  }
}
```

4.5.3 Convergence algorithm 2

Let's describe the second algorithm :

1. Magneto calibration (the UAV has to be flying)
2. Receive GPS datas
3. Turn to wright angle
4. While distance is decreasing, go forward
5. If target reached land, otherwise go to step 3.

```c
if ( (landed == 1) && (calibration == 0) ){
  printf("start␣calibration\n");
  calibrate_magneto(NULL);
  sleep(4);
  calibration = 1;
  printf("Calibration␣done\n");
}

if ( (landed == 1) && (calibration == 1) && (mission == 0) ) {
  datas = get_comm_datas();
  extract_coord(datas.gprmc_string,&depart);

  datas_target = get_comm_datas_target();

  if ((check_gps_coord_struc(&depart) > 0) && (check_gps_coord_struc(&
     datas_target.dest) > 0)) {
    navigation(&depart, &datas_target.dest, &distance, &angle, NULL); //&
       relatif_error

    turn_angle2(angle ,5.0);

    while (last_distance > distance) {
      fprintf(redir_sortie,"La␣distance␣restante␣est␣%f\n",distance);
      fflush(redir_sortie);
      speed.power = 3;
      send_order(forward,(void *)&speed);
      last_distance = distance;
      sleep(1);
    }

    if (distance < 10.0){
      send_order(land,NULL);
      printf("LANDING␣\n");
      mission = 1;
      fflush(redir_sortie);
      exit(0);
    }
  }
}
```

5 Final results

6 Conclusion

Conclusion