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Control System for Navigating a Domestic Drone

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ABSTRACT

This paper describes the design, building and testing of a Drone Flight Navigation (DFN) system used to control the movement of livestock away from the ploughing fields. The inputs to the DFN system include different sounds of livestock to be removed from the fields. The output of the system will be the irritating sounds to the livestock and also deploy a rotating umbrella-like cloth and flashing LED lights to scare the animals even more. The input and output sounds are stored in a database and can be updated with preferred sounds. We have successfully simulated and programmed a prototype DFN system using ALTERA UP1 Development Board. Also on this paper, we discussed drone power management system (DPMS) which ensures that the drone has enough battery power before each flight. For future developments, GPS and video camera capabilities can also be included into the design so that the farmer will be able to observe what the system is seeing and possibly give live instructions.

Keywords: *Development Board, DFN, DPMS, GPS, input sounds, livestock, output sounds, UP1*

I. INTRODUCTION

Food security is everyone's concern at the moment, particularly when there are challenging effects such as Elnino effect which impact negatively on food production. Countries therefore are coming up with programmes which will improve food security and Botswana is no exception. Botswana, who is reliant on agriculture amongst other alternatives, has come up with programmes to assist general population to produce food. Some of the programmes include ISPAAD and NAMPAAD, [1]. At the same time, Botswana also encourages rearing of livestock such as cattle hence a beef-exporting country. Methods of cattle rearing in Botswana vary, such as from ranches to communal areas where cattle freely roam the area. The free-roaming cattle in communal areas have brought in some conflict situations where cattle get into the fields and destroy crops thus contributing to food insecurity in the country. The cattle can destroy crops at anytime, day or night. This conflict situation has not only hampering efforts to produce food (farm yield) but also it brings conflicts between cattle owners and crop owners, Efforts have been put in place to control the movement of cattle away from the fields. Some fields are fenced to separate communal grazing areas from ploughing fields, but the initiatives still appear not adequate enough to control cattle away as they still find their way into the fields. To improve on the control of cattle and other livestock in the fields, some new innovative ways are explored and one of those is to utilize a drone, [2].

Drones are a fairly new technology with many applications. When used to control livestock movement in the fields, the basic drone navigational techniques need to be altered. For example, the drone should be able to detect the presence of cattle in the fields and be able to fly to where they are, and be able to scare them away. The advantage of a drone is that is can fly around the field effortlessly. The drone can utilise geographical positioning systems (GPS), to navigate through the fields.

1.1 Applications of Drones in Agriculture

Two types of aircraft are used for agricultural purposes: fixed wing aircraft and multi-rotor aircraft. Fixed wing aircraft are suited to assess large areas, like a field or pasture. Multi-rotor aircraft can hover and observe at lower altitudes, which are better for individual animal assessments. Various cameras, recorders and infrared or thermal sensors can be added depending on the data desired [3, 4].

Agricultural drones are used by farmers to obtain an aerial overview of the area in which they keep their livestock. Thermal imaging and high definition cameras allow farmers to track and monitor their livestock remotely, identifying any issues in real time, thus enabling them to resolve issues quickly and efficiently. Farming drones can be equipped with different types of cameras, including night vision, thermal imaging, and motion sensors.

Figure 1. Unmanned drone system surveying a landscape

Farmers typically require Unmanned Aerial Vehicles, UAVs to be pre-programmed for flight, using the ground station software to demand that the flight path is contained within their flying height and property line, creating a restricted box around the property. When operating in this way, each cattle check can then be part of a routine consisting of auto-launching the system for flight, and also monitoring the live video feed on screen. UAV animal tracking allows for the surveillance of large spaces, even during the night. UAVs can cover large areas, provide both GPS location as well as visual information and produce a low noise footprint, which does not scare the animals. UAVs can be equipped with multiple camera types or sensors to provide accurate and complete information, thereby lowering stock control time and costs. Figure 1 shows a drone navigating through the fields.

Farmers have been utilizing UAVs by preprogramming them for flight using the ground station software. When doing this, each cattle check can be part of a routine that consists of auto launching the plane for flight, and monitoring the live video feed on screen [5, 6].

1.2 Overview of the proposed system

The proposed DFN system uses a conventional drone as a flight vehicle. The drone’s control unit is replaced by a semi-autonomous DFN control unit which is able to steer the drone following a software programme. The DFN is programmed to respond to the presence of livestock and timed intervals, and then produce specific animal sounds to control the movement of livestock away from the ploughing fields.

The system can adapt to changing behaviour of the livestock and adjust timed intervals accordingly. The user can interact with the system remotely so that he can reprogram the system on the fly.

FPGAs were chosen as the programmable platform because of their versatility, robustness and secure communication using powerful encryption techniques [7, 8, 9].

II. THE PROPOSED DRONE NAVIGATION SYSTEM

Using the conventional drone as a flight vehicle, the proposed Drone Flight Navigation, DFN, will be used to control the drone flight path. Therefore, the DFN will replace the original drone flight controller. For this project, a 6-axis gyroscope quadrocopter drone has been purchased to demonstrate the basic principle of livestock control system.

2.1 Organisation of the DFN system

The quadrocopter drone control unit will be replaced by the DFN controller Furthermore, a motor driven umbrella-like cloth is attached to the bottom of the drone. The cloth is deployable when the drone flies out to scare livestock. When not in use, the drone is parked in an enclosure unit to secure it from rain and vandalism. As seen in figure 2, the enclosure is raised well above ground.

The docking station also consists of a PV power supply and charging system for the drone. Before it flies out to do field surveying, the drone checks it power resources. During the survey, power is constantly checked to ensure that the drone will be able to make a return. The drone is also fitted with light weight panels as a small backup. When faced with a hurricane, the drone may be forced to abandon survey or force land.

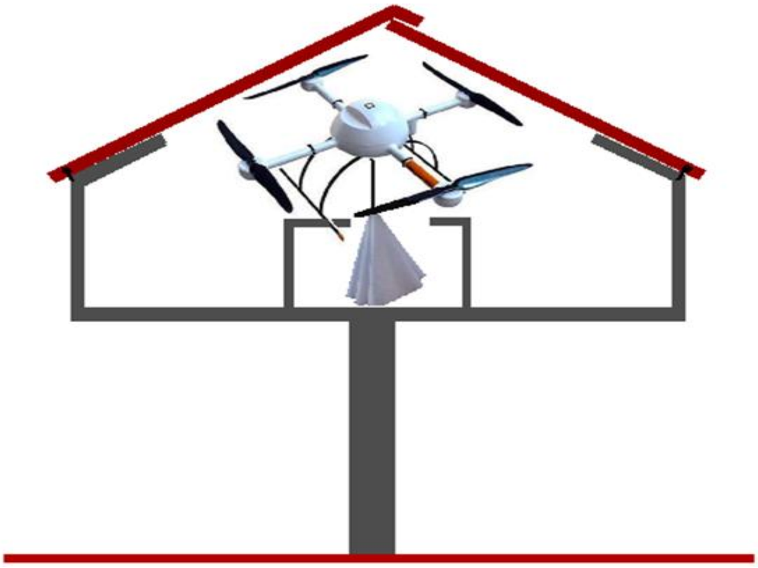


Figure 2. Docking Station for the DFN drone

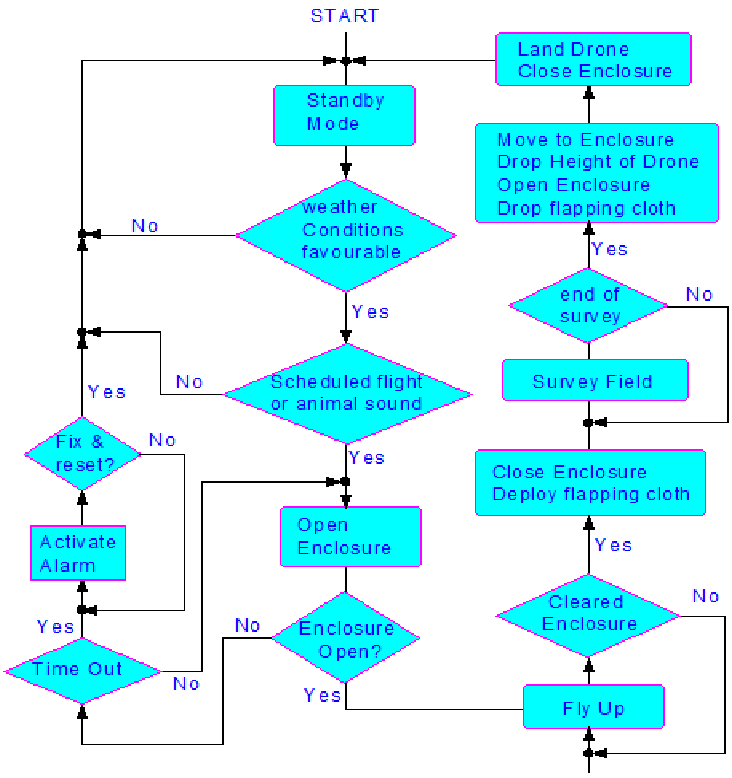


Figure 3. Flow Chart for the Proposed DFN System

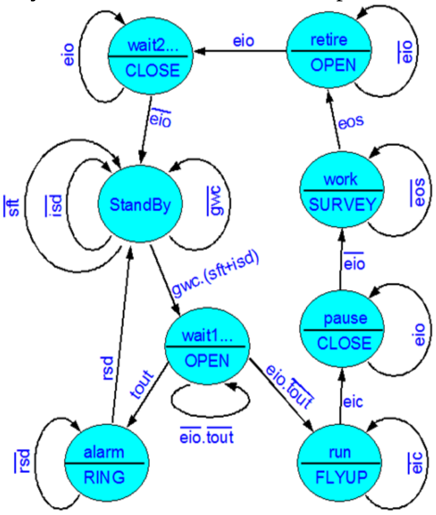
2.2 Operation of the DFN Control Unit

The DFN system is programmed to respond to animal sounds, timed schedule, visual information (visual identification) and weather conditions. Sounds made by different animals are stored in the system database. These sounds are input sounds to the system for animal identification. For example, when cattle are roaming around in the fields, the DFN system will pick up their sound and match it with the one stored in the database, to positively identify these sounds as coming from cattle. The system will then produce output sounds like scary barking sounds of dogs and also irritating noises to drive cattle away. A high pitched intermittent loud noise at 8000 hz is very stressful for them [5]. By using video, the DFN system can also match live images with those from the database in order to identify animals. The operation of the DFN system is best described using the flow chart of figure 3.

When idle, the drone remains in standby mode and secured in its docking station (figure 2). If the weather conditions are not favourable, eg strong winds, rain, the drone remains in the station. If animal sounds or scheduled flight time is detected, the system will attempt to open the enclosure, failing of which an alarm will go off after a suitable time out. The system will go back to idle mode upon resetting the alarm. However if the enclosure is opened successfully, the drone will fly up and deploys a flapping cloth after it has cleared the enclosure. The cloth has reflective material on it so that when it rotates, light from the drone's LEDs will be dispersed to the ground below. As the light sparkles, it will instil fear on cattle thus disturbing cattle from entering the fields, especially at night. Contrasts of light and dark have such a deterrent effect on cattle Using the input sound detected, the drone will produce the corresponding output sound(s) and will herd in the direction where the input sound came from. In case of a scheduled flight, the drone will follow a pre-defined route. However, the drone will still respond to input sounds if it encounters any. At the end of the survey, the drone will go back to its enclosure following the same procedures as when taking off, [4].

III. DESIGN & SIMULATION OF THE DFN CONTROLLER

The overall aim of this project is to replace the quadrocopter drone control unit with the proposed DFN control unit. l be replaced by DFN controller which is represented by the flow chart of figure 3.



The Flow Chart of Figure 3 can be represented by the FSM of figure 4. From the FSM, the text editor design file (tdf), (truth table – table 1), can be generated. The tdf file is simulated to generate output waveform results of figure 5.

Input abbreviations are explained as;
good weather conditions = gwc
scheduled flight time = sft
input sound detected = isd
restored = rsd
enclosure is open = eio
time out = tout
enclosure is cleared = eic
end of survey = eos

Figure 4. Finite State Machine (FSM) for the DFN Control Unit**.**

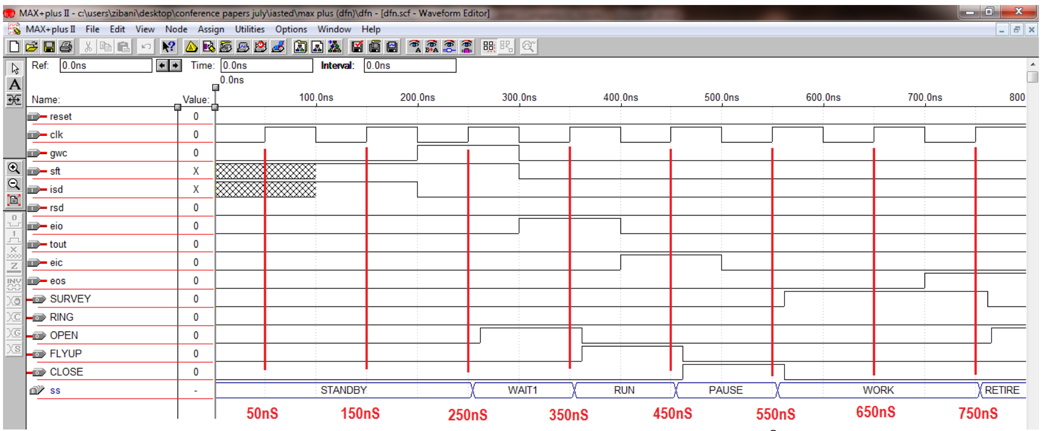


Figure 5. Simulation Waveform for DFN Control Unit. 8states x 2^8 input combinations!

8 conditions were tested for the simulator. Those conditions are tested at a positive clock going edge (shown by red vertical lines).

@50nS, the weather conditions are bad (gwc=0), the scheduled time flight and input detected (sft=isd=x) are irrelevant, so the system remains in the STANDBY mode.

@150nS, sft=1, isd=0, but gwc=0, so system remains in STANDBY.

@250nS, weather conditions are good (gwc=1) & sft=1, isd=0. System follows scheduled flight time. Next state is WAIT1.

@350nS, the enclosure opens (eio=1) before timeout (tout=0). The system moves to state RUN.

@450nS, the drone flew past the enclosure (eic=1), so the system proceeds to PAUSE state to close the enclosure.

@550nS and 650nS, eos=0, the drone is surveying the fields.
@750nS, the survey is completed (eos=1), and the system goes to RETIRE state, (and eventually to STANDBY).
Table 1 is used by the max Plus Compiler to generate the waveform behaviour (Figure x) of the DFN controller. Not all inputs are relevant at every state and state transition. For example, looking at the FSM, the only inputs relevant to STANDBY state are gwc, sft and isd. The transitions to WAIT1 state are **gwc.sft**+**gwc.isd**. by using a kmap, one can easily find that the looping conditions are $\overline{gwc} + \overline{sft}.\overline{isd}$. These 4 cases of the STANDBY state are indicated in table 1.All irrelevant transitions are padded with x's (for don't cares

3.1 ALTERA's Max Plus II development System

The flow chart of figure 3 can also be represented by a finite state machine, FSM, shown in figure 4. From the FSM, table 1 can be generated. This table is the truth table or code table for the DFN control unit. The DFN code has been successfully compiled and simulated using ALTERA's Max Plus II development software. The simulation results are discussed in figure 5. The output waveforms agree with the FSM of figure 4.
The DFN design was later programmed into an FPGA chip, contained in UP1 Development Board, (shown in Figure 4). For this project, FPGAs were chosen as development platforms because of their parallel processing capability, full programming flexibility and powerful hardware encryption techniques, [9]. The user can remotely re-configure and re-programme the hardware.

```
% DFN.tdf %

SUBDESIGN DFN
(
clk, reset                                  :INPUT;

gwc, sft, isd, eio, eic, eos, tout, rsd     :INPUT;

OPEN, CLOSE, RING, FLYUP, SURVEY            :OUTPUT;
)

VARIABLE
ss:MACHINE WITH STATES(STANDBY, WAIT1, ALARM, RUN, PAUSE, WORK, RETIRE, WAIT2);

BEGIN
ss.clk=clk;
ss.reset=reset;

TABLE
% present                                                                             next %
% state.       Inputs                                         outputs                 state. %
ss,            gwc, sft, isd, eio, eic, eos, tout, rsd  => OPEN, CLOSE, RING, FLYUP, SURVEY,  ss;

STANDBY,       1,   1,   x,   x,   x,   x,   x,    x    => 0,    0,     0,    0,     0,      WAIT1;
STANDBY,       1,   x,   1,   x,   x,   x,   x,    x    => 0,    0,     0,    0,     0,      WAIT1;
STANDBY,       0,   x,   x,   x,   x,   x,   x,    x    => 0,    0,     0,    0,     0,      STANDBY;
STANDBY,       x,   0,   0,   x,   x,   x,   x,    x    => 0,    0,     0,    0,     0,      STANDBY;

WAIT1,         x,   x,   x,   x,   x,   x,   1,    x    => 1,    0,     0,    0,     0,      ALARM;
WAIT1,         x,   x,   x,   1,   x,   x,   0,    x    => 1,    0,     0,    0,     0,      RUN;
WAIT1,         x,   x,   x,   0,   x,   x,   0,    x    => 1,    0,     0,    0,     0,      WAIT1;

ALARM,         x,   x,   x,   x,   x,   x,   x,    0    => 0,    0,     1,    0,     0,      ALARM;
ALARM,         x,   x,   x,   x,   x,   x,   x,    1    => 0,    0,     1,    0,     0,      STANDBY;

RUN,           x,   x,   x,   x,   0,   x,   x,    x    => 0,    0,     0,    1,     0,      RUN;
RUN,           x,   x,   x,   x,   1,   x,   x,    x    => 0,    0,     0,    1,     0,      PAUSE;

PAUSE,         x,   x,   x,   0,   x,   x,   x,    x    => 0,    1,     0,    0,     0,      WORK;
PAUSE,         x,   x,   x,   1,   x,   x,   x,    x    => 0,    1,     0,    0,     0,      PAUSE;

WORK,          x,   x,   x,   x,   x,   0,   x,    x    => 0,    0,     0,    0,     1,      WORK;
WORK,          x,   x,   x,   x,   x,   1,   x,    x    => 0,    0,     0,    0,     1,      RETIRE;

RETIRE,        x,   x,   x,   0,   x,   x,   x,    x    => 1,    0,     0,    0,     0,      RETIRE;
RETIRE,        x,   x,   x,   1,   x,   x,   x,    x    => 1,    0,     0,    0,     0,      WAIT2;

WAIT2,         x,   x,   x,   0,   x,   x,   x,    x    => 0,    1,     0,    0,     0,      STANDBY;
WAIT2,         x,   x,   x,   1,   x,   x,   x,    x    => 0,    1,     0,    0,     0,      WAIT2;


END TABLE;
END;
```

Table 1. Truth table for the DFN Controller.

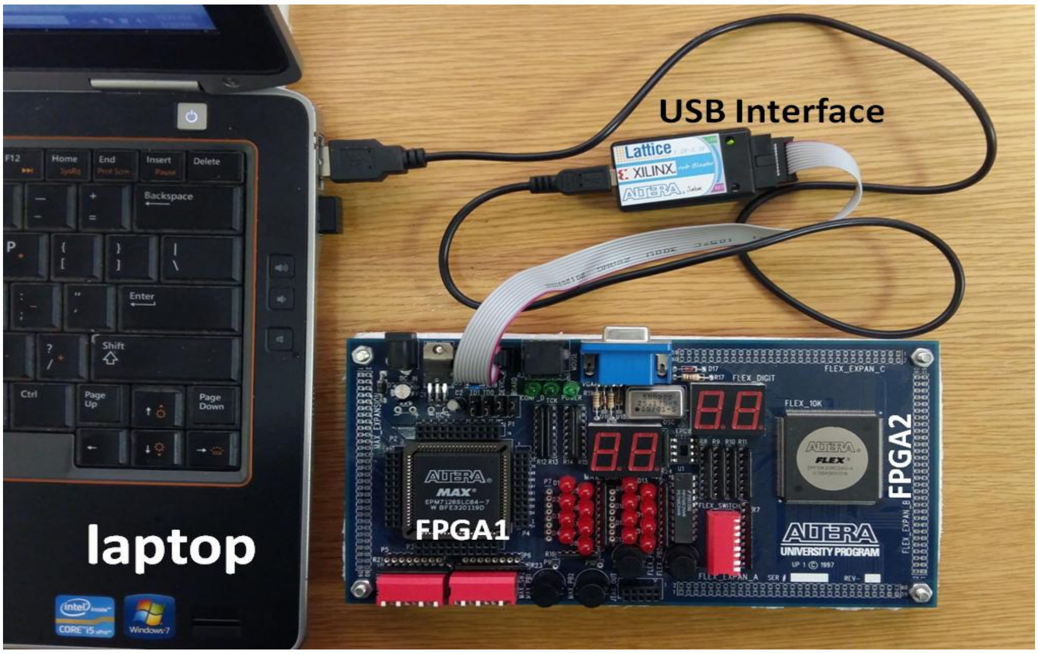


Figure 6. UP1 Development System

3.2 Drone Power Management System

The drone power management system (DPMS) ensures that the drone has enough power before it can move around in the fields. That means the battery capacity should not fall below a pre-set value which corresponds to the minimum power required to fly the drone back to the docking station. The drone may have to abandon its mission if its power is lower than the required minimum. The two drone control systems, DFN [10] and DPMS ensures a safe drone manoeuvre.

Figure 7 shows the basic DPMS. The DFN has to make a flight request from the DPMS (the idle state). The drone will not fly if the battery power cannot sustain the intended flight duration. Meantime the drone battery will be charging. If the battery power drops to below the critical level, the drone will force land. Its system will be sustained using solar panels on the drone itself.

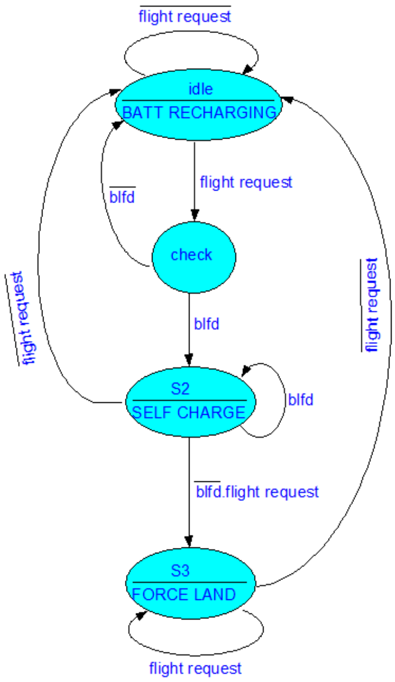


Figure 7. Drone Power Management System
(blfd=battery lower than flight duration)

3.3 Future Development

The perimeter of the target field will be defined using GPS coordinates. The IR cameras can be used for identification of livestock. RFID can also be used for positive animal identification

GPS and video capabilities can enable the farmer to observe what the system is detecting and possibly undertake proactive measures.

The drone system thus developed can be used to control other animals/birds by simply reprogramming. The proposed system can be integrated into other systems like internet of things, IoT

IV. CONCLUSION

A joystick controlled conventional drone was able to hover around with a flapping cloth attached to it. This proves that we can equip a more powerful drone with control gardgets and be able to move it around the fields. The successful simulation and prototyping of the DFN control unit further proves that this concept is plausible. It can also be applied to other situations such as driving wild animals away from unwanted areas since it can be updated with specific animal sounds.

The drone can also be customised to hunt for livestock, and also give the farmer feedback on the well-being of their crops.

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