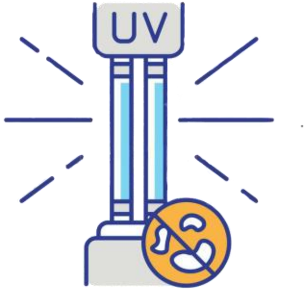
MUSR

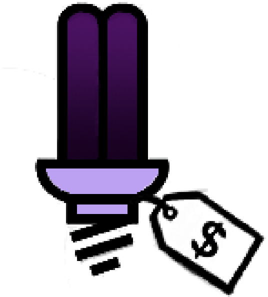
A LOW-COST **MU**LTIPURPOSE **S**TERILIZATION **R**OBOT

Introduction



UVC light facilities are commonly used in hospitals, laboratories, and water sterilization as Ultraviolet light can kill or inactivate nearly every kind of pathogen

Problem



High-tech sterilization equipment required for maximum safety is expensive, and many institutions lack the resources for it.

DESIGN REQUIREMENTS

The objective of this project is to provide an efficient, effective, low-cost sterilization solution.

MOVEMENT

Has autonomous and remote-control capabilities

CLEANING METHODS

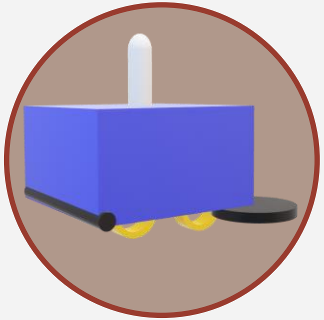
Uses UV Sterilization with complimentary Vacuum and Mop

Vacuuming and mopping promote maximum efficacy by cleaning surfaces before ultraviolet sterilization, by removing any materials that will block the UVC rays.

PROTOTYPE 1

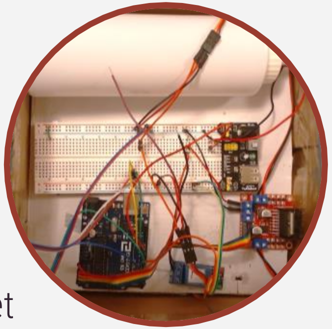
PHASE 1: STRUCTURAL BUILDING

- 2 motorized wheels, 2 free-spinning wheels
- 2 moppers (attached to back)
- Vacuum nozzle (attached to front)
- UVC light (attached to top)
- Sensors (attached to front)



PHASE 2: ELECTRONIC ASSEMBLING

- Arduino UNO for the control unit
- Motor driver to control the direction/speed of wheels
- Infrared sensor to detect objects
- Relay module to control the ultraviolet light

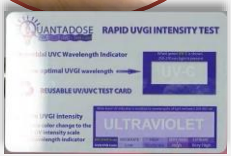


PHASE 3: PROGRAMMING

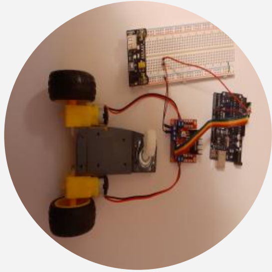
- Robot programmed using Arduino IDE
- Works autonomously, uses sensors to maneuver around avoid objects.
- Steadily moves in a back-and-forth motion.

PHASE 4: TESTING

- Random objects (differing sizes) placed in front of the robot to test autonomous movement
- UV tested using dosimeter cards. Showed whether the UV was of optimal wavelength and intensity for sterilization.



DESIGN IMPROVEMENTS IN PROTOTYPE 2



Structural Building

- 4-wheel design into 3 wheel design
- 2 motorized wheels, 1 castor wheel
- Nearly the same stability as 4 wheel design
- Improved turning accuracy

Electronic assembling

- Infrared sensor removed from design,
- Two more ultrasonic sensors were added on either side
- Reduce problems during autonomous driving.

Programming

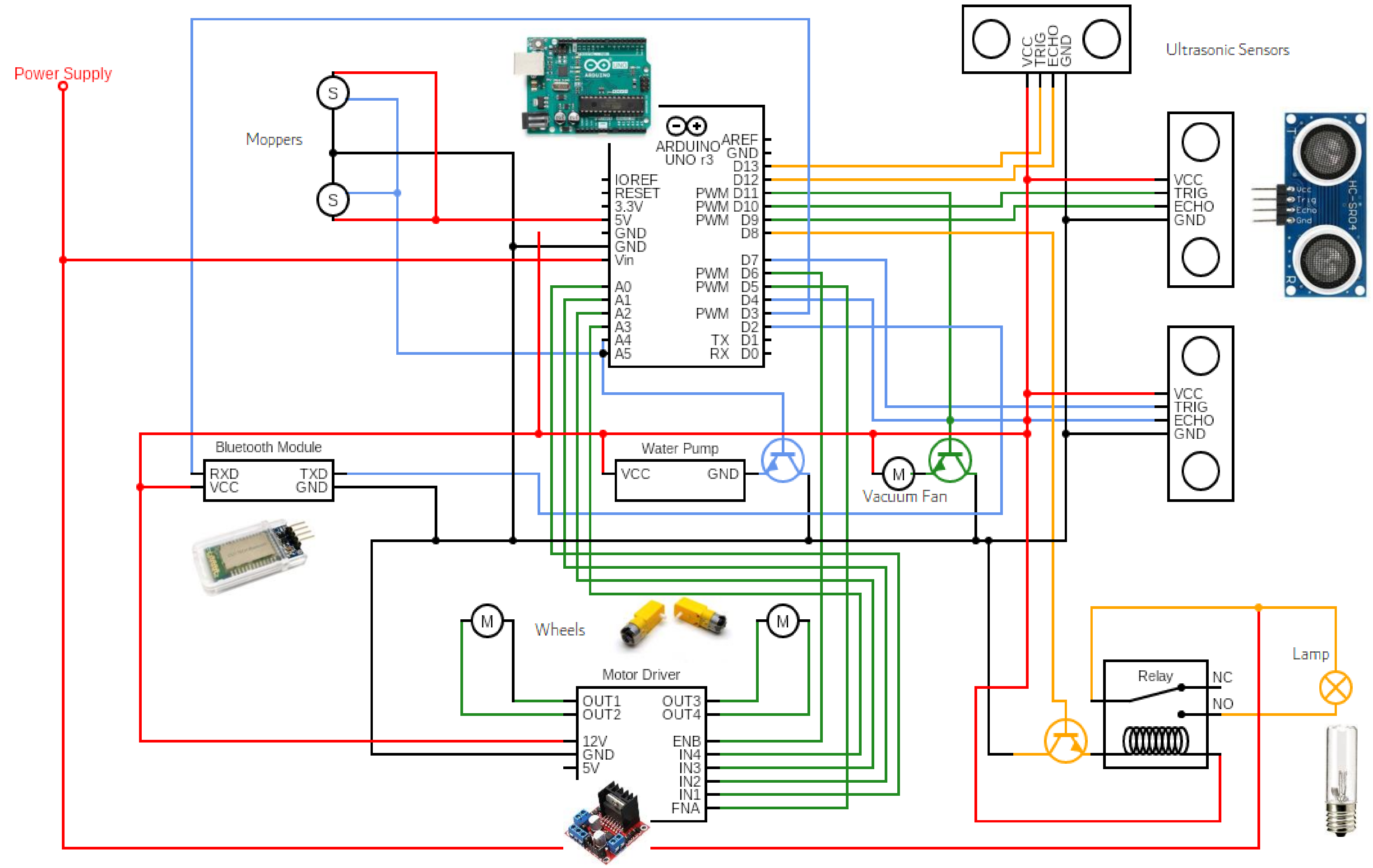
- Sensors on either side of the robot programmed move the robot around objects
- Senses objects to the right or left of the Robot.

Added Feature:

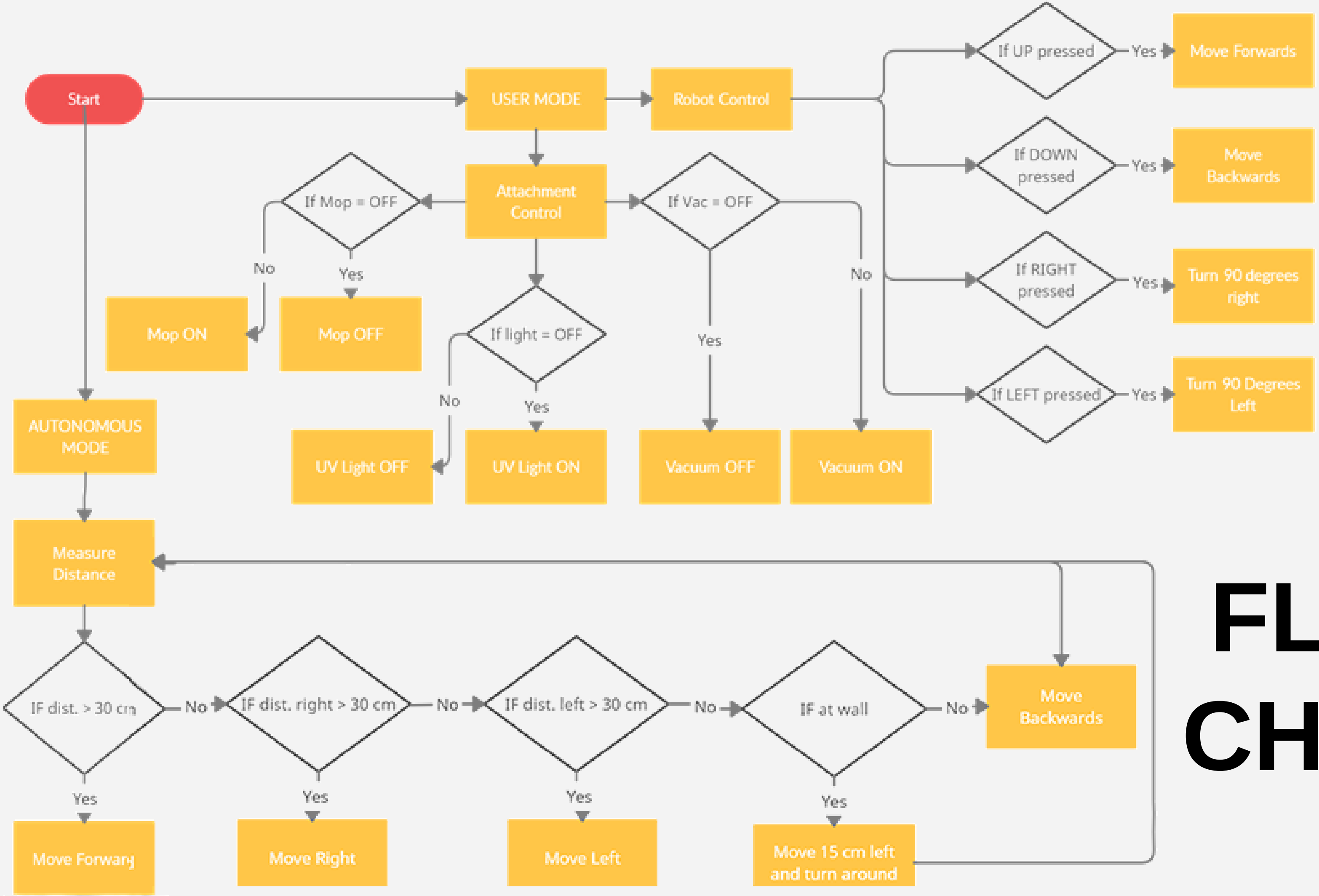
- Remote control facility added with a mobile app.
- Turn on/off each of the appliances
- Manually control the robot's movement.
- Developed in Android Studio

CIRCUIT DIAGRAM

PROTOTYPE 2



FLOW CHART


Start
USER MODE
Robot Control
If UP pressed
Yes
Move Forwards
If DOWN pressed
Yes
Move Backwards
If RIGHT pressed
Yes
Turn 90 degrees right
If LEFT pressed
Yes
Turn 90 Degrees Left
Attachment Control
If Mop = OFF
No
Yes
Mop ON
Mop OFF
If Vac = OFF
Yes
No
Vacuum OFF
Vacuum ON
If light = OFF
No
Yes
UV Light OFF
UV Light ON
AUTONOMOUS MODE
Measure Distance
IF dist. > 30 cm
No
Yes
Move Forward
IF dist. right > 30 cm
No
Yes
Move Right
IF dist. left > 30 cm
No
Yes
Move Left
IF at wall
No
Yes
Move 15 cm left and turn around
Move Backwards

Ultraviolet Light Testing

Requirements	1 Meter			ACC.	2 Meters			Acc.	3 Meters			Acc.
Wavelength between 250-270 nm: “UVC” Present on Card	Yes	Yes	Yes	100%	Yes	Yes	Yes	100%	Yes	Yes	Yes	100%
Intensity > 300 μW/cm²: “Ultraviolet” present on card	Yes	Yes	Yes	100%	Yes	Yes	Yes	100%	No	No	No	0%
Intensity Level	Mod.	Mod.	Mod.		Mod .	Mod.	Mod.		n/a	n/a	n/a	

Autonomous Driving in well-lit conditions, no obstacles

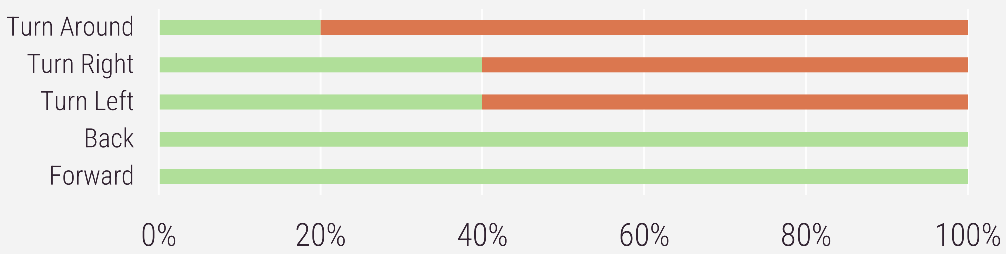
ACTION	PROTOTYPE 1					ACC.	PROTOTYPE 2					ACC.
Move forward	Yes	Yes	Yes	Yes	Yes	100%	Yes	Yes	Yes	Yes	Yes	100%
Move backward	Yes	Yes	Yes	Yes	Yes	100%	Yes	Yes	Yes	Yes	Yes	100%
Turn 90 degrees towards the left	No	Yes	No	No	Yes	40%	Yes	Yes	No	Yes	Yes	80%
Turn 90 degrees towards the right	No	No	Yes	No	Yes	40%	Yes	Yes	Yes	Yes	Yes	100%
Turn around 180 degrees	No	No	No	Yes	No	20%	Yes	Yes	Yes	Yes	Yes	100%

AUTONOMOUS ACTION	CONDITION	PROTOTYPE 1: INFRARED					ACC.	PROTOTYPE 2: ULTRASONIC					ACC.
		T1	T2	T3	T4	T5		T1	T2	T3	T4	T5	
Detect Obstacle	Small Objects	Yes	Yes	No	No	Yes	60%	Yes	Yes	Yes	Yes	Yes	100%
Avoid Obstacle		Yes	No	No	No	Yes	40%	Yes	Yes	Yes	Yes	Yes	100%
Exit an enclosure		No	No	No	No	Yes	20%	Yes	Yes	Yes	No	Yes	80%
Detect Obstacle	Medium Objects	Yes	Yes	No	Yes	No	60%	Yes	Yes	Yes	Yes	Yes	100%
Avoid obstacle		No	Yes	No	Yes	No	40%	Yes	Yes	No	Yes	Yes	80%
Exit an enclosure		No	No	No	Yes	No	20%	Yes	No	Yes	Yes	Yes	80%
Detect Obstacle	Large Obstacles	Yes	No	No	No	Yes	40%	Yes	Yes	Yes	Yes	Yes	100%
Avoid obstacle		Yes	No	No	No	Yes	40%	No	Yes	Yes	Yes	Yes	80%
Exit an enclosure		No	No	No	No	Yes	20%	No	Yes	Yes	No	Yes	60%

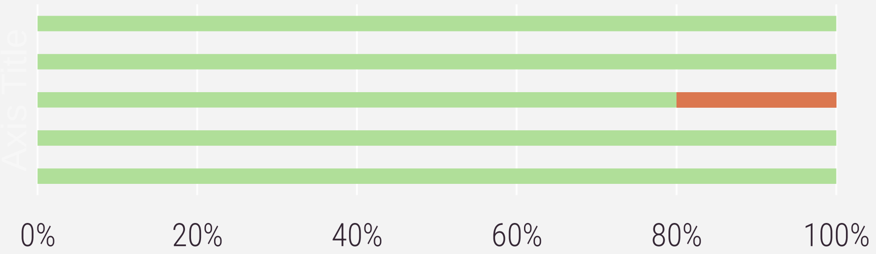
REMOTE ACTION	APP BUTTON	RESULT				
Move forward	Forward	Yes	Yes	Yes	Yes	Yes
Robot rotates 90 degrees towards Left/Right	Backward	Yes	Yes	Yes	Yes	Yes
The Robot rotates 180 degrees	Turn left	Yes	Yes	Yes	Yes	Yes
Turn Light On/Off	Turn right	Yes	Yes	Yes	Yes	Yes
Turn Vacuum On/Off	Turn around	Yes	Yes	Yes	Yes	Yes
Turn Mop On/Off	Ultraviolet Light	Yes	Yes	Yes	Yes	Yes

Autonomous Driving in well-lit conditions, no obstacles

Prototype 1

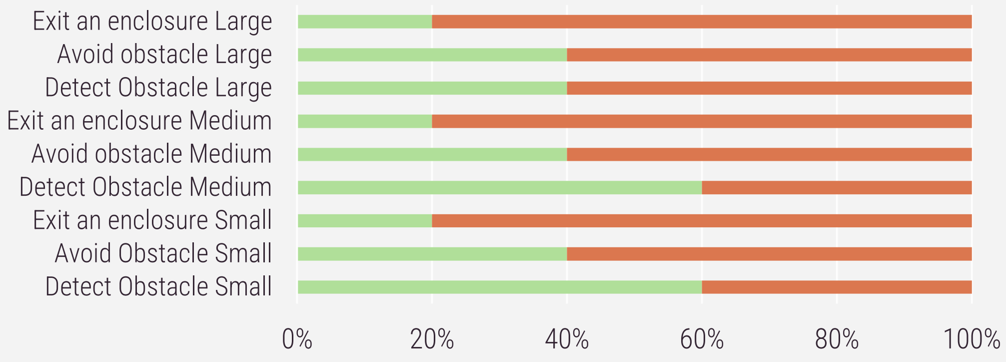


Prototype 2

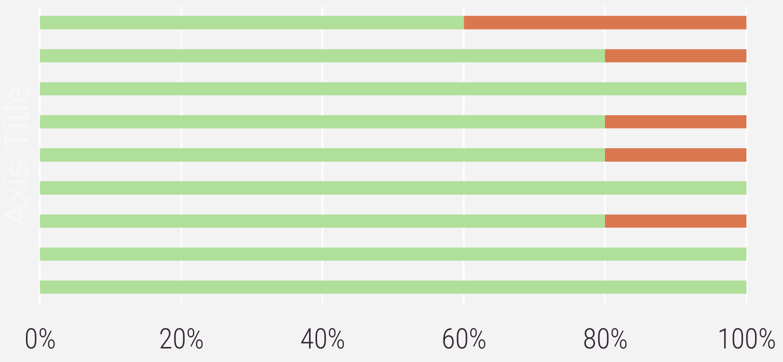


Autonomous Driving in different conditions

Prototype 1



Prototype 2



Cost Analysis and Comparison

ITEM	COST
Arduino	$20
IR Sensor	$1
Ultrasonic Sensor X2	$2
Bluetooth Module	$5
UV Light	$50
Motors, Wheels, and Motor Driver	$12
Parts for Mop	$5
Parts for Vacuum	$5
Miscellaneous	$30
TOTAL:	$130

TRU-D SMART UVC $125,000

TRU-D has sensors to measure dosage, and is a strictly UV light sanitizer, is large, bulky, and non-moving.

Xenex UVC System $81,000

Xenex has motion-detecting software, is also strictly UV light, large, and nonmoving.

Bioquell's Q-10 HPV system $47,000

Bioquell makes use of hydrogen peroxide vapor for sterilization, and is also large and non-moving

RESULTS AND CONCLUSION

Prototype 1 had inconsistencies in turning due to friction in the back wheels. Replacing the back two wheels with a castor wheel solved the problem while maintaining balance. Prototype 1 was also unable to detect the objects in 2-3 of the 5 trials, unable to maneuver around the objects in more than 2 of the 5 trials, and unable to escape the 3-sided enclosure more than once, by force. To increase accuracy during obstacle avoidance, the infrared sensor was removed and two ultrasonic sensors were added to either side of the robot. The ultraviolet light tests showed that for 1 and 2 meters, the light was over 300 $\mu W/cm^2$, however at 3 meters the intensity dropped.

- As the dosimeter cards are reusable, there is no acquired dosage over time. The UVC lightbulb may also be switched out for one with a higher intensity to increase the dosage.
- **Ultraviolet light** is considered one of the **most effective sterilization methods**, and it becomes **more effective** when paired with **traditional cleaning methods**.
- The final model was a **cost-effective prototype** with the ability to **vacuum, mop, and sterilize using ultraviolet light**. MUSR is fully **autonomous**, with the ability to **move around the room and around surrounding objects**. It can be **manually controlled** using a **mobile app** when necessary.

Overall, MUSR demonstrates a successful design of a sanitizing robot model that meets all design requirements.

SAFETY

Safety hazards associated with exposure to Ultraviolet Light

- Skin injury by photochemical reactions
- Ex: Erythema
- Injury to the cornea
- Possible inflammation, lesions, and formation of cataracts.
  It is important to always wear protective clothing, eyewear, and gloves when working with ultraviolet light.

Wear protective clothing, eyewear, and gloves. Ultraviolet testing was conducted in a separate room. bulb was replaced with a regular LED bulb during other testing

FUTURE RESEARCH

Specific 3-D printed base models, for better organization and compactness of the model.

Experimentation regarding the height of the UVC bulb, so as to better reach all parts of the room.

Human detection and automatic shutoff, instead of manual shutoff using the app.

LIMITATIONS

- An inability to test with live bacteria and viruses. Due to the pandemic, there was little access to laboratories and mentors for supervision.
- The ongoing pandemic led to an inability to test the model outside the scope of my home.
- The model could not be tested in the presence of people, due to the harm UVC can cause to humans, so all ultraviolet testing had to be completed in a separate room.
- Due to the expensive price of a radiometer, I was not in a position to acquire one for use during the project. Radiometer's are display more precise dosage/irradiation values than dosimeter cards.