Divide and Conquer 2.0: Wirelessly Connected Laser Shooting Gallery

Group Information

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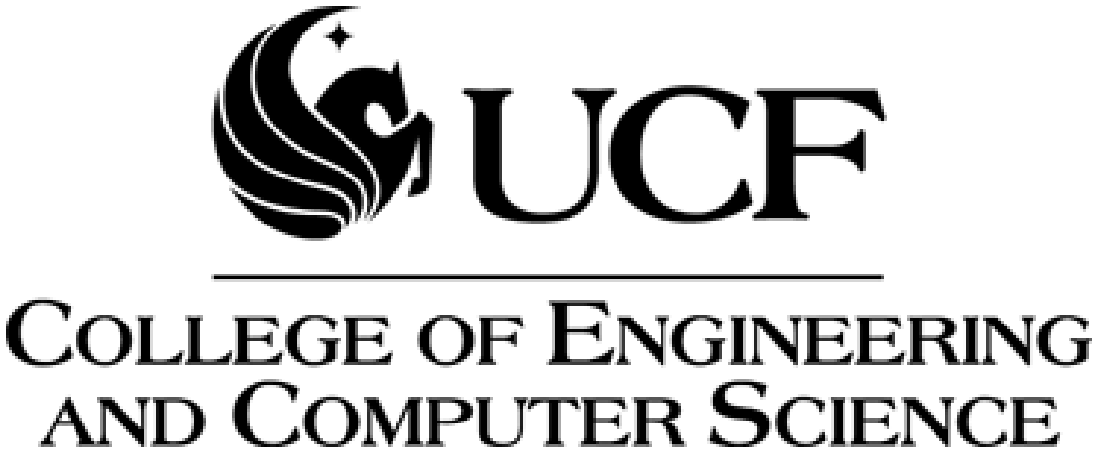

Overview

In this paper, we propose a new design for a laser shooting gallery that is meant to improve upon traditional gallery systems. The purpose of this project is to create a wireless laser shooting system that is reconfigurable, expandable, and convenient to use, with the goal of creating a better user experience.

Motivation

Typical proprietary shooting galleries have limited reconfigurability outside of their core structure. Most existing systems rely on fixed, hard-wired points that can typically only be set up in expensive, permanent installations, limiting both configuration possibilities and market reach. However, with the recent explosion in low-power and low-cost wireless computing, we believe that a solution involving multiple discrete, self-contained, low-cost wireless targets alongside a custom-designed "gun" controller and software suite would allow for increased user convenience, more interesting user experiences, and additional features that traditional, systems are unable to achieve.

Description

The "Gun" Controller

The main controller for the system is a single device, styled after a traditional laser tag gun or pistol. Its core functionality is two-fold; it serves as the master controller for the entire game system, organizing and managing game data and device behavior for the various targets in the system, and it also serves as the main user interface for the system, with a traditional trigger input activating its laser diode. In addition, a simple status screen on the controller can inform the user about the game state or device status. Other sensory functionality might also be included if time permits, such as aural or tactile feedback through speakers and motors.

A relatively modest microcontroller with built-in wireless capabilities would be preferred for this role – while managing game and device statuses over a wireless network might be complicated, it's something that doesn't require a massive amount of computing power. It's mostly event-based, and as such could be designed to be energy and computationally efficient.

All these components require power, and as such, should be powered via an onboard battery. This battery requires some chip to manage its status, as well as to provide some utilities for charging and discharging it. The battery should also be able to be recharged while inside of the device, using a standard connector.

One or More Target Devices

Targets are a critical component of a shooting gallery setup. The core functionality of a target, in this system, is to communicate with the main controller and wirelessly signal a successful hit whenever it receives a hit from the laser diode. This functionality is expanded with a display (either through some form of traditional display or LED array) or even a speaker, in order to convey to the user some feedback that a hit has been registered, or even display extra information about the game state. These are all managed by an on-board microcontroller.

The microcontroller here also requires wireless capabilities, to signal to the main controller that a hit has been registered. While it is not managing game state, but rather acting as

a follower to the controller device, it still might require some more advanced computing resources in order to drive the onboard display or optional audio component.

As with the controller, a target device should contain a battery alongside a battery management circuit and charging port.

Embedded Software and Game Control

There are quite a few interconnected parts to this system and joining them all together to create a cohesive gameplay or overall user experience is the role of the software running directly on the microcontrollers on each device. The software running on these devices not only needs to manage the devices' state, react to input events, etc., but also handle networked events, like game state alterations or interactions with a mobile app. As there are two different levels of device in this system, each with vastly different responsibilities and behaviors, the Controller and Targets will each need their own bespoke software package.

The Controller's software will likely be the most complex, as it carries the responsibility of managing and configuring game states, validating the network status of the entire system, interfacing with the user through physical and mobile controls, and its own system management (battery, laser shooting, etc.).

Game Modes

Providing a small collection of interesting, fun, and highly "replayable" game modes as part of the software is critical to the success of the final, larger product. A few examples or ideas as to what these might entail are listed below. Playtesting would be required to fine-tune timing and ideas for each game mode.

Time Trial

How many targets can you clear before time runs out? All targets light up and must be shot by the user. Once all are out, they all light up again. A timer on the controller's display informs the user how long they have left. Their total number of targets hit is tallied and displayed at the end.

Whack-A-Mole

Like the Time Trial, Whack-A-Mole would be a game mode in which the player must shoot targets as they appear – however, only a few targets light up at a time, and turn off if they're not hit fast enough. The player must be quick and accurate to score high.

Horde

Targets light up one by one, with increasing frequency between each activation. If a target is left on for too long, the game is over. The amount of time a target has been active for is indicated by the color of the display on the target. Multiple targets can be active at once. The amount of time a target can be active before ending the game becomes faster and faster as the game continues. Scoring is evaluated by how long the player lasted and how many targets they shot.

One-Shot

This game is about accuracy. You have one shot, which is refilled each time you successfully hit a target. Only one target appears, but it has the countdown functionality of Horde mode. Shoot the target, another one lights up. Only one is active at a time. If you miss, you lose.

Mobile Application

To make gameplay more interactive and intuitive, the user will be able to interface with the system via a mobile application to configure aspects of gameplay. The application will communicate with the system wirelessly to allow the user to select from multiple game modes. The application will also receive information from the system to display the user's score, system status, and other gameplay metrics.

Requirements

The minimum technical requirements for our system are listed below in Table 1. The requirements highlighted in blue are those that are the most easily demonstrable.

Number	Purpose	Description	Requirement
1	Performance	The controller should have a high active uptime	≥ 5 hours
2	Performance	Each laser target should have a high active uptime	≥ 8 hours
3	Performance	The time between pulling the trigger and the target's visual response should be small	≤ 0.1 seconds
4	Performance	The system should have a quick startup time	≤ 25 seconds
5	Performance	Target pairing should be completed in minimal clicks	≤ 4 clicks
6	Energy	The controller should be energy efficient, consuming a small amount of power	≤ 3000 mAh
7	Usability	The controller should achieve a low maximum weight	≤ 10 lbs
8	Usability	The target should achieve a low maximum weight	≤ 5 lbs
9	Usability	The system should be in "ready to play" state within a short period after startup	≤ 2 minutes

Table 1. System Requirements

Constraints

Constraints on the system are listed below in Table 2. This list includes the requirements that our system must follow to be in compliance with federal and local policies, as well as to ensure easy use and maintainability of the product.

Number	Purpose	Constraint
1	Environmental	All components should be RoHs compliant
2	Health & Safety	The system should not expose operators to harmful laser radiation or cancerous materials. At minimum, the system should meet the requirements of an FDA Class IIIa device
3	Legal	The development and testing of the system should abide by the procedures outlined in UCF's "Weapons on University Property and at University Events" policy (UCF Policy 3-119.2)
4	Legal	Intellectual property investigation should be conducted to ensure no infringement on existing patents
5	Maintainability	The targets and the controller should be able to be accessed for maintenance without destructive manipulation of the product
6	Maintainability	The devices should be able to operate without a mandatory connection to an online service or a mobile app
7	Maintainability	Downloading firmware updates to each device should be possible to allow for future improvements
8	Usability	The controller and targets must use tactile buttons for functions

Table 2. System Constraints

Standards

The industry established standards we plan to use in the design of our system are listed below in Table 3.

Number	Purpose	Standard
1	Safety	UL Testing Certification
2	Safety	Proper labeling of the system for regulated components (e.g. battery, controller, cancerous material)
3	Reliability	IPXX Testing
4	Functionality	Wi-Fi 802.11xx
5	Manufacturability	The system should be built to the 3-layer PCB standard
6	Reliability	All PCBs should use conformal coating

Table 3. System Standards

House of Quality

The house of quality comparing and contrasting the engineering and marketing requirements of the system is shown in Figure 1 below.

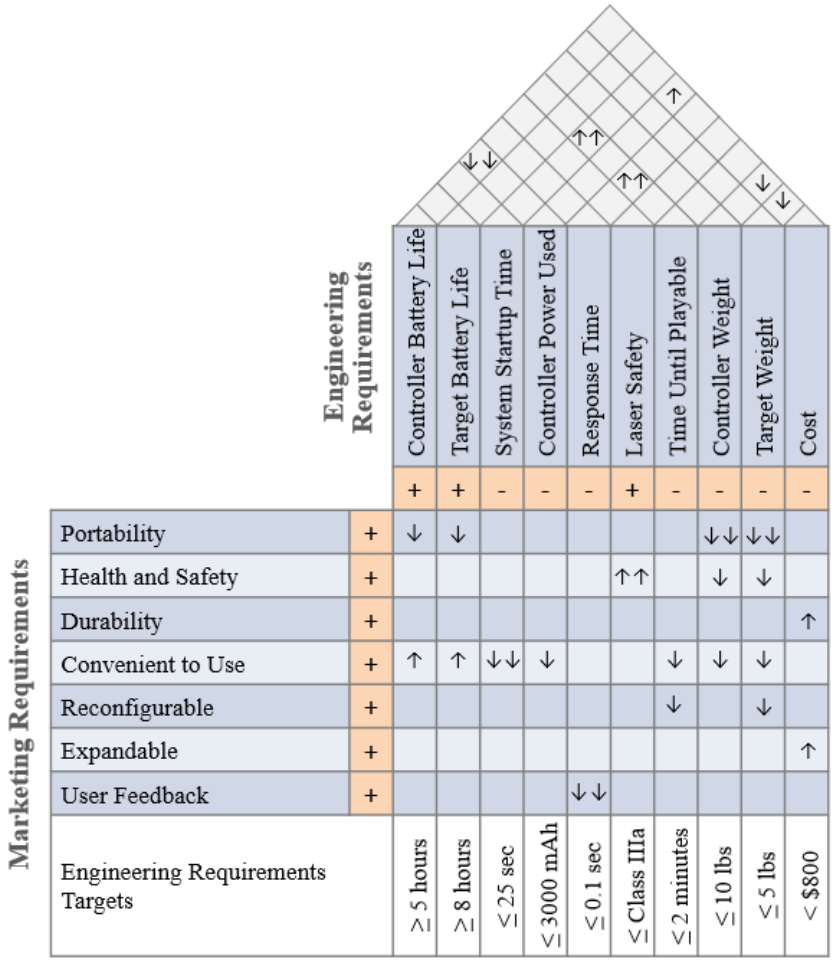

Figure 1. House of Quality

Block Diagrams

Block diagrams for our system, including the status of each unit and the member responsible for the design of each subcomponent, are shown in the figures below. The hardware block diagram is shown in Figure 2. Hardware Block DiagramFigure 2 and the software block diagram is shown in Figure 3.

Hardware

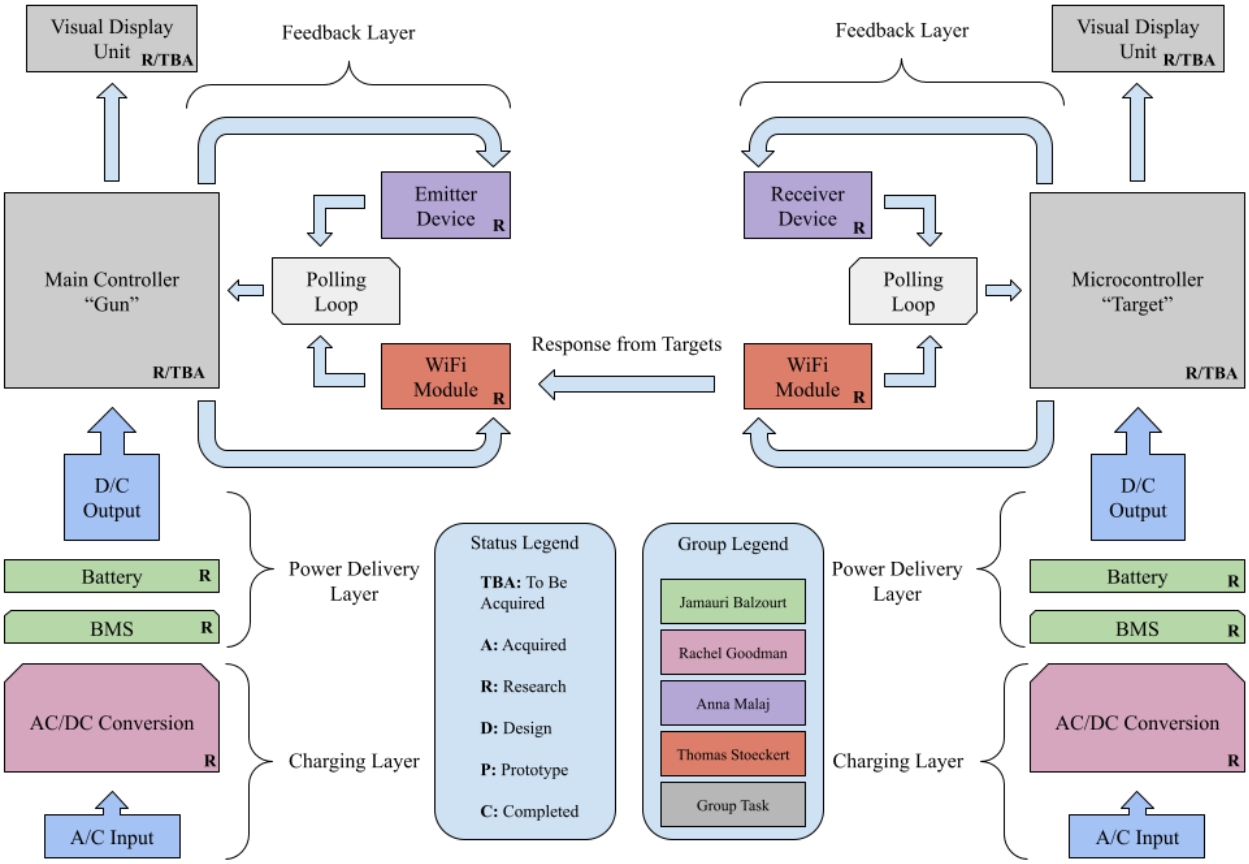

Figure 2. Hardware Block Diagram

Software

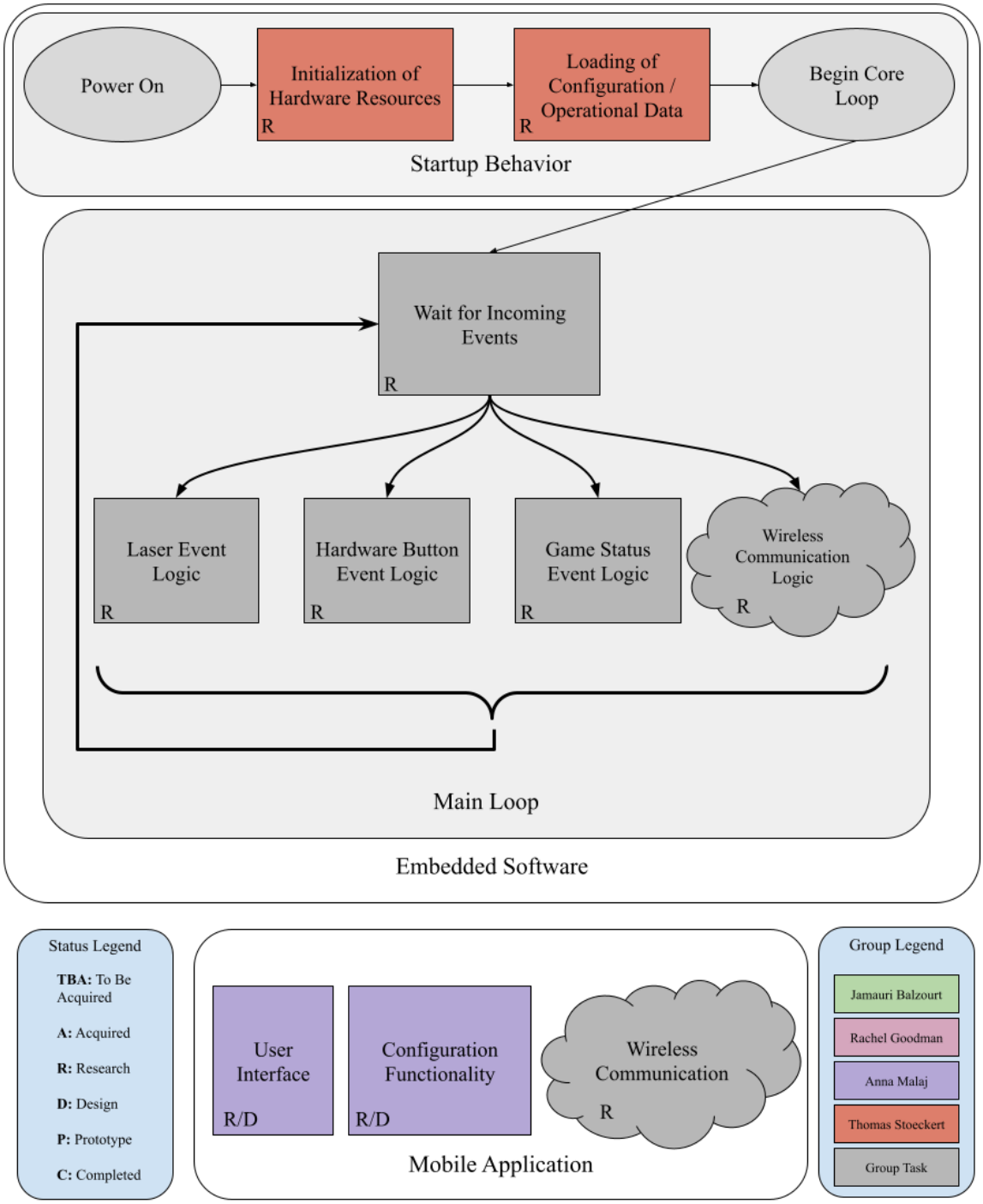

Figure 3. Software Block Diagram

Budget

This project will be funded by the group directly, with costs being split evenly among all four group members. The estimated cost range for each item is given below in Table 4, as well as the estimated quantity of each item, and the minimum and maximum total costs.

Item	Quantity	Price/Unit ($)
MCU	5	4
Battery (Controller)	3 (min.)	15-50
Battery (Target)	3 (min.)	10-40
Enclosure (Controller)	2 (min.)	50-60
Enclosure (Targets)	3 (min.)	15-30
LED Array/ LED Panel	4 (min.)	10-30
Controller	5 (min.)	6
IR Receiver	5 (min.)	5
Photodiode (for calibration)	4 (min.)	3
Services	N/A	100
Total:		**Min: $447** **Max: $787**

Table 4. Project Budget Breakdown

Milestones

Deadlines for project deliverables and their associated tasks are shown in the tables below. The plan for Fall 2021 is given in Table 5 and the plan for Spring 2022 is given in Table 6.

Fall 2021

Task	Assigned To	Progress	Start	End
Attend Senior Design Bootcamp (9/1)				
Form Groups	All	DONE	8/24	8/26
Determine Meeting Platform	All	DONE	8/26	9/1
Decide Meeting Schedule	All	DONE	8/26	9/1
Brainstorm Project Ideas	All	DONE	8/26	9/1
Divide and Conquer 1.0 (9/17)				
Choose Project Idea	All	DONE	9/1	9/6
Establish Project Motivation	Thomas	DONE	9/6	9/8

Establish Project Goals	Anna	DONE	9/6	9/8
Determine Game Modes / Rules	Thomas	DONE	9/6	9/8
Determine Requirements	All	DONE	9/6	9/8
HW Block Diagram	Jamauri, Rachel	DONE	9/8	9/15
SW Block Diagram	Thomas, Anna	DONE	9/8	9/15
Establish Milestones	Anna	DONE	9/8	9/15
Begin Task Breakdowns	Anna	DONE	9/8	9/15
Determine Budget	Jamauri, Rachel	DONE	9/15	9/17
Assign Project Roles	All	DONE	9/15	9/17
Divide and Conquer Meeting With Dr. Richie (9/22)				
Take Notes on Recommended Revisions	All	DONE	9/22	9/22
Ask Clarifying Questions	All	DONE	9/22	9/22
Divide and Conquer 2.0 (10/1)				
Refine Requirements, Constraints, and Standards	All	DONE	9/22	10/1
Refine Task Breakdowns	Anna	DONE	9/22	10/1
Create House of Quality Diagram	Rachel	DONE	9/22	10/1
60 Page Draft (11/5)				
Research and Document Related Work	All	TO DO	10/1	10/5
Refine Requirements, Constraints, and Standards	All	TO DO	10/1	10/5
Create Hardware Schematic	Jamauri, Rachel	TO DO	10/5	10/12
Create PCB Design	Jamauri, Rachel	TO DO	10/12	10/19

Define Hardware Testing Plan	Jamauri, Rachel	TO DO	10/12	10/19
Create Software State Diagram	Thomas, Anna	TO DO	10/5	10/29
Create Software Flow Chart	Thomas, Anna	TO DO	10/5	10/29
Define Communication Protocol Between Embedded Software and Mobile App	Thomas, Anna	TO DO	10/5	10/29
Design UX for Mobile App	Thomas, Anna	TO DO	10/5	10/29
Define Software Testing Plan	Thomas, Anna	TO DO	10/29	11/5
Create Integration Testing Plan	All	TO DO	10/29	11/5
Create Comparison Charts for Each Part	All	TO DO	10/19	11/1
Select Parts	All	TO DO	11/1	11/2
Order Parts	All	TO DO	11/2	11/5
100 Page Draft (11/19)				
Build and Test Hardware Prototype	Jamauri, Rachel	TO DO	11/5	11/19
Write and Test Software Prototype	Thomas, Anna	TO DO	11/5	11/19
Refine and Expand Project Details	All	TO DO	11/5	11/19
Final Report (12/7)				
Build and Test Hardware Prototype	Jamauri, Rachel	TO DO	11/19	12/7
Write and Test Software Prototype	Thomas, Anna	TO DO	11/19	12/7
Refine and Expand Project Details	All	TO DO	11/19	12/7

Table 5. Fall 2021 Task Breakdown

Spring 2022

Task	Assigned To	Progress	Start	End
Tasks To Be Determined Once Requirements Are Known				
CDR Presentation (TBD)				
CDR Meeting (TBD)				
Submit Project Reviewer Commitment Form (TBD)				
Conference Paper (TBD)				
Midterm Demo (TBD)				
Midterm Meeting (TBD)				
Group Website (TBD)				
Final Presentation (TBD)				
Final Report (TBD)				
Present at Senior Design Showcase (TBD)				
Exit Interview (TBD)				

Table 6. Spring 2022 Task Breakdown