IoT Device for Reduction of Roe Deer Fawn Mortality During Haymaking

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Abstract. In this paper, we propose a novel approach in smart farming with the deployment of centrally controlled IoT-scaring devices in meadows with the goal to reduce the killing of roe deer fawn during haymaking. These deaths are due to fawns not actively avoiding threats in their first two weeks of life, employing a defensive strategy of hiding scentless and motionless in order to avoid predation instead. Currently, they are searched and removed from areas to be mowed by hand. Our approach allows for a reduction of the labour required in advance of a scheduled mowing. During field tests, the effectiveness of the devices has been shown in northern Germany.

Keywords: Smart farming · LoRaWAN · Wildlife protection · IoT · fawn mortality

1 Introduction

1.1 Motivation

In case of danger, a roe deer fawn (as shown in Fig. 1) presses itself firmly on the ground and remains motionless. The flight instinct only sets in after the second week of life. In nature this is a good strategy against predation, but this behaviour is useless against a mowing machine. The German Wildlife Foundation (Deutsche Wildtier Stiftung) estimates that 92,000 fawns are threatened with mowing death every year on the 2.3 million hectares of grassland in Germany. Besides the obvious ethical reasons to avoid the mowing death of newborn animals, there are also economic and legal reasons.

The grass cuttings harvested from mowing are often processed into silage. If the cuttings are contaminated with carcass parts, it can become a breeding ground for the bacterium *Clostridium Botulinum* [4]. In the anaerobic conditions of silage, this bacterium secretes Botulinum toxin, a neurotoxin that causes botulism [2]. This toxin is considered one of the most potent poisons known to occur in nature and can kill cattle fed this silage within a few days [4]

Likewise, various German courts have ruled that landowners are liable to prosecution if the mowing death of wild animals is considered possible and no

Fig. 1: Roe deer fawn hiding in meadow (Author: Jan Bo Kristensen) and *Kitzretter* field effector deployed on meadow

appropriate measures are taken to prevent animals from setting or to scare them away. [1] In Germany, section 17 (1) of the German Animal Protection Act is particularly relevant here: *Whoever kills a vertebrate animal without reasonable cause is liable to a custodial sentence not exceeding three years or to a monetary penalty.*

Unfortunately, the main deer birthing season in May and June coincides with the first grassland cutting, so farmers have to take measures to save the fawns before mowing. However, these measures are very labour- and time-intensive and thus a challenge, especially on large areas.

The solution proposed in this work is designed to reduce the labour required for the saving of fawns while also decreasing mowing deaths. It is proposed to deploy multiple centrally controllable IoT deer-scaring devices. These are to be placed in and around meadows used for haymaking in advance of the mowing season.

The scaring devices are then supposed to be activated the night before a scheduled mowing. Once activated, varying localized audio-visual disturbances are emitted intermittently, running throughout the entire night. This is supposed to decrease the attractivity of the effected meadow, thus giving the doe an incentive to call her fawn and move it to a neighbouring safe hiding area.

1.2 Structure

This paper is structured as follows: In section 2, the approach for protection of wildlife before and during haymaking currently employed by farmers and hunters laboriously are discussed. Additionally, the current state of research on sensory perception of roe deer is explored with regard to the design of scaring cues.

Section 3 describes the implementation of the proposed solution, starting with a high level overview of the entire application and detailing the aspects of all components of the IoT-scaring device.

The effectiveness of the proposed devices and network is discussed in section 4, wherein the results of field tests conducted in northern Germany are evaluated. Finally, in section 5 the results and insights gained for further work are discussed.

2 Related Work

This section describes methods currently employed to reduce fawn mortality in preparation for haymaking with specific focus on the perceptual sensitivity concerning scaring cues of roe deer.

2.1 Available Methods for Detection and Rescue of Fawns

In order to avoid killing breeding and setting animals during haymaking, various approaches are proposed by the *Deutsche Wildtier Stiftung*:

A principle measure is to start mowing as late as possible, completely avoiding the breeding and setting seasons and prevent the mowing death of many animals. During mowing season, choosing daylight hours for mowing can avoid unnecessary animal deaths, as at night the necessary headlights disorientate wild animals [4]. Another measure is the mowing a parcel from the inside out to leave a protected escape route for the animals . Additionally, disc mowers lead to more animals being killed than bar mowers because of their strong suction effect.

Measures to be taken before mowing include searching the meadow with the help of dogs or drones (UAV, equipped with thermal imaging) shortly before mowing and taking them to safety or mark nests and fawns so that they are spared. Also, if a mowing is scheduled, measures can be taken to deter game beforehand. Traditionally, simple scarecrows constructed from wooden poles with large plastic bags attached to the top have been used. Electronic acoustic and visual game scaring devices have also become available in recent years. While both these scaring devices work, they need tight scheduling of deployment because of the roe deer's habituation to the devices, lessening the effect [7].

The deployment itself is labour intensive since many scaring devices must be placed to cover large patches of land. Also, when the weather conditions are suitable for haymaking, many farmers in a given area will want to mow simultaneously. Another problem is that all this work will be in vain if the mowing can not be performed on the scheduled day. In that case, the scaring devices have to be removed from the meadows to avoid habituation and redeployed once the new mowing date arrives, or the labour intensive searching of the meadow with dogs or drones has to be repeated.

2.2 Auditory and Visual Sensitivity of Roe Deer

When designing a stationary device to scare away (roe) deer, the sensory perception of roe deer must be studied to determine which colours and sound frequencies deers can perceive and thus which stimuli can be employed to drive them away. Since roe deer are not a frequent topic in established scientific publications [5], the literature research was oriented towards related species such as the fallow deer (Dama dama) and the white-tailed deer (Odocoileus virginianus).

Vision In game animal's eyes, more rods (sensitive to brightness) are present than cones (sensitive to colours). In cloven-hoofed game, the ratio is 9 to 1 [8], giving up to 100 times better vision in dark environments compared to humans.

Unlike humans, cloven-hoofed game usually have only two types of cones (dichromacy), one for short-wave light from ultraviolet to blue and one for green to yellow. Green tones can be perceived and distinguished very well, whereas red and brown tones are difficult to differentiate.

Blue stands out in a natural green environment. The most sensitive range is around 500nm, 497nm in white-tailed deer and dam deer [6]. The most sensitive short-wave range in both species is 450-460nm in the mid- and long-wave range 530-550nm [6]. Wild animals often feel disturbed by visual changes in their territory alone and avoid them. However, the habituation effect occurs quickly if no other negative effects emanate from a change [9]. With regard to this, randomised scare cues seem to be the means of choice.

Hearing Deer have large auricles that they can turn independently up to 180°. It has been shown that white-tailed deer hear frequencies from about 0.25 kHz to 30 kHz, with the greatest sensitivity in the range between 4 kHz and 8 kHz [3]. The situation is similar for conspecifics. Furthermore, deer tend to focus their attention on low frequencies rather than ultrasound. The longer the wavelength, the lower the intensity needed to reach the sound threshold, the more suitable the signal [10].

3 Implementation

In summary, roe deer fawn mortality during haymaking should be reducable if there exists a way to generate randomized audio-visual cues perceptible by roe deer in and around meadows, which can be activated just in time prior to the mowing to avoid habituation effects and all this with a low workload for setup and retrieval.

Given these design parameters, we propose a centralized networked solution based on smart scaring devices to be placed in the field, communicating wirelessly with a central server application which is itself controlled by users through a web-application.

3.1 Network Overview

The approach of the *Kitzretter* (eng: fawn guard) system to reduce the mortality of fawns during haymaking, designed at the University of Applied Sciences Emden/Leer in cooperation with the Aurich hunters' association, is the use of IoT devices that can be individually controlled and configured by a central server based on the radio technology LoRaWAN[1].

Field Devices are deployed in advance independent of the mowing schedule. They communicate wirelessly using LoRaWAN with the infrastructure of *The Things Community Stack* (TTN). The TTN forwards requests to a web application (see Fig. 2) and routes replies back to the devices. This enables a user to do monitoring and control and allows the scheduling of scaring effects just prior to the mowing, avoiding any habituation effect on the animals.

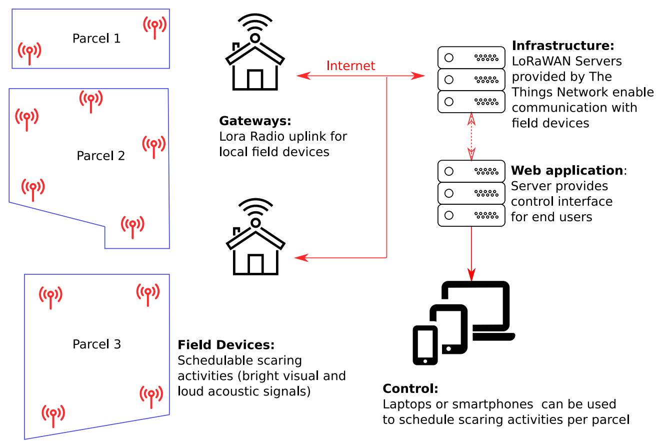


Fig. 2: Architecture and components of the proposed *Kitzretter* network: meadows (parcel 1 ..n) with IoT-scaring Field Devices (FE) , and public or private LoRaWAN-Gateways.

3.2 Wireless Communication

A plethora of wireless communication technologies usable for IoT devices exist, such as GSM, Sigfox or LoRaWAN.

Using cellular radio as data connection for the devices was rejected for multiple reasons. First and most importantly, many rural areas in Germany, which are the primary environment for the devices, have notoriously bad cellular network coverage, so a reliable connection cannot be assured. Additionally, mobile operators are in the process of shutting down GSM (2G, 3G) networks in favour of more modern technologies (LTE, 4G, 5G). While LTE provides higher data rates, the maximum range of a cell is limited and coverage in rural Germany is rather sparse. Also, providing each device (about one to two per hectare are required) with a cellular subscription would increase the operating cost substantially.

[1] compare `https://lora-alliance.org/`

The commercially available network architecture provided by Sigfox provides long range transmission capabilities, but was rejected since Sigfox does not provide built-in authentication nor encryption. Also, no free network plan is available, putting it at a cost disadvantage.

The corporation The Things Industries provides The Things Stack Community Edition, a free, community based deployment of a LoRaWAN network free of charge which has been selected for the *Kitzretter* devices' communication.

The low bandwidth provided by LoRaWAN due to it's diminutive data rate and fair-use airtime restrictions when using the community network plan are not a limitation for the proposed approach since only very little data communication is required as described in section 3.4. If a rural location does not provide a local LoRaWAN Gateway, a private or mobile gateway with a cellular connection can be deployed within reach of the meadows, equipped with a larger cellular antenna if necessary as illustrated in Fig. 2.

3.3 Web Application

The user frontend for control of the scaring activities provides registering of devices and users, monitoring of the devices status and scheduling of scaring activities for clusters of devices, all accessible through the user preferred web browser. The backend communicates with The Things Community Network (TTN) using the web-hook API: Whenever the TTN receives a data packet from a field device, the application receives a HTTP POST request containing the contents of the packet.

Replys generated by the backend are then returned to TTN and delivered to the field devices using TTN's uplink to the local LoRaWAN Gateways. The web application used to control a *Kitzretter* network is written in the Rust programming language. It is self-contained and can easily be deployed to Linux based server of choice, either in house or rented from a public cloud.

3.4 Design of Field Effectors

The battery-operated devices to be placed in meadows are called field effectors (FE, see Fig. 1). Each FE is tagged with an unique QR-code which can be recorded during deployment using a geotagging camera (e.g. any smartphone with GPS receiver) to record it's position.

Hardware The FE consist of a scaring module called Effectorboard and a logic and communication module called Loraboard as illustrated in Fig 3. The Loraboard is a custom circuit board equipped with a NXP 32-bit Cortex M0 micro-controller unit (MCU) and an integrated LoRaWAN-module *RFM95W*, with the antenna line connecting to an U.FL coaxial connector.

For power supply, the board is equipped with mounting clips for two standard 18650 LiPo-battery cells and a charge control circuit providing an USB 2.0 Micro-B connector as charging port.

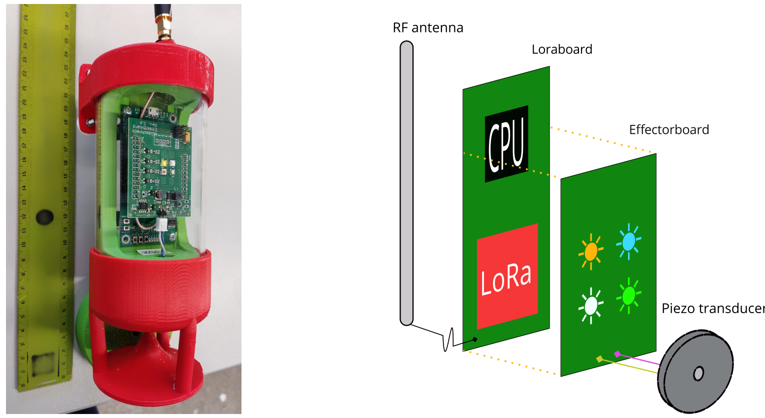


Fig. 3: Components of the proposed *Kitzretter* field effector (FE)

In consideration of the auditory and visual sensitivity of roe deer as discussed in section 2.2, the Effectorboard mounted on top of the Loraboard, is equipped with four high powered LEDs (350mA each) in the colours amber, green, white and blue for visual effects and an amplifier stage driving an external piezo transducer for the emission of audio signals with a sound pressure level of up to 95 dB (square wave, 1 KHz, 0.5 m distance).

The components are bolted to a 3D-printed holder and mounted inside a transparent acrylic pipe with a length of 10 cm and a diameter of 70 mm, sealed rubber rings and 3D-printed screw-on caps. The upper cap carries an external whip antenna while the lower cap contains the piezo transducer firing downward on a conic omnidirectional sound diffuser (compare Fig. 3).

Firmware The firmware is designed for low power usage during deployment over several weeks. To achieve this, activity is limited to short phases while most of the time, the field effectors are in sleep mode. In following, a short description of the devices behaviour is given.

On power-up, the devices try to connect to a local LoRaWAN Gateway immediately. On connection, the server sends the current time for clock synchronization, followed by any scheduled scaring activities. The current state of the initialization is indicated with coloured LEDs.

Once the initialization phase is over, the LEDs blink three times before going dark, indicating switch-over to standby mode. In standby mode, the CPU and radio are powered down to conserve energy. The internal RTC (realtime-clock), driven by an external oscillator for higher precision, is used to wake up the MCU periodically to send an 'alive' beacon and to be able to receive newly scheduled scaring activities.

This continues until the time of a scheduled scaring activity is reached or power runs out. During a scaring activity, one of several preprogrammed scaring sequences are played back. The available effects are visual and auditory, using the very bright LEDs mounted on the Effector board and the emission of waveforms generated numerically with Direct Digital Synthesis (DDS). This allows for both square wave beeps of 100 Hz to 15 kHz or playback as well as digital samples, such as barking dogs or the warning call of the Eurasian jay *(Garrulus glandarius)*[2].

The Firmware is based on a port of the open-source LMIC-driver[3], originally designed for use with Arduino compatible 8-Bit micro-controller boards, to the ARM-based LPC11xx-platform used by this project.

4 Evaluation

In May and June 2019, successful initial tests were carried out with prototypes of the system created as part of student work in the rural municipality of Großefehn in the district of Aurich, Germany, proving the technical viability of the proposed solution. In the springtime of 2020 and 2021, further field evaluations focussing on network, timing and network coverage were conducted with up to 16 of the revised version of the *Kitzretter* field effectors (FE) as described in section 3.

4.1 Scaring Effectiveness

For a field test, FE are deployed all over the target area, leaving a distance of about 40 m to 80 m between them (compare Fig. 4a and 4b). The deployment is done a week or two in advance of the planned scaring in order to be sure the Effectors scare of the deer and not the deployment activities.

Some of the target areas had LoRaWAN network coverage from gateways several kilometres away, but for reliable synchronous scaring it was necessary to install a local gateway on a barn of the neighbouring farm. In places where no public gateway was within range, a trailer mounted battery powered gateway with an antenna height of 3.5 m was set up.

Scaring activity typically last for several hours of intermittent playback of scaring effects running for a minute or two, followed by 15 to 30 minutes of silence. Scaring activities can be scheduled remotely at arbitrary times via the web application, and are typically scheduled from dusk the day before a planned mowing until the next dawn in order to maximize the disturbance.

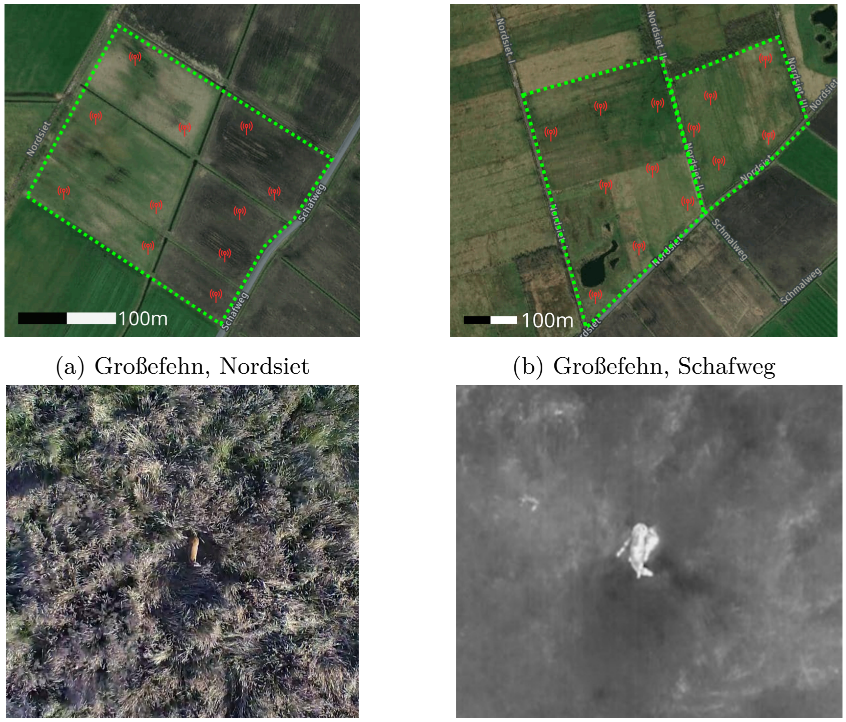
In order to determine the scaring effectiveness, an unmanned aerial vehicle (UAV) with a thermal imaging camera is used to seek out fawns in the meadows prior to and after a test cycle, with the absence of fawns after a scaring cycle considered a successful trial (compare Fig. 4c and 4d).

Five evaluation trials were conducted in different locations between April and June of 2021. Observation of the trials was performed by members and associates of the Aurich hunting association. The results are promising:

In two of the five trial areas, no roe deer and fawns were detected by the drones prior to the scaring activity, probably due to very wet weather in the

[2] A bird common across Eurasia with a harsh, rasping screech that it uses upon sighting of predators

[3] `https://github.com/mcci-catena/arduino-lmic`



(a) Großefehn, Nordsiet

(b) Großefehn, Schafweg

(c) Aerial image of fawn

(d) Thermal image of fawn

Fig. 4: *Kitzretter* setup in trial areas

area and subsequent low growth of vegetation. Four fawns were detected in the third location and further two in the forth. In the fifth trial area, no fawns but two does were present. In all five trial areas, neither adult roe deer nor fawns were present in the morning after scaring activity. This indicates that the doe has led the fawns out of the meadow. Accordingly, no intervention or action by humans was necessary to search for or remove the animals before the upcoming mowing.

5 Conclusion

In this work, the *Kitzretter* network, a smart networked digital scaring device, is presented and shown to have the ability to reduce roe deer fawn mortality during haymaking.

As is evident from this report, it can be difficult to conduct trials in the field since multiple factors may interfere with test arrangements and animal behaviour cannot be planned. Since every scaring activity in locations with roe deer present resulted in the deer leaving, it appears that some effectiveness of the *Kitzretter* devices has been confirmed.

A secondary goal of *Kitzretter* is to reduce the labour required for the rescue of fawns. This is achieved twofold: first, since the deployment is independent from the actual mowing date, a meadow can be prepared in advance, avoiding scheduling conflicts for those conducting the deployment. Second, since the scaring activities decrease the attractivity as a hiding place, the roe does call their fawns from the meadows themselves, such that the step of locating and picking up or marking the fawns is no longer necessary.

In conclusion, the system using LoraWAN in rural environments for synchronised scaring has been shown to work during our trials. In the 2022 haymaking season it is planed to conduct more trials with a greater number of FE in multiple locations across Germany to validate our approach with a larger amount of data points and to find the optimal parameters, such as minimum devices per hectare and selection of most efficient audio-visual scaring cues.

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