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PROJETO INTEGRADO
1º Trimestre – 2022

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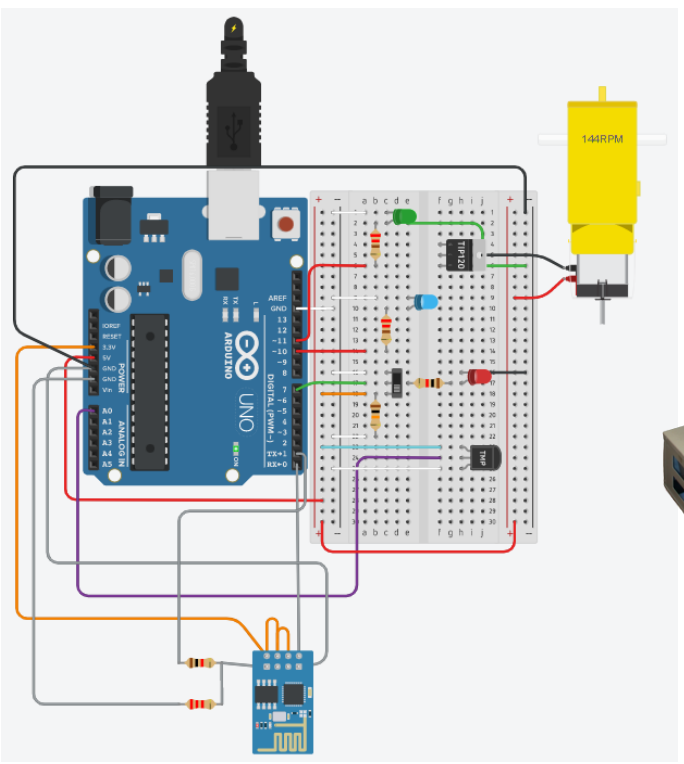
Universidade do Vale do Paraíba

Unidade de Estudo - INTERNET DAS COISAS
Unidade de Estudo - PENSAMENTO COMPUTACIONAL

Tema 01 - DESCONTAMINAÇÃO DE AMBIENTE PÚBLICO



Grupo 12:

Thiago Felipe Santos Ribeiro
Thais de Morais Vieira
Michelle Karoline de Lima
Matheus Oliveira Custodio
Rainer Ferraz Passos

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PROJETO INTEGRADO

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DESCONTAMINAÇÃO DE AMBIENTE PÚBLICO

Disciplina: Internet das Coisas

Pensamento Computacional

Série: 1º Trimestre – 2022

Professor(es):

Rodrigo Marudi

Nivaldo de Andrade

Aluno(s):

Thiago Felipe Santos Ribeiro - 1012022100391

Thais de Morais Vieira - 1012022100664

Michelle Karoline de Lima - 1012022100481

Matheus Oliveira Custodio - 1012022100301

Rainer Ferraz Passos - 1012022100326

SÃO JOÃO DA BOA VISTA , SP

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1 INTRODUÇÃO

O Projeto Integrado do primeiro trimestre de 2022 teve como objetivo a experimentação da modelagem de um sistema de Descontaminação de qualquer tipo, mas com ênfase em ambientes públicos e com proposição do uso de dispositivos do tipo Arduino para o controle e construção da lógica do sistema imaginado.

1.1 PROBLEMA PROPOSTO

Diante desse contexto, sob o desafio de propor uma solução que utilize tecnologia, para a higienização de escolas, foram iniciadas as interações entre os membros do Grupo 12, utilizando alguns dos conceitos da metodologia *Design Thinking*, conforme orientado pelo professor da Unidade de Ensino (UE) Internet das Coisas (IoT). Esse processo inicial foi registrado nas imagens do Apêndice A, sobre a *JamBoard* criada com a finalidade de estruturar e persistir o problema em si, as possibilidades, as dificuldades inicialmente imaginadas e as ideias obtidas (ideação).

1.2 CONCEITO GERAL

Após esse processo de ideação, o grupo construiu a percepção de que os ambientes escolares necessitariam contar com mais de um sistema de higienização e monitoramento, abrangendo os diferentes meios de contato e transmissão. Assim, ao final do processo de ideação, o Grupo 12 considerou três possibilidades de sistemas que deveriam ser complementares: monitoramento de pessoas e contatos, descontaminação de água e descontaminação do ar. O grupo optou por uma dessas vertentes, sobre a qual desenvolver a atividade proposta, a descontaminação do ar, com a utilização de um circulador que força passagem de ar por ambiente com luz ultravioleta da faixa C (UV-C).

2 ATIVIDADE

2.1 IDEAÇÃO

Conforme introduzido na Seção 1.2, sobre o conceito assumido para o trabalho, o processo de ideação simplificado a partir do *Design Thinking*, levou à opção pela terceira abordagem do problema.

Para tal, foi ponderado que sistemas de identificação e monitoramento de pessoas já seria algo interessante para as escolas, mesmo antes do período pandêmico, por questões de segurança. De forma semelhante, o tratamento centralizado da água consumida na escola (para qualquer finalidade - limpeza, cocção de alimentos e beber), também teria uma maior possibilidade de ser algo controlado previamente pela instituição, por conta das demandas de segurança alimentar e sanitária.

Assim, a opção pela descontaminação do ar seria uma atividade complementar às duas anteriores, constituindo todo um sistema ainda mais amplo de proteção (segurança criminal, patrimonial, alimentar e sanitária), mas que teria mais probabilidade de ser uma novidade em mais escolas e, assim, uma demanda cujo atendimento surtiria maior impacto em termos quantitativos de unidades.

2.2 PROPOSTA ABORDADA

Após a opção pelo desenvolvimento de um sistema de controle sobre descontaminação do ar, conforme esclarecido na Seção 2.1, prosseguiu-se na consulta de publicações sobre descontaminação, mas com foco em como fazê-la no ar e, se possível, com as pessoas ainda dentro do ambiente em descontaminação.

Nessa fase, foi identificado que o uso de UV-C é bastante eficaz, no entanto, tem a desvantagem de ser prejudicial também para as pessoas.

Por outro lado, foi identificado um artigo, obtido com o apoio da bibliotecária da UNIVAP, a partir de um dos portais de periódicos assinados pela Universidade, que apresenta

resultados adequados na descontaminação do ar, utilizando protótipos testados em São Carlos-SP.

Para tal, a solução experimentada pelos pesquisadores da UFSCar e da USP usa um ventilador para fazer o ar circular por dentro de um tubo com lâmpadas UV-C dentro de si. Como o tubo e seu revestimento ficam opacos para essa luz, evita-se que alcance as pessoas do ambiente e permite que se mantenha ligado mesmo enquanto transitam pelo local.

Essa publicação que apresenta o dispositivo e os resultados da pesquisa de seus efeitos, bem como a notícia da experimentação de seu uso se encontram no Anexo A deste relatório.

A existência de um dispositivo com resultados testados, ainda que protótipo, foi fator preponderante para a opção do Grupo por usá-lo na atividade. O segundo fator foi considerar o conceito aplicável no contexto do ano corrente.

Além da aplicabilidade como parte de um amplo sistema, já descrita, considerou-se que o ano corrente (2022) é ano de eleições, situação em que as escolas são amplamente frequentadas por pessoas que não estão cadastradas no sistema de gestão escolar (identificação e monitoramento), tampouco devem fazer uso relevante e repetitivo de água oferecida pela rede própria do local (descontaminação de água). No entanto, os eleitores podem se aglomerar e criar ambiente propício para transmissão de contaminantes pelo ar, entre os eleitores e também com os mesários e demais coordenadores do processo eleitoral.

Assim, valorizando a aplicabilidade ampliada no contexto atual e o realismo da utilidade do dispositivo selecionado, a atividade se voltou para modelar, com Arduino e *protoboard,* um sistema de controle do "DescontaminaTube", considerando:

a) usar os dados reais protótipo real (Anexo A) como modelo do dispositivo;
b) usar o ambiente Tinkercad, apresentado em aula, para modelar o circuito de controle (Apêndice B):
    - com item para ligar e desligar;
    - com sensor de temperatura;
    - com lógica capaz de avaliar a temperatura e, autonomamente, desligar o ventilador e as luzes, em caso de indício de superaquecimento;
    - com placa para conexão à internet; e
    - com capacidade de envio da informação se está ligado e se a temperatura desativou luzes e ventoinha, por segurança.
c) usar o ambiente ThingSpeak para receber o dado de status do circuito no TinkerCad e deixar disponível como *feed* (imagem no Apêndice C) para o App Inventor consumir, atualizando o status do dispositivo no aplicativo para celular; e

d) usar o ambiente App Inventor, apresentado em aula, para modelar um aplicativo para celular (Apêndice C), capaz de apresentar o status do dispositivo controlado pelos circuitos modelados no TinkerCad.

2.3 APLICAÇÃO DE CONCEITOS DE INTERNET DAS COISAS

A própria estrutura da ideia do projeto se alinha com os conceitos apresentados sobre IoT, inclusive sobre sua representação em camadas. No caso,, um sensor avalia a temperatura do dispositivo monitorado, a lógica embarcada define um comportamento adequado (alterando o status - luzes/ventoinha ativados ou não), o status definido é transmitido e disponibilizado via internet e um aplicativo, em dispositivo móvel de um usuário, consome a informação disponível e oferece a informação para o usuário tomar decisões.

Nesse último ponto, está incluído um dos pilares da segurança em IoT (acesso, confidencialidade e autenticidade), o conceito de segurança no acesso à informação, pois o consumo do dado disponível na internet exige do aplicativo a chave atualizada do *feed*, bem como a interface com o usuário (Apêndice C) exige que usuário e senha adequados tenham sido inseridos, para acesso à tela onde se carrega a informação de status do dispositivo.

2.4 APLICAÇÃO DE CONCEITOS DE PENSAMENTO COMPUTACIONAL

Os Apêndices B e C apresentam o código implementado para o circuito de controle do dispositivo de luz UV-C e para o aplicativo mobile (em blocos). Inevitavelmente ambos trazem alguns conceitos apresentados em Pensamento Computacional, mas é notória a relevância das estruturas de controle.

Mesmo, a estrutura de controle simples foi suficiente e, mais, necessária e presente não só no arduino para a decisão sobre desativar lâmpadas e/ou motor aquecidos, mas também na definição de variável do status, no acesso seguro ao aplicativo mobile, bem como na configuração de cores da tela desse aplicativo, para interação com o usuário.

3 CONSIDERAÇÕES FINAIS

Este documento relata o processo percorrido na elaboração de um protótipo de monitoramento para um dispositivo de Luz UV-C. Iniciando na motivação da escolha e seu processo de ideação, passando pela modelagem do circuito de controle e sua lógica, pela modelagem de um aplicativo móvel e sua programação e pelo uso de uma nuvem para o recebimento dos dados de status e seu fornecimento para esse aplicativo móvel comentado.

Quanto aos recursos utilizados, o circuito de controle e sua lógica, as lâmpadas e a ventoinha foram simulados no ambiente do TinkerCad. Essa aplicação envia pela internet seus dados de status.

A página ThingSpeak foi utilizada como uma nuvem para receber esses dados enviados e disponibilizá-los para serem consumidos por outros aplicativos.

A modelagem e emulação de um aplicativo para celular, a ser utilizado por usuário autorizado, foi realizada com os recursos do MIT App Inventor 2. Nesse último ambiente, foram criadas três telas e sua lógica de funcionamento, de forma a permitir login do usuário, exemplo de leitura e leitura efetiva do status do dispositivo de Luz UV-C, consumindo o serviço de *feed* dessa informação, do ThingSpeak, obtido do TinkerCad.

Como sugestão de evolução do protótipo obtido, consideram-se: construir modelo com oferta de corrente alternada no sistema de controle; identificação de mais parâmetros relevantes de serem medidos; implementar a possibilidade de ligar/desligar remotamente o dispositivo; aperfeiçoamento da apresentação gráfica do aplicativo móvel; e definição de banco de dados para validar login/senha de usuários autorizados.

ANEXO A - Artigos originais do dispositivo de luz ultravioleta

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Efficiency of an air circulation decontamination device for micro-organisms using ultraviolet radiation

T.Q. Corrêa [a,*], K.C. Blanco [a], J.D. Vollet-Filho [a], V.S. Morais [a], W.R. Trevelin [b], S. Pratavieira [a], V.S. Bagnato [a,c]

[a] São Carlos Institute of Physics, University of São Paulo, São Carlos, São Paulo, Brazil
[b] Unimed São Carlos, São Paulo, Brazil
[c] Texas A&M University, College Station, TX, USA

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SUMMARY

Background: The concern with environmental security to avoid contamination of individuals was intensified with the crisis established by SARS-CoV-2. The COVID-19 pandemic has shown the necessity to create systems and devices capable of clearing the air in an environment of micro-organisms more efficiently. The development of systems that allow the removal of micro-droplets mainly originating from breathing or talking from the air was the motivation of this study.

Aim: This article describes a portable and easy-to-operate system that helps to eliminate the droplets or aerosols present in the environment by circulating air through an ultraviolet-C (UV–C) reactor.

Methods: An air circulation device was developed, and a proof-of-principle study was performed using the device against bacteria in simulated and natural environments. The microbiological analysis was carried out by the simple sedimentation technique. In order to compare the experimental results and the expected results for other micro-organisms, the reduction rate values for bacteria and viruses were calculated and compared with the experimental results based on technical parameters (clean air delivery rate (CADR) and air changes per hour (ACH)).

Findings: Results showed that the micro-organisms were eliminated with high efficiency by the air circulation decontamination device, with reductions of 99.9% in the proof-of-principle study, and 84–97% in the hospital environments study, contributing to reducing contamination of individuals in environments considered to present risk.

Conclusion: This study resulted in a low-cost and relatively simple device, which was shown to be effective and safe, and could be replicated, especially in low-income countries, respecting the standards for air disinfection using UV-C technologies.

* Corresponding author. Address: São Carlos Institute of Physics, University of São Paulo, Av. Trabalhador São-carlense, 400, PO Box 369, São Carlos, São Paulo, Brazil.
E-mail address: thatrini@gmail.com (T.Q. Corrêa).

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Introduction

Among the challenges faced in microbiological control are contaminations capable of being transmitted by air through droplets spread by exhalation, and that remain in the air for a specific time. Airborne infectious diseases, such as seasonal flu and influenza pandemics, represent the most significant challenges for global public health [1]. These diseases alone are responsible for an extensive part of the routine uses of public healthcare systems. Concerns about these infections have intensified efforts to prevent their transmission, and approaches using ultraviolet-C (UV–C) radiation have been frequently studied as a microbiological control tool [2–4].

Airborne viruses, such as influenza viruses, rhinoviruses of the common cold, and the SARS-CoV-2 virus, are transmitted by droplets emitted from an infected individual while speaking, coughing, sneezing, and even during breath exhalation. These actions produce aerosols and droplets of various sizes that can carry viruses and start new infection events when inhaled by non-infected individuals [5–7]. The size of these droplets determines how long they remain in the air, which means they may stay suspended for long periods. Individuals circulating in such a contaminated environment may have an increased chance of becoming infected with these viruses just by breathing these aerosols and droplets [7].

Studies show that both the ability of SARS-CoV-2 to be transmitted [8] a few days before infected individuals experience any symptoms and the existence of undiagnosed asymptomatic individuals make prevention difficult and require intervention in crowded environments. Thus, a viable alternative for reducing exposure to airborne viruses involves the inactivation of viruses present in aerosols and on surfaces [9,10]. The recommended measures of social distance, hand hygiene, surgical masks, personal protective equipment, and frequent disinfection of surfaces have proven to reduce contagion risk [11–14]. However, when people remain indoors for long periods, such as in classrooms, shared offices, outpatient and hospital environments, and public transport vehicles, these methods may not reduce viral transmission rates to a level low enough to prevent pandemic growth.

Thus, additional measures to complement those already mentioned and to reduce the spread of viruses are necessary to enable a certain level of labour activity, especially in environments where social distancing recommendations are difficult or impossible to follow, as is the case with hospitals. To minimize the transmission of SARS-CoV-2 and other viruses by air and, consequently, to reduce the chances of contagion, it is necessary to continuously inactivate the viruses in the aerosols spread in the environment. Regarding this type of decontamination, UV-C radiation can be used in autonomous decontamination systems that promote air circulation within environments [15].

Ultraviolet germicidal irradiation (UVGI) is a disinfection method that uses UV radiation of a short wavelength (100–280 nm), primarily at 254 nm [16]. There are different light sources under UV-C wavelengths: low-pressure mercury lamps, medium-pressure mercury lamps, UV-C light-emitting diodes (LEDs), continuous and pulsed xenon arc lamps, krypton-chloride excimer (KrCl*) lamps, krypton-bromine excimer (KrBr*) lamps. Low-pressure mercury lamps have been used for disinfecting air, water, and surfaces for over 90 years. These low-pressure mercury lamps are still the most practical and most efficient method of generating germicidal radiant energy. However, UV-C LEDs are finding essential applications recently and could be used for both targeted surface disinfection and air disinfection [17].

Unlike other methods used for disinfection, UV-C radiation can provide a fast and significant inactivation of micro-organisms through a physical process that directly affects viruses' genetic material without leaving any traces or by-products as a result [15,16]. The germicidal action of UV-C radiation is very well accepted and is frequently used in several systems for decontamination of surfaces and personal protective equipment. Various UV-C disinfection products have become available on the market in response to the COVID-19 pandemic [15]. However, due to the harmful effects of UV-C on biological tissues [18,19] and variable effectiveness depending on the irradiation parameters [20], further studies in the field to more appropriately define protocols are still necessary.

UVGI can be used to disinfect water, surfaces and air. Air disinfection may occur by irradiating the upper-room air only, irradiating the entire room in the absence of people, or irradiating air as it passes through enclosed air-circulation, ventilation or air-conditioning systems [16,21,22]. These air decontamination systems require complicated installation and are costly, being more indicated for hospital facilities. UV-C radiation satisfies the requirements for rapid, complete and economically viable installation among the available alternatives. Nevertheless, it is necessary to avoid human skin exposure to this radiation. The best possible technique involves the indirect use of the radiation, without exposure of the individual.

In this study, we proposed a straightforward set-up that can be moved to different places and can be easily assembled. We reported the development and a proof-of-principle of such a portable, low-cost air decontamination device for micro-organisms, in general, using UV-C radiation. The device was tested using a Gram-negative bacteria strain, *Escherichia coli*, as a model micro-organism. The results were compared with theoretical reductions estimated for bacteria and viruses, with the aim of providing evidence of the set-up's ability to minimize the spread of such micro-organisms in the environments.

Methods

Air decontamination device set-up and characteristics

An ideal air sanitizer must produce a flow that ensures the contaminated air is exposed to UV-C as soon as it is sucked into the device, to ensure that the micro-organisms do not locate themselves in the filter or other parts of the system. The fan is placed in a direction that produces a negative pressure such that the aerosol is decanted after the air has passed by the lamps. The device proposed allows HEPA or electrostatic filters to be placed after the fan for further clearance of the air; however, we did not use any filters in our experiments because we aimed to explore only the UV-C effect. The air decontamination device (Figure 1) comprised a base made of 1020 steel plate and a 12-inch white PVC pipe structure. A fan motor with a propeller (Gemini, Loren Sid, Brazil; 130 W) was placed at the top of the device to promote air circulation. The flow

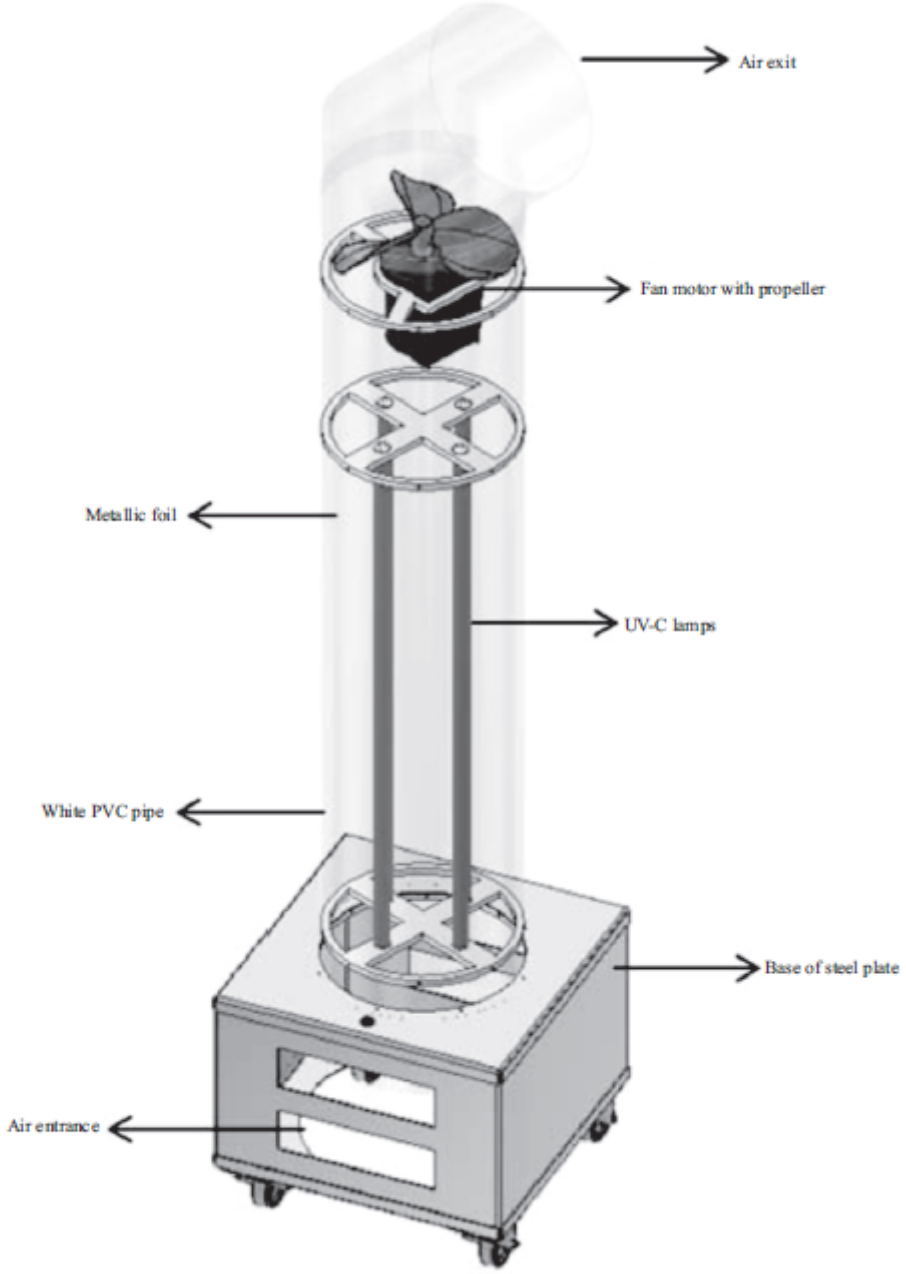

Figure 1. Air decontamination device set-up and characteristics.

rate was 0.217 m^3/s (780.9 m^3/h), and the rotation was 1300 rpm. Four mercury low-pressure vapour lamps were distributed around the PVC pipe, inside the device, to promote air decontamination. The UV-C lamps (OSRAM Puritec Germicidal HNS 30W 96V G13, Italy) emitted at 254 nm and produced an average irradiance of 2.08 mW/cm^2 (20.8 W/m^2) for this wavelength. The white PVC pipe was internally covered with an aluminum metallic foil (UV–C reflectivity 75%) [23] that prevented PVC pipe degradation and reflected most of the UV-C radiation. The system is described schematically in Figure 1.

The device that was developed was designed to decontaminate the particles suspended in the air, minimizing contamination among individuals in the same environment. All of the air needs to circulate quickly through the UV-C irradiation system, promoting rapid decontamination, and in accordance with technical parameters used to appraise the efficacy of air decontamination devices based on UV-C technologies, such as the clean air delivery rate (CADR) and air changes per hour (ACH). In addition, the negative pressure produced by the device provides faster decantation of particles which, once on the ground, do not easily reach the breathing zone of individuals. Therefore, device operation occurs when an almost-laminar airflow is created close to the floor. This flow drags the suspended particles into the device. The airflow containing the particles passes through the system with intense UV-C radiation exposure and is released into the environment by the upper part of the device. When the airflow passes through the UV-C lamps, it is decontaminated in a few seconds. A diagram of the air decontamination device operation is shown in Figure 2.

The following sections describe two different assay situations: a proof-of-principle study in a controlled environment and another study performed in a hospital environment. These studies allowed us to compare real-life conditions versus controlled conditions. Table I describes the parameters of the compared environments.

Microbiological assays: a proof-of-principle study

The air decontamination device's microbial action was evaluated with the Gram-negative bacteria *E. coli* (ATCC 25922). The bacteria were stored at -20ºC in Tryptic Soy Broth (TSB) with 40% glycerol and reactivated in Brain Heart Infusion (BHI) agar plates at 37°C for 24 h. After this, seven colonies were resuspended in 10 mL of TSB, and bacteria were incubated at 37°C for 16 h under static conditions. An aliquot of 500 µL of this suspension was diluted in 9.5 mL of fresh TSB and incubated at 37°C until the mid-log phase of growth. The inoculum suspension was quantified through optical density (Cary 50 Bio UV-Vis Spectrophotometer, Varian, Australia) at 600 nm and adjusted for 107 cfu/mL. This suspension was homogenized, centrifuged at 1000 × *g* for 15 min, and resuspended in phosphate-buffered saline (PBS).

E. coli suspension was transferred to a nebulizer reservoir, placed at the bottom of the air decontamination device because it pulls air from the bottom and releases air from the top. Thus, the air in a 3 m × 2 m × 1 m lab experimental room (ER) was contaminated with the aid of a nebulizer, and bacteria in the air were investigated under two conditions: in the absence and the presence of the air decontamination device.

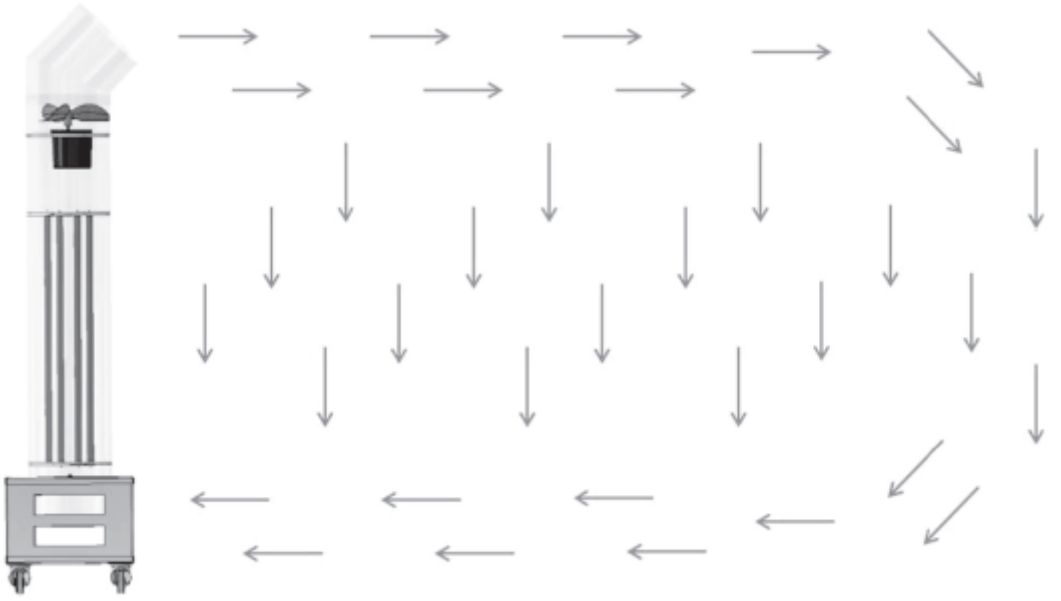

Figure 2. Diagram of the air decontamination device operation. The arrows indicate the direction of circulation and negative pressure promoted by the device.

The microbiological analysis was carried out by the simple sedimentation technique to prove the air decontamination. In this technique, Petri dishes containing solid culture medium are distributed throughout the environment and remain open for a predetermined period to collect microbiological samples from the air.

Bacteria were nebulized for 5 min in the experimental room in the air decontamination device's presence to evaluate the control group, but with the air circulation system and the UV-C radiation system turned off. During this period, Petri dishes containing BHI agar culture medium were placed at different points in the environment to collect bacteria. The same procedure was performed to evaluate the UV-C group, but with the air circulation system and the UV-C radiation system turned on to promote decontamination. During this period, Petri dishes containing BHI agar culture medium were placed at different points in the environment to collect bacteria. For both groups evaluated, control and UV-C, the Petri dishes were kept open for 5 min to perform the collection. Then, all Petri dishes were incubated at 37ºC for 24 h and evaluated for the presence or absence of bacteria in the culture medium. The temperature and relative humidity of the air were both measured during the assays.

This microbiological assay, characterized as a proof-of-principle study, was carried out on two different occasions.

Studies in a hospital environment

A hospital emergency care facility in the city of São Carlos (SP, Brazil) was used as a non-controlled environment to prove the system's efficiency in an environment under natural conditions of contamination.

Three rooms with different uses were investigated: the hospital reception lobby (RL), which includes a waiting room; the emergency care observation room (OR); and the emergency care screening room (SR). Two equivalent devices were used, identified as 'A' and 'B'. In the first experiment, on two different days, for the largest room, RL, both air decontamination devices (A and B) were arranged simultaneously to obtain the best air circulation. In a second experiment, on two different days, for each of the other two rooms (OR and SR), just one device was placed (device A at OR and device B at SR). The arrangement is best observed in the scheme shown in Figure 3.

The simple sedimentation technique described in above was also used to perform this assay. However, two different culture media were used for collecting air micro-organisms from this environment: BHI agar and Sabouraud Dextrose agar (SDA). BHI agar is a culture medium used to cultivate a wide variety of micro-organisms, being recommended to cultivate aerobic bacteria. The SDA agar is a non-selective culture medium for the specific cultivation of pathogenic and non-pathogenic fungi.

For collections, five Petri dishes containing BHI agar culture medium and five Petri dishes containing SDA culture medium were used for each device. Therefore, for each device, 10 plates were used to collect micro-organisms from the air. The plates were distributed over various points close to each device for the control group and remained open for 1 h. During that time, the devices remained off, with the air circulation system and the UV-C radiation system turned off. Immediately after collecting the control group samples, devices were turned on for 24 h, i.e. both the air circulation and the UV-C radiation systems remained on. After that, five new Petri dishes containing BHI agar culture medium and five new Petri dishes containing SDA culture medium were distributed at the same collection points. The plates remained open for 1 h to collect the UV-C group samples. At the end of the collections, the Petri dishes with BHI agar were incubated at 37ºC for 24 h, while the Petri dishes with SDA were incubated at 35ºC for 48 h. After this period, the counting of colony-forming units was performed.

This study in a hospital environment was carried out on two different occasions.

Theoretical estimate for comparison

As an approach to compare the efficacy of the decontamination proposed, we calculated the reduction rate (RR) based on Kowalski [24,25], where k represents the survival fraction dose coefficient; I_m is the average irradiance of the light sources, and E_t the exposure time.

$$RR = 1 - \exp(-k\, I_m\, E_t) \quad (1)$$

The exposure time is obtained from the ratio between the volume of air irradiated V_{UVC} and the airflow Q:

$$E_t = V_{UVC}/Q \quad (2)$$

The value of k is usually obtained for the micro-organism of interest and is similar among viruses and among bacteria. Average values based on several studies collected by Kowalski [25] can be obtained for viruses and bacteria ($k_{virus} = 0.3\ m^2/J$; $k_{bacteria} = 0.9\ m^2/J$). The irradiance was averaged from several collections in the central part of the duct internally covered in aluminum foil, for a mean value of $I_m = 20.8\ W/m^2$.

For a comparison between the bacteria experimental results and expected results for other micro-organisms, the RR values for bacteria and viruses were calculated and compared with the experimental results.

Technical parameters (CADR and ACH)

There are technical parameters used to appraise the efficacy of air decontamination devices based on UV-C technologies. CADR and ACH are common parameters and allow comparison between devices. CADR is a device rate and corresponds to the airflow Q in m^3 per hour. Ideally, CADR should be no lower than $^2/_3$ of the total volume (i.e. the air in the room) per hour. ACH can be obtained from the ratio between CADR and the total volume of air within the room to be decontaminated. ACH can vary for different environments, depending on the volume of the environment, the estimated amount of room air changes and passers-by needs. Considering a hospital environment, where patients with respiratory conditions are expected, a minimally expected ACH is about 4 (i.e. four whole room air changes per hour) [26,27]. In addition, for rooms with different occupation levels (furniture, people), the total air volume in a room is estimated to be between 80 and 90% of the room's total volume [26,28].

For an indication of the viability of the proposed device for air clearance according to the room of interest, the CADR and ACH values were calculated for the different rooms investigated.

Table I
Parameters and dynamics of collected samples for both proof-of-principle study (controlled environment) and hospital environment study (real-life environments)

	Controlled environment:	Hospital environment		
	experimental room	Reception lobby	Observation room	Screening room
Volume (m^3)	6	54	28.35	12
Nebulization time (min)	5	–	–	–
Collected micro-organisms	*Escherichia coli*	Air micro-organisms	Air micro-organisms	Air micro-organisms
Analysis technique	Simple sedimentation	Simple sedimentation	Simple sedimentation	Simple sedimentation
Evaluated groups	Control × UV-C	Control × UV-C	Control × UV-C	Control × UV-C
Collection time (min)	5	60	60	60

Statistical analysis

Data are shown as the average number of colony-forming units, and results in the graph are expressed as mean ± standard deviation (SD). The Shapiro–Wilk test verified the normality of the data. The results were analysed statistically using a one-way analysis of variance (ANOVA), and the post hoc Tukey test was applied for comparisons between experimental groups (control and UV-C). The software Origin 2020 software (OriginLab Corp.) was used to carry out these statistical analyses, with a level of significance of 0.01 between groups.

Results

Experimental results

Figure 4 shows the Petri dishes used to collect the nebulization of *E. coli* during the proof-of-principle study. In the plates used for the control group collection, microbial growth made it possible to observe the bacterial colonies distributed by the culture medium. In the plates used for collecting the UV-C group, there was no microbial growth, as shown by the culture medium without bacterial colonies. This result shows the effectiveness of the device with regard to the control of bacteria transmitted by the air.

Figure 5 shows the Petri dishes used to collect micro-organisms from the air during the studies in the hospital emergency care facility. It is possible to observe the colonies' reduction after the device operation for 24 h in different environments.

Table II shows the mean values of the colony-forming units counts of the Petri dishes containing the two culture media and their respective SDs for each investigated environment. Figure 6 shows the results presented in Table II and the percentage of microbial reduction achieved by the action of the air decontamination device for each considered environment.

Theoretical comparison

The theoretical exposure time *Et* and the airflow *Q* based on the device parameters were determined for the prototype used to calculate the RRs for both bacteria and viruses, and these RRs were compared with the experimental results. V_{UVC} being the volume of air surrounding the UV-C lamps ($V_{UVC} = 0.059$ m^2), and the measured airflow ($Q = 0.217$ m^3/s, obtained from the average air velocity in the tube, 3.2 m/s), the exposure time for the device was $E_t = 0.272$ s.

Considering the average irradiance, the obtained *Et*, and the *k* values for different micro-organisms, the *RR* general theoretical values for bacteria and viruses are respectively presented below:

$$RR_{bacteria} = 1 - \exp(-[0.9][20.8][0.272]) = 0.994 \quad (3)$$

$$RR_{virus} = 1 - \exp(-[0.3][20.8][0.272]) = 0.817 \quad (4)$$

Thus, the expected reduction observed for bacteria and viruses were, respectively, 99.4% and 81.7%.

Also based on the experimental conditions, the lab ER (ER = 6 m^3, zero occupation, thus $V_{ER} = 6$ m^3), the hospital RL (RL = 60 m^3, reduced occupation, thus 90%, $V_{RL} = 54$ m^3; using two devices), the emergency care OR (OR = 31.5 m^3, higher occupation, thus 80%, $V_{OR} = 28.35$ m^3), and the emergency care SR (SR = 15 m^3, reduced occupation, thus 90%, $V_{SR} = 12$ m^3) were considered for ACH evaluation; the results are shown in Table III.

Discussion

The first studies on the efficacy and application of UV-C radiation for air disinfection were carried out almost 100 years ago [16]. Despite the early successes in demonstrating the effectiveness of UV-C, the technology was largely abandoned and forgotten. The concern regarding UV-C exposure, the production of ozone by germicidal lamps, UV-C lamp maintenance, and thew fact that it would be ineffective at higher humidity were some of the reasons for the abandonment of UV-C technology in air disinfection strategies [16].

However, the efficacy of UV-C radiation technology as a disinfection tool is widely accepted. Numerous studies have demonstrated the effectiveness of UV-C in eradicating various micro-organisms, including bacteria, fungi and viruses [29,30]. Moreover, the literature has reported that the inactivation of viruses in the air with UV-C is efficient [31]. Recent studies have shown that SARS-CoV-2 could be inactivated rapidly by UV-C radiation [32,33], stimulating even more research in this field. Storm *et al.* (2020) showed that for contaminated surfaces, only seconds of exposure are required for complete inactivation, allowing for easy implementation in decontamination workflows [34]. This efficacy is so well known that several systems have been proposed to sanitize the air, food, masks, materials, etc. [35–38]. Indeed, the literature showed that UV-C radiation is efficient for bacteria, fungi, and influenza virus reduction [29,39,40].

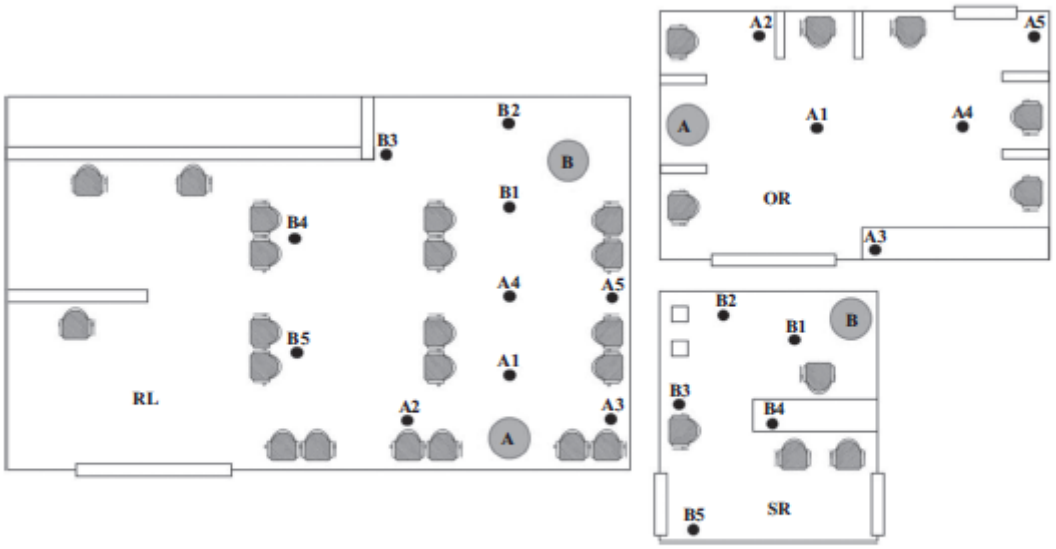

Figure 3. Scheme of the hospital emergency care department in the city of São Carlos (SP, Brazil), where the studies with the two air decontamination devices were performed. OR, observation room; RL, reception lobby; SR, screening room. The devices are drawn as circles with the letters 'A' and 'B'. The collection points are marked as small black balls numbered from 1 to 5. Scheme not to scale.

Our study is an initial investigation based on the development and characterization of a new portable, low-cost air decontamination device for micro-organisms using UV-C radiation. Herein we presented the first results of a proof-of-principle assay and their comparisons with theoretical reduction estimates for bacteria and viruses, with the aim of providing evidence of the device's ability to minimize the spread of those micro-organisms in the environments.

The air decontamination device by UV-C radiation developed for this study and described here proved to be safe and efficient to be used in environments occupied by people, because the UV-C lamps are inside the device, ensuring that no radiation is propagated to the environment, and thus that people are not exposed to it. This safety is vital because exposure to UV-C radiation can cause skin burns, in addition to ocular keratitis due to the damage they can cause to DNA [18,41].

The premise of the device is to decontaminate the particles suspended in the air, minimizing the chances of contamination of individuals present in the same environment. For this to succeed, all of the air must circulate through the device. With the action of UV-C lamps installed internally, air decontamination occurs simultaneously. In addition, the system was structured to generate a pressure gradient in the environment, providing faster decantation of particles and aerosols that are suspended in the air (Figure 2). This mechanism causes particles and aerosols to be taken to the ground, avoiding their permanence in the air for hours, which reduces the contamination index.

In the proof-of-principle study, carried out in a closed and controlled environment, the micro-organisms were eliminated with high efficiency. In 1 hour of air circulation in this controlled environment, the rate of micro-organism decrease was above 99.9% (i.e. greater than three logarithmic orders). The system operates with an air circulation of 780.9 m^3 per hour. It means that, when turned on, all the air in a medium-sized room (e.g., 5 m × 5 m × 4 m) passes eight times through the system per hour approximately. The system's great advantage is that all the air that circulates goes through the decontamination process, and the negative pressure promoted by the system increases air particle deposition on the floor, representing a lower risk of inhalation of contaminated particles for bypassers.

Further, this 3-log order reduction was superior to the theoretical preview based on the device's parameters and the air conditioning of the environments studied (1–2 log orders, depending on the micro-organism). CADR for the device and the ACH values for the environments of choice for this study were also far superior to the minimum considered adequate for environments where personnel and patients with respiratory conditions are common passers-by.

The results presented in the hospital environment study showed that the best microbial reduction occurred in environments without natural air circulation, i.e. in environments with little air circulation, represented here by the OR and the SR. The RL of the hospital emergency care department was subject to ventilation with a natural airflow since the entrance doors always remained open. The air decontamination device A located in the RL (Figure 3) was less subject to natural ventilation than device B. However, in both, the same natural air current competed with the airflow circulation induced by the airflow devices. Even with this unfavorable situation for the device, in which most of the air was naturally renewed with little chance of circulation through the system, there was a

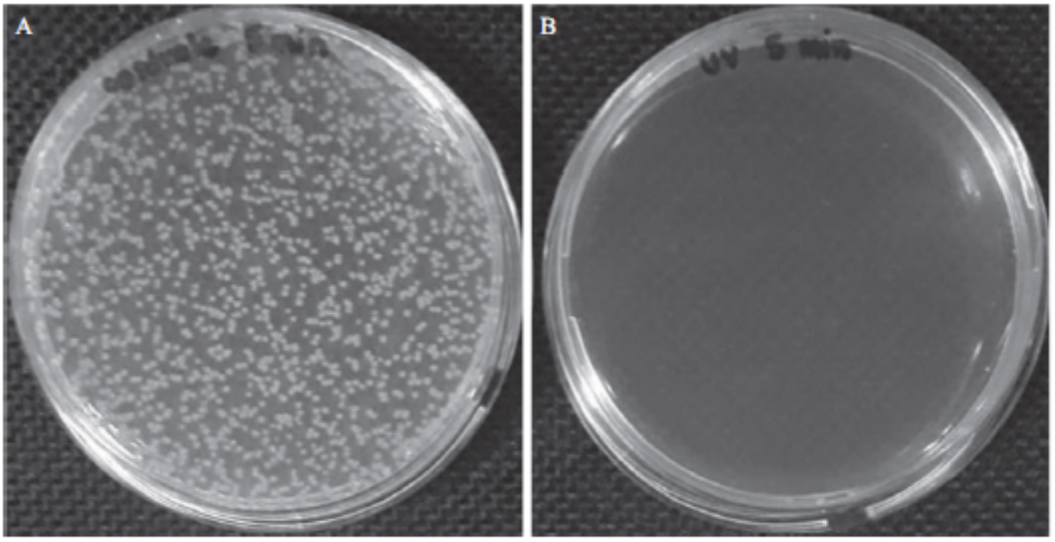

Figure 4. Petri dishes with Brain Heart Infusion agar culture medium 24 h after collecting the nebulized *Escherichia coli* for 5 min in the lab experimental room: (a) control group, with the device off; (b) ultraviolet-C group, with the device on.

high microbial reduction, ranging from 84% to 91%. This microbial reduction is significant, considering the natural air circulation that occurs within this environment.

In environments with little air circulation, such as the OR and SR, the microbial reduction varied from 94% to 97%. These values represent significant reductions, showing that the

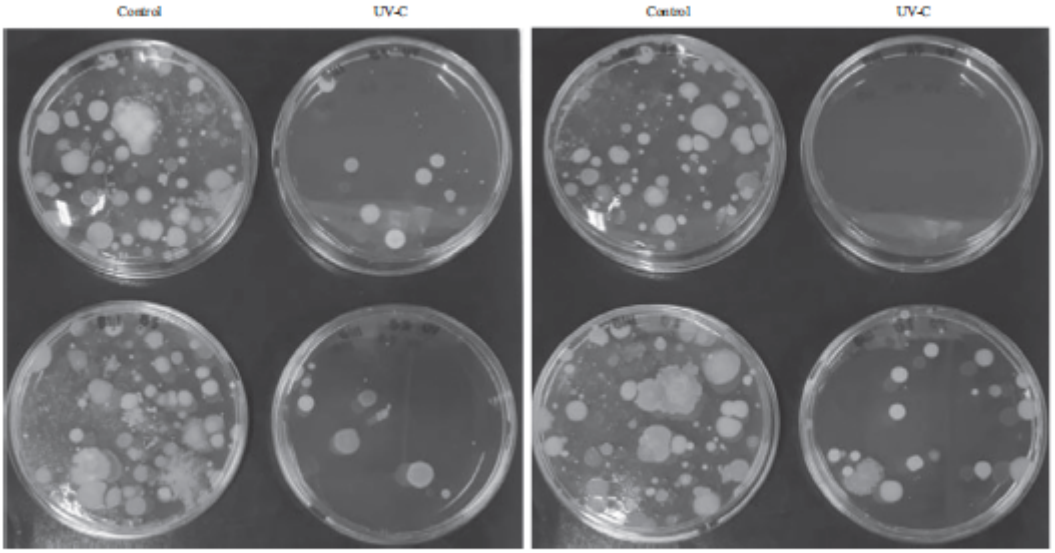

Figure 5. Petri dishes with Brain Heart Infusion agar culture medium containing the colony-forming units for the control group, with the device off (left side of each image), and ultraviolet-C group, with the device on for 24 h (right side of each image) of different points of the evaluated rooms in the hospital emergency care in the city of São Carlos (SP, Brazil).

Table II
Colony-forming units (cfu) average values counted on Petri dishes containing Brain Heart Infusion and Sabouraud Dextrose agar culture media for both the control and ultraviolet light (UV–C) groups in all environments evaluated in the hospital emergency care department, and their respective standard deviation (SD) and statistical relevance values

	RL (device A)		RL (device B)		OR (device A)		SR (device B)	
	Control	UV-C	Control	UV-C	Control	UV-C	Control	UV-C
Average cfu	221.6	20.0	232.2	38.2	93.8	2.8	152.8	9.8
SD	30.4	11.4	54.2	11.7	25.7	1.6	72.7	5.1
Statistical relevance	$P<0.01$		$P<0.01$		$P<0.01$		$P<0.01$	

devices could direct virtually all the air from these environments to their interior, inactivating most of the micro-organisms present in droplets and/or aerosols dispersed in the air. Thus, the devices managed to return cleaner air to these environments, preventing the spread of micro-organisms through it. On average, it can be said that the devices were able to reduce over 90% (1 log order) of micro-organisms present in the air of the evaluated environment.

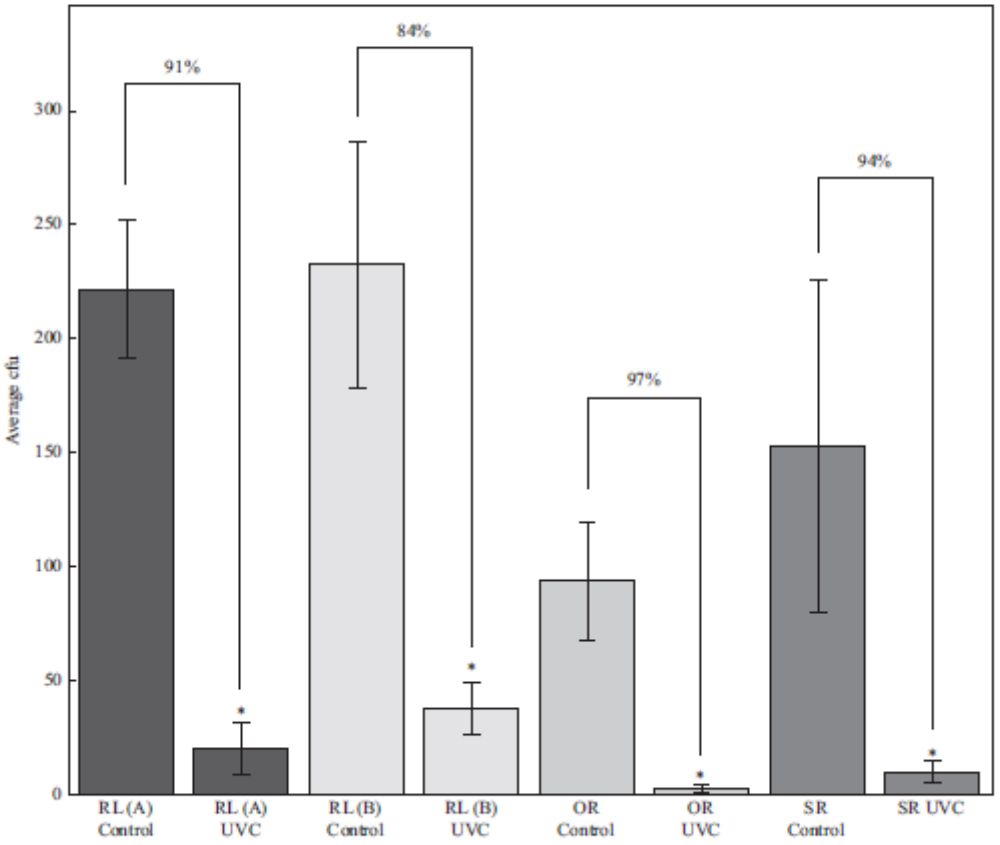

Figure 6. Number of colony-forming units (cfu) counted in Petri dishes containing Brain Heart Infusion agar and Sabouraud Dextrose agar culture medium for the control and ultraviolet-C groups in the evaluated environments in the hospital emergency care and their respective standard deviations. Data are shown as mean ± standard deviation of two independent assays. The values of the percentage microbial reduction for each evaluated environment are shown above the bars. The asterisks denote statistical significance at $P<0.01$ (analysis of variance (ANOVA) and Tukey test). OR, observation room; RL, reception lobby; SR, screening room.

Table III
Air changes per hour (ACH) for different environments

	ER (6 m^3 air)	RL (54 m^3 air)	OR (28.35 m^3 air)	SR (12 m^3 air)
ACH	130.5	14.5 (29 for 2 devices)	27.5	65

OR, observation room; RL, reception lobby; SR, screening room.

The relevance of producing an experimental room to compare results with the hospital environment was to create controlled conditions for this comparison. The experimental room was built inside our laboratory. It was composed of a plastic frame involving a thick (1 mm) PVC layer with a total volume of 6 m^3. Regarding the choice of rooms in the hospital, we chose three rooms. The hospital RL choice, which includes a waiting room, was due to the large flow of people (thus providing a high probability of contamination for comparisons with control groups). The emergency care SR choice was made because every patient seeking care has to pass by this room, thus the probability of dissemination of infectious diseases is expected to be high in this room. The emergency care OR choice was made because patients who have been identified as requiring immediate care usually spend 30 min to 2 h there; thus, as some of them are generally affected by infectious diseases, it increases the potential for contamination of other patients and personnel.

The three hospital rooms are all examples of real, highly demanding decontamination environments present in any medical facility, which are subjected to many uncontrollable factors for the determination of contamination agents. Therefore, comparing this to a controlled environment might help to justify the obtained-versus-expected results.

The use of air decontamination devices with UV-C radiation has shown the potential to decrease micro-organisms suspended in the air in environments with a high risk of contamination. The extrapolation of results suggest that reduction might also be obtained for viruses because the predictions (based on parameters) show a similar expected reduction for viruses and bacteria alike. Thus it might be effective against SARS-CoV-2 viral particles suspended in aerosols (in fact, k_{virus} for coronavirus in the air is 0.377 [21,25], resulting in an $RR_{Coronavirus} = 88.15\%$). The tested air decontamination devices with UV-C radiation could help to reduce the risk of contagion for patients and health professionals working on the front line of the COVID-19 pandemic.

Regarding SARS-CoV-2 and the COVID-19 pandemic, scientists worldwide have reported the presence of the SARS-CoV-2 in aerosols, suggesting that the airborne transmission route is highly dominant for the spread of this virus, mainly in insufficiently ventilated spaces, which promotes longer-range transmission [42–45]. Epidemiologists estimate that about 10% of infected individuals are responsible for 80% of SARS-CoV-2 transmission [46], and thus the prevention of super-spreading is an important action in limiting the COVID-19 pandemic. When it is impossible to avoid agglomerations in facilities that are expected not to suspend activities during pandemic crises, such as hospitals, emergency departments, public transportation, and in large agglomeration situations such as classrooms, offices and department stores, one of the alternatives in containing the advance of SARS-CoV-2 dissemination is to implement air circulation devices with UV-C radiation.

Additional methods to prevent viral spread are necessary to balance the needs of social distancing and the management of economic, industrial and social activities that impact people's routines and the economy during pandemics. In this scenario, UV-C technology shows itself to be an affordable, fast and scalable alternative (in contrast with more long-term planning actions involving filters and chemicals), with the potential to positively impact on people's welfare and safety [3]. Such a reality reinforces the importance of controlling the occupancy of shared spaces and, further, specific studies to improve strategies for air circulation and disinfection in environments with little air circulation, particularly in more vulnerable environments, such as healthcare facilities and nursing homes [45]. As an additional advantage, the investigated device has shown an excellent cost–benefit ratio. By providing air decontamination using affordable technology, it is possible to increase the safety of patients and local workers as well, without heavily burdening the operational cost of medical facilities.

As a final remark, light delivery has technical issues that must be properly addressed to ensure the decontamination capacity via optical approaches. Because irradiance is greatly dependent on the distance of the light source and irradiation geometry, properly managing them includes developing devices projected specifically for this task. This includes reports from competent professionals with backgrounds in optics so as to describe adequate use of the light sources, including evaluation of sufficient irradiance output and placement of light sources in rooms.

Avoiding UV-C light irradiation reaching passers-by with UV-C light during decontamination is also a consideration, which is challenging to perform during working hours (which for medical facilities can be 24 h a day). Our approach irradiated the air surrounding the lamps, encased by a plastic structure such that no UV-C light reaches passers-by. It ensures all air is brought into the reactor's internal circulation, ensuring efficient decontamination. Such concerns are essential for clinical care and for equipment to be properly decontaminated, maximizing safety and uniformity; otherwise, shade spots for irradiation, exposition of people to UV-C light and insufficient light delivery may hinder the decontamination effect expected.

In conclusion, this study, which was carried out for the development of a portable and low-cost air decontamination device for micro-organism reduction, could bring benefits in terms of the health of the population, patients and health professionals, and minimize the labour and economic consequences related to maintenance of professional sanitary conditions. Places with a high degree of circulation of people (such as healthcare environments) must be continuously sanitized and, especially for airborne pathogens, this type of technology has proven to be very useful. This study confirmed that a low-cost and relatively simple device might eliminate bacteria and viruses from particles in the air, minimizing the transmission of various types of micro-organisms between people. This device can be safely replicated, especially in low-income countries, respecting the standards for air disinfection using UV-C technologies.

Conflict of interest statement
None declared.

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"Programa Experimental de Sanitização do Ar" no Hospital da Unimed São Carlos

O Hospital da Unimed São Carlos recebeu um Sanitizador de Ar, desenvolvido Grupo de Óptica do IFSC/USP, sob a supervisão do pesquisador Prof. Vanderlei Bagnato, contribuindo com o experimento do grupo sobre o equipamento que promove a descontaminação de partículas suspensas no ar. O experimento conta também com a Bióloga, Thaila Quatrini Corrêa, e a Biomédica, Kate Blanco, ambas do CEPOF – IFSC/USP.

Os circuladores de ar com reatores a luz UVC foram idealizados para descontaminar o ar de forma continua, até porque gotículas e aerossóis expelidos à medida que as pessoas falam, respiram ou tossem, estão carregados de microorganimos contidos na saliva e nas vias respiratórias. Em locais de alta circulação e de estadia de pessoas, estes equipamentos serão, certamente, indispensáveis. A princípio, o sistema opera com grande segurança e sem risco para as pessoas, podendo ser empregado em diversas situações.

Resultados

No Hospital da Unimed São Carlos, o equipamento foi alocado em diferentes ambientes: recepção do pronto atendimento 24 horas, sala de triagem e sala de medicação. Ao final, o grupo verificou que, em média, pode-se afirmar que os circuladores de ar com luz ultravioleta foram capazes de reduzir acima de 1 log (90%) de microrganismos presentes no ar do ambiente avaliado, correspondendo a uma grande melhora da situação microbiana do ambiente.

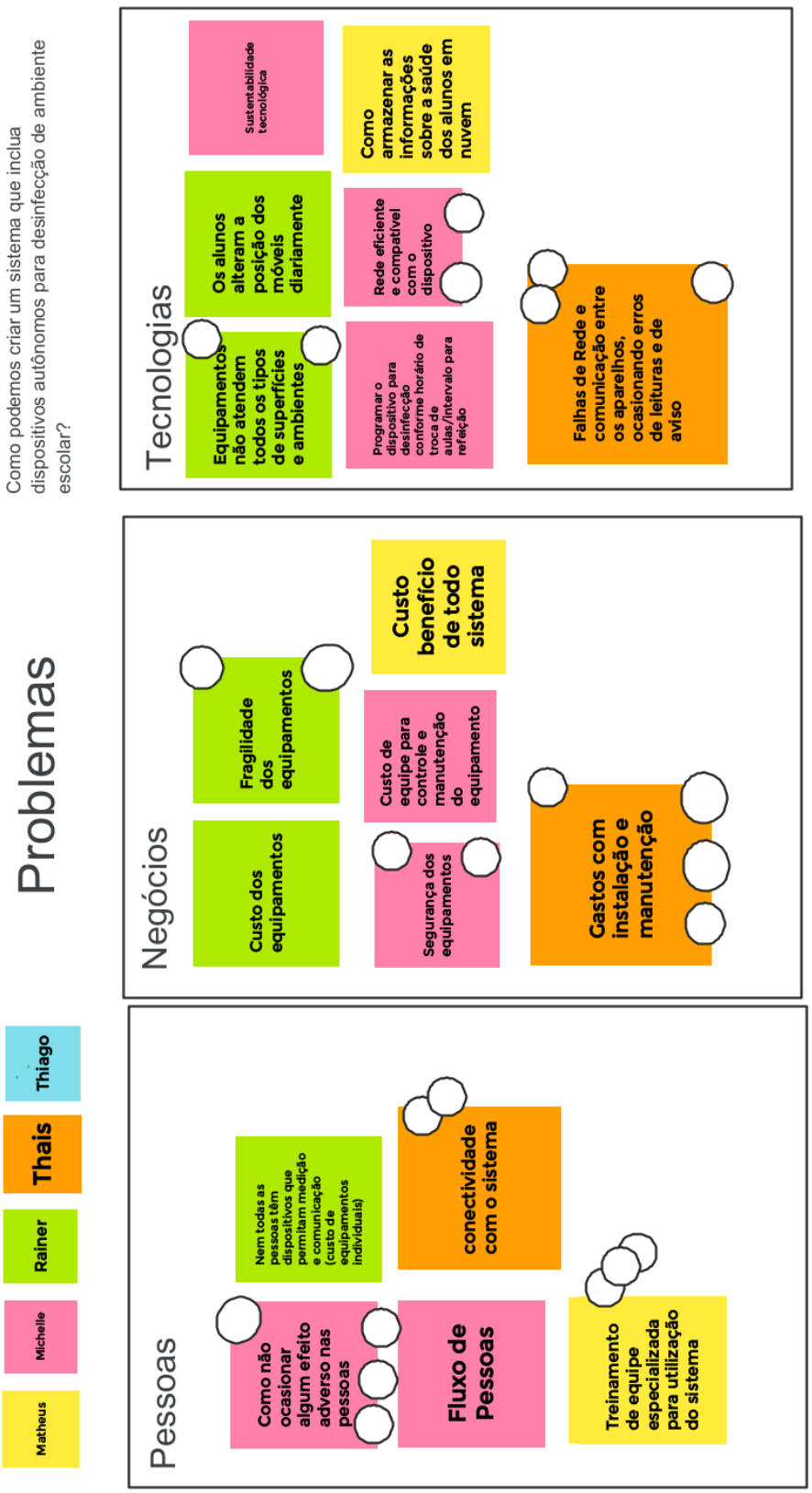
Como funciona o Sanitização do Ar?

O novo equipamento faz com que todo ar existente em um determinado recinto circule rapidamente por um sistema, que, usando radiação UVC interna, descontaminando o mesmo de forma rápida. Além disso, o sistema desenvolvido promove um gradiente de pressão, proporcionando a decantação mais rápida das partículas que, estando no chão, não chegam facilmente à área de respiração das pessoas. Em outras palavras, o sistema remove as partículas da área de respiração, sem causar poeiras, diminuindo as chances de contágio.

(In: UNIMED São Carlos)

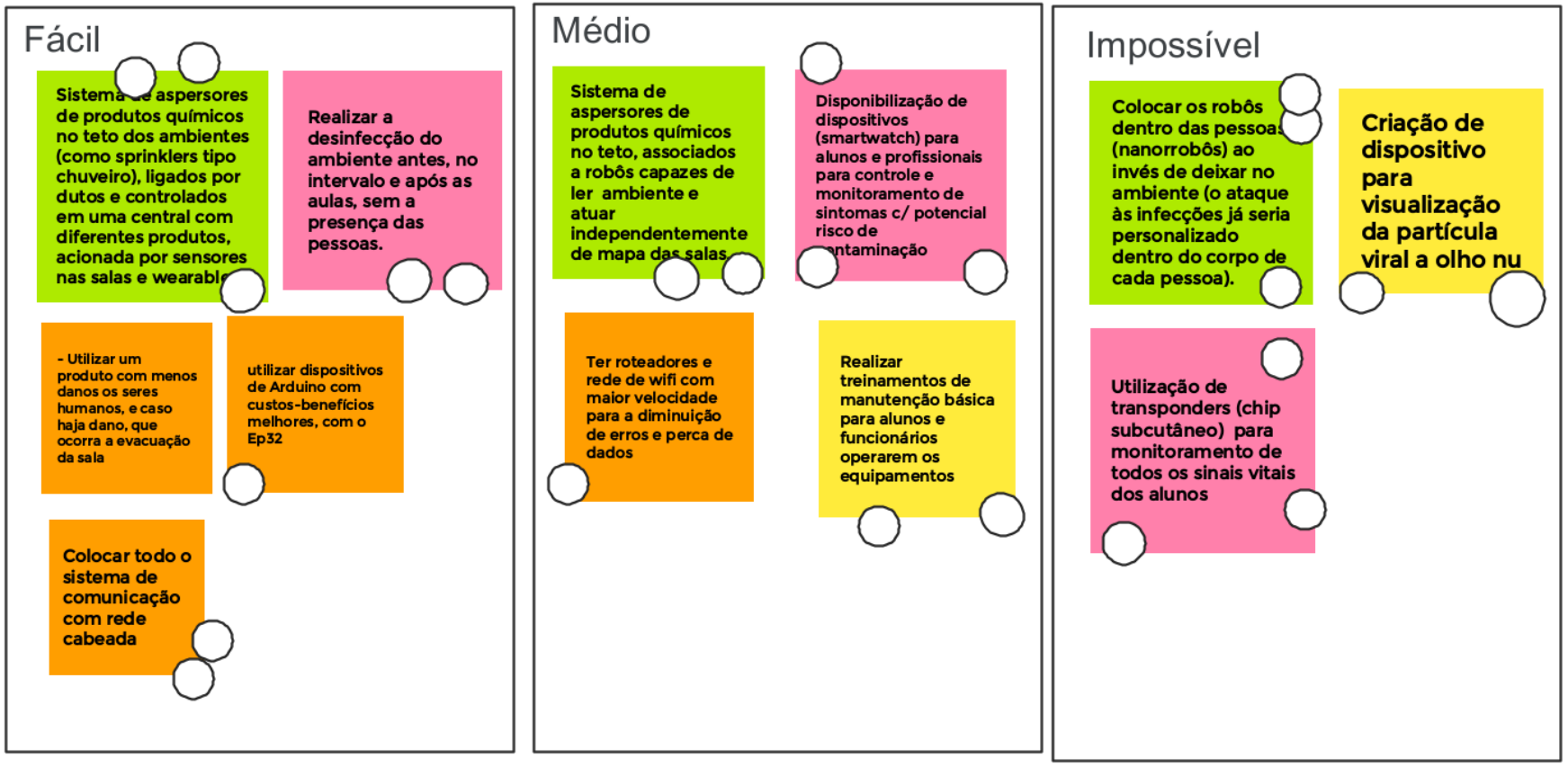
Assessoria de Comunicação – IFSC/USP

APÊNDICE A - Jamboards do processo de elaboração do projeto



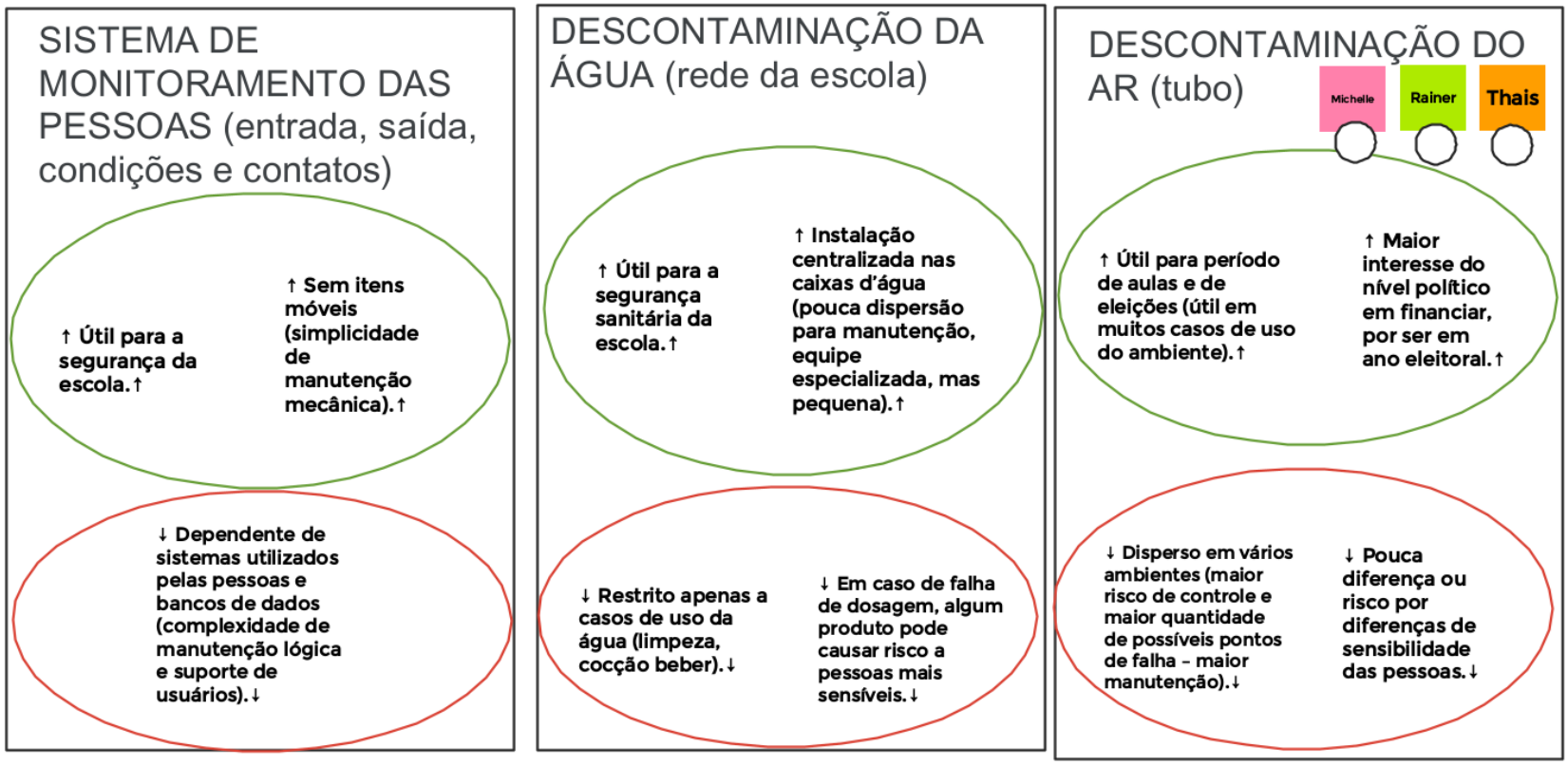
Soluções (separadas por complexidade ou dificuldade de implementação)

Ideação

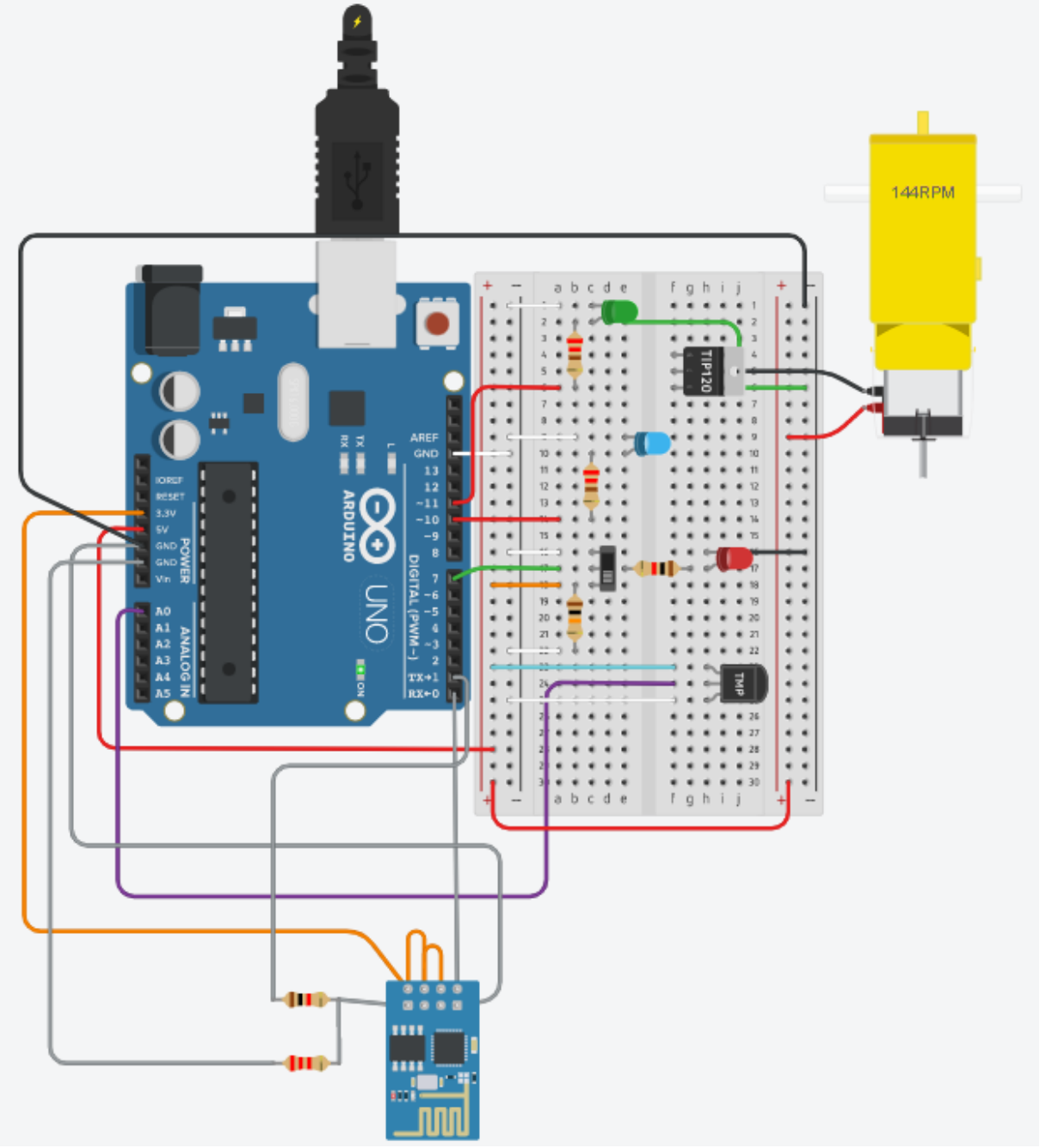


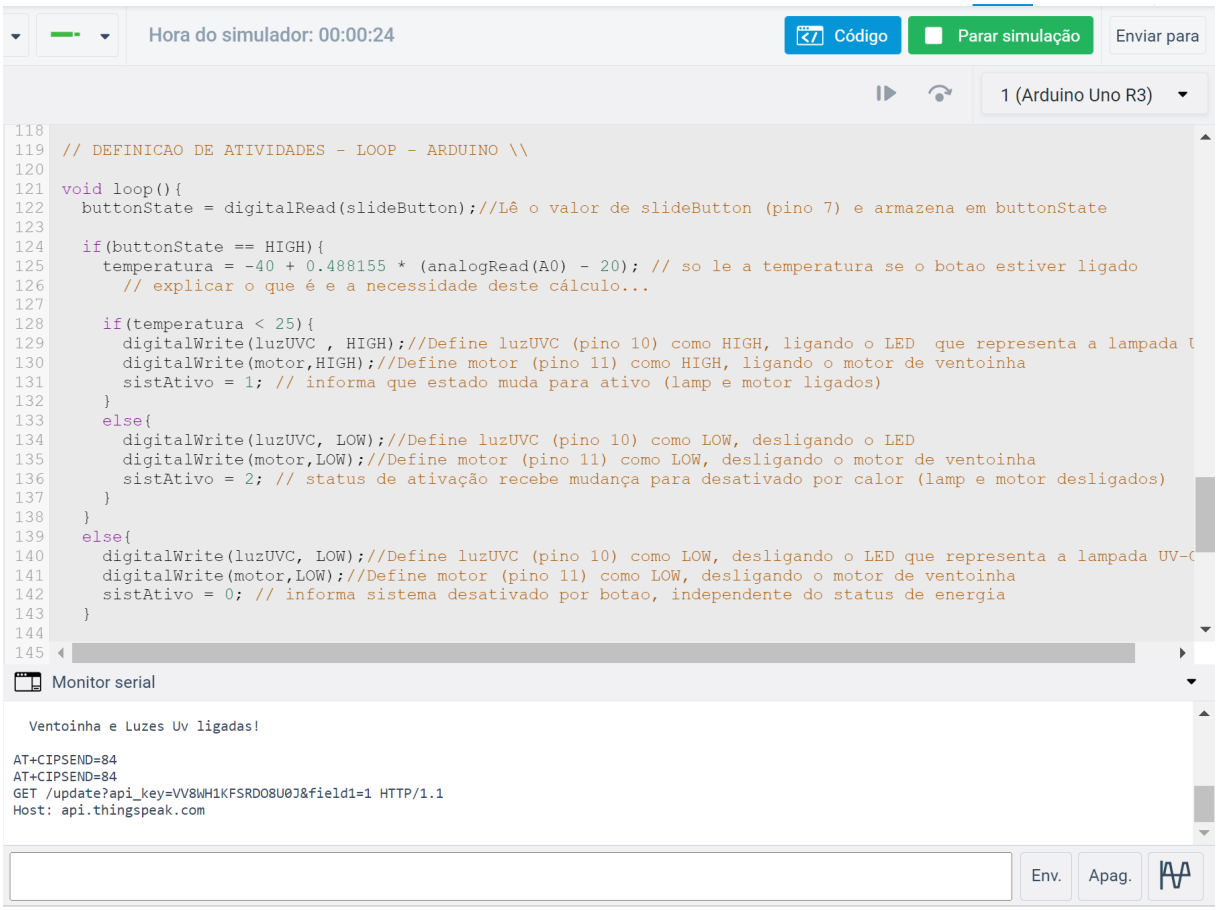
Soluções (discutindo vantagens e desvantagens como percepção de valor - para escolha de uma inicial)

Ideação (Percepção de valor)



APÊNDICE B - Diagramas e código para arduino e placa de controle do dispositivo





/* UNIFEOB - UNIVAP
Grupo 12 - PI 2022_01 IoT & PComp

Thiago Felipe Santos Ribeiro 1012022100391
Thais de Morais Vieira 1012022100664
Michelle Karoline de Lima 1012022100481
Matheus Oliveira Custodio 1012022100301
Rainer Ferraz Passos 1012022100326

VERSAO CORRENTE (v4 - 10/04/2022)
*/

// DEFINICAO DE VARIAVEIS NOMES DE PINOS\\

int slideButton = 7; // define pino 7 como comando liga/desliga do dispositivo inteiro
int luzUVC = 10; // define pino 10 como comando liga/desliga das lâmpadas UV-C
int motor = 11; // define pino 11 como comando liga/desliga do motor da ventoinha
int tmpSens = A0; // define pino A0 como entrada analogica da informacao da temperatura

// DEFINICAO DE OUTRAS VARIAVEIS GLOBAIS\\

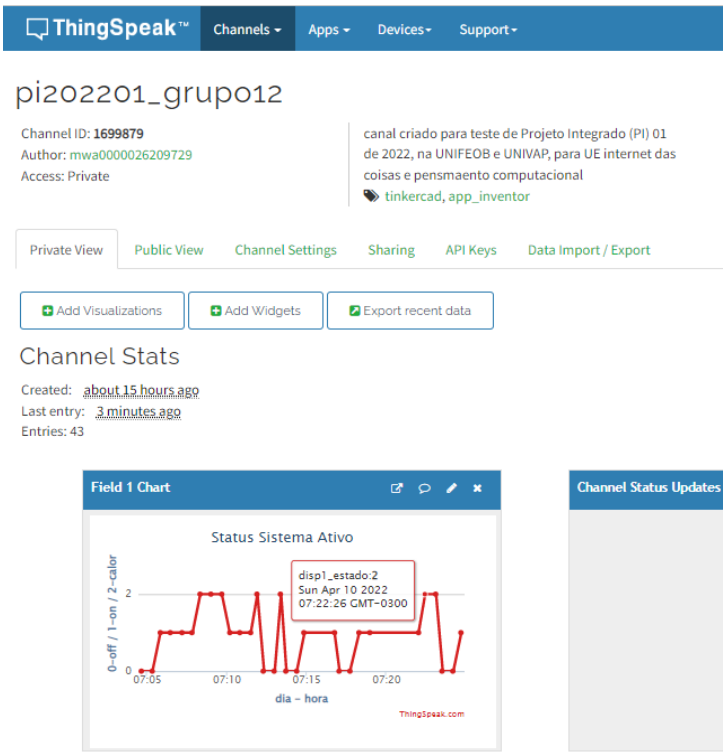
int buttonState = 0; // variavel para informar se botão slide está ligado

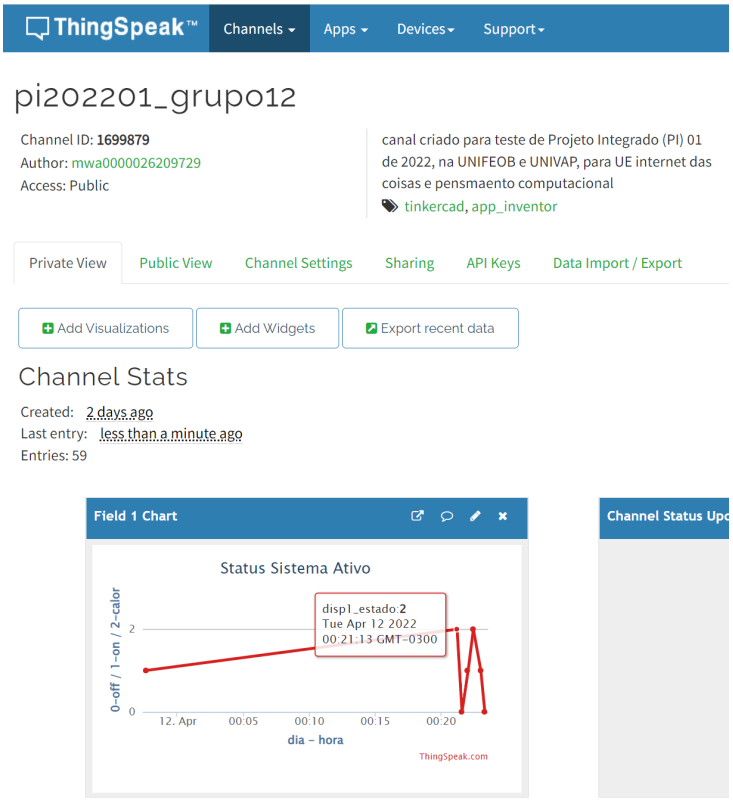
```
double temperatura      = 0; // variavel para informar a temperatura

int buttonStateAnterior = 1; // variável para identiicar se houve mudança ligado/desligado do slideButton

int sistAtivo           = 0;
/* variavel sistAtivo identifica se sistema esta ativo ou nao
   pode estar ligado (buttonState != 0) - mas não estar ativo (ventoinha e lâmpadas desligadas)
   caso 0 = desativado por botao (botao deslizante desligado)
   caso 1 = ativo (botao deslizante ligado e temperatura ok)
   caso 2 = desativado por calor (botao deslizante ligado e temperatura alta)
*/

int sistAtivoAnterior   = 1;
    // variável para identiicar se houve mudança ligadas/desligadas das lâmpadas e ventoinhas

int primeiroLoop        = 1;
    // variavel para controle do caso especifico do primeiro loop



// DEFINICAO DE VARIAVEIS PARA PLACA WIFI \\

String ssid     = "Simulator Wifi";  // SSID de uma rede wifi para conectar
String password = "";                // wifi sem senha CUIDADO
String host     = "api.thingspeak.com"; // abrir o API da pagina ThingSpeak
const int httpPort   = 80;           // define a porta http
String uri      = "/update?api_key=VV8WH1KFSRDO8U0J&field1=";
    // uri para inserir dados no canal do Grupo 12


// DEFINICAO DE SETUP INICIAL PLACA WIFI \\

int setupESP8266(void) {
  // iniciar a communicação serial (porta?) do ESP8266
  Serial.begin(115200);   // Serial por USB para computador
  Serial.println("AT");   // Serial por portas Tx / Rx para ESP8266
  delay(10);              // espera resposta do módulo ESP
  if (!Serial.find("OK")) return 1;

  // conectar ao 123D Circuits Simulator Wifi - definir rede e fornecer senha
  Serial.println("AT+CWJAP=\"" + ssid + "\",\"" + password + "\"");
  delay(10);        // espera resposta do módulo ESP
  if (!Serial.find("OK")) return 2;

  // iniciar conexao TCP com o servidor - frase com o endereço da api do thingspeak e porta
  Serial.println("AT+CIPSTART=\"TCP\",\"" + host + "\"," + httpPort);
  delay(50);        // espera resposta do módulo ESP
  if (!Serial.find("OK")) return 3;

  return 0;  // coloca resposta porque a funcoes cobram resposta, menos funcoes void
}
```

```
// FUNCOES DE ATIVIDADES DA PLACA WIFI PARA O LOOP DO ARDUINO\\

void enviaStatusESP8266(void) {

  int status = sistAtivo;
                    // variavel com o status a ser enviado, recebe o valor atual da sistAtivo
       // - sistema ligado/desligado e OK/quente (caso 0,1 ou 2)

   // contruir a mensagem HTTP - pacote com a uri para escrever mais a palavra de dados e o servidor
  String httpPacket = "GET " + uri + String(status) + " HTTP/1.1\r\nHost: " + host + "\r\n\r\n";
  int length = httpPacket.length();

  // enviar o tamanho da mensagem - comprimento
  Serial.print("AT+CIPSEND=");
  Serial.println(length);
  delay(10); // espera resposta do módulo ESP
  if (!Serial.find(">")) return;

  // enviar a mensagem http request
  Serial.print(httpPacket);
  delay(10); // espera resposta do módulo ESP
  if (!Serial.find("SEND OK\r\n")) return;
}


// DEFINICAO SETUP INICIAL ARDUINO \\

void setup(){
  Serial.begin(9600);
  pinMode(luzUVC , OUTPUT);    //Define luzUVC (pino 10) como saída
  pinMode(motor, OUTPUT);      //Define motor (Pino 11) como saida
  pinMode(slideButton , INPUT);//Define slideButton (pino 7) como entrada
  pinMode(tmpSens, INPUT);     //Define o sensor de temperatura (pino A0) como entrada

  setupESP8266();              //chama a funcao que faz setup do modulo ESP8266
}


// DEFINICAO DE ATIVIDADES - LOOP - ARDUINO \\

void loop(){
    buttonState = digitalRead(slideButton);//Lê o valor de slideButton (pino 7) e armazena em
buttonState

  if(buttonState == HIGH){
      temperatura = -40 + 0.488155 * (analogRead(A0) - 20); // so le a temperatura se o botao estiver
ligado
      // explicar o que é e a necessidade deste cálculo...

            if(temperatura < 25){
          digitalWrite(luzUVC , HIGH);//Define luzUVC (pino 10) como HIGH, ligando o LED  que
representa a lampada UV-C
      digitalWrite(motor,HIGH);//Define motor (pino 11) como HIGH, ligando o motor de ventoinha
      sistAtivo = 1; // informa que estado muda para ativo (lamp e motor ligados)
    }
```

```
          else{
     digitalWrite(luzUVC, LOW);//Define luzUVC (pino 10) como LOW, desligando o LED
     digitalWrite(motor,LOW);//Define motor (pino 11) como LOW, desligando o motor de ventoinha
        sistAtivo = 2; // status de ativação recebe mudança para desativado por calor (lamp e motor desligados)
          }
  }
  else{
      digitalWrite(luzUVC, LOW);//Define luzUVC (pino 10) como LOW, desligando o LED que representa a lampada UV-C
    digitalWrite(motor,LOW);//Define motor (pino 11) como LOW, desligando o motor de ventoinha
    sistAtivo = 0; // informa sistema desativado por botao, independente do status de energia
  }

  if(sistAtivo == 1 && (primeiroLoop == 1 || sistAtivoAnterior != 1)){
    Serial.println("\n  Ventoinha e Luzes Uv ligadas!  \n");
    // só imprime no monitor em caso de mudança de ativado/desativado ou se for o primeiro loop
  }

  if(sistAtivo == 2 && sistAtivoAnterior < 2){
    Serial.println("\n  Ventoinha e Luzes Uv desligadas por calor!  \n");
      /* só imprime no monitor em caso de mudança de ativação ou se for ligado já com temperatura alta*/
  }

  if(buttonStateAnterior == 1 && buttonState == 0){
     Serial.println("\n  Dispositivo energizado, mas interruptor local desligado!  \n");
        /*imprime no monitor que dispositivo está ligado à energia, mas o botão deslizante local está desligado,
            apenas se tiver ocorrido mudança, assim evita encher a tela do monitor com a mesma informacao*/
  }

  sistAtivoAnterior = sistAtivo;
   // status de ativação recebe mudança para ativado(1)/desativado por botão(0)/calor(2)
  buttonStateAnterior = buttonState; // carrega a variavel estado anterior com o estado atual
  primeiroLoop = 0;                 // informa que já houve o primeiro loop
  enviaStatusESP8266();             // chama funcao para enviar o dado do status (sistAtivo)
  delay(3000); // Intervalo de 3 segundos antes de checar se foi ligado/desligado ou ativado/desativado
}
```

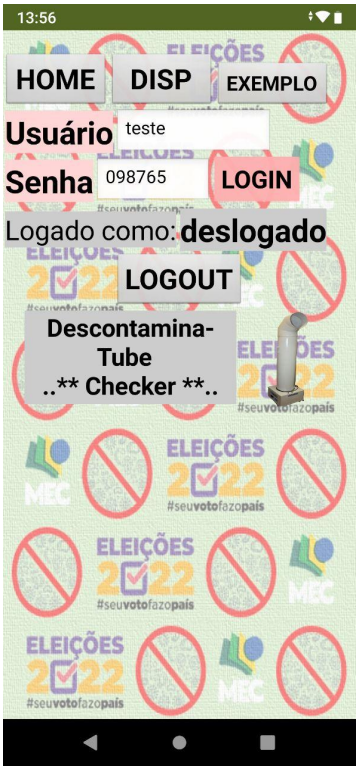
APÊNDICE C - Dados trafegados na internet e diagramas e código do controle mobile do dispositivo

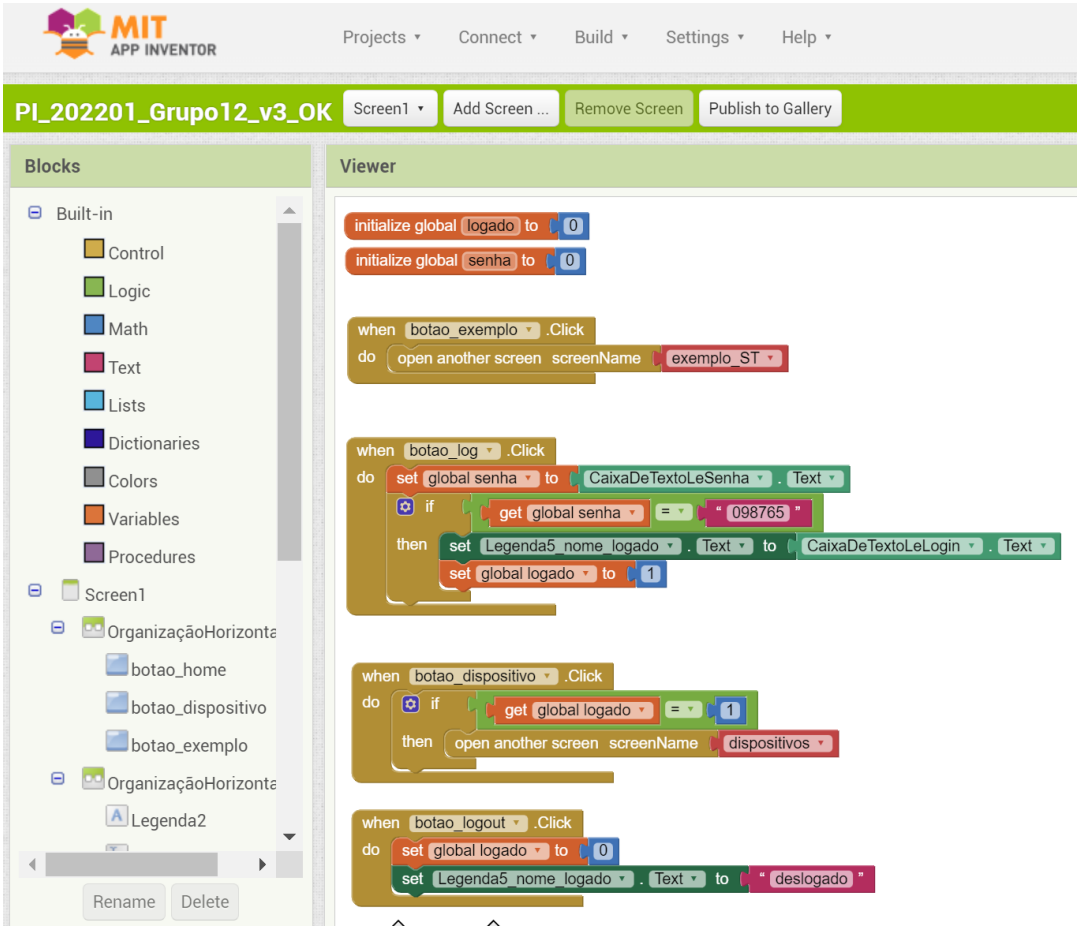


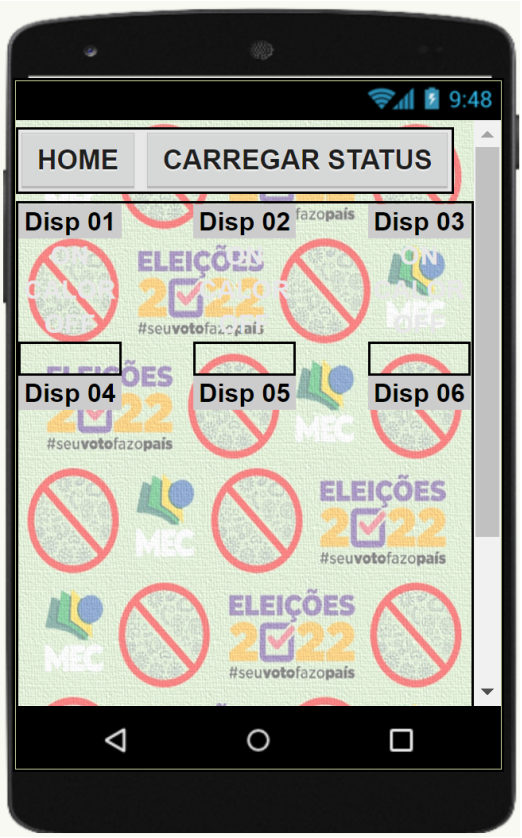



9:48
HOME
DISP
EXEMPLO
Usuário
teste
Senha
098765
LOGIN
Logado como:

LOGOUT
DescontaminaTube
..** Checker **..


13:56
HOME
DISP
EXEMPLO
Usuário
teste
Senha
098765
LOGIN
Logado como:
deslogado
LOGOUT
Descontamina-
Tube
..** Checker **..

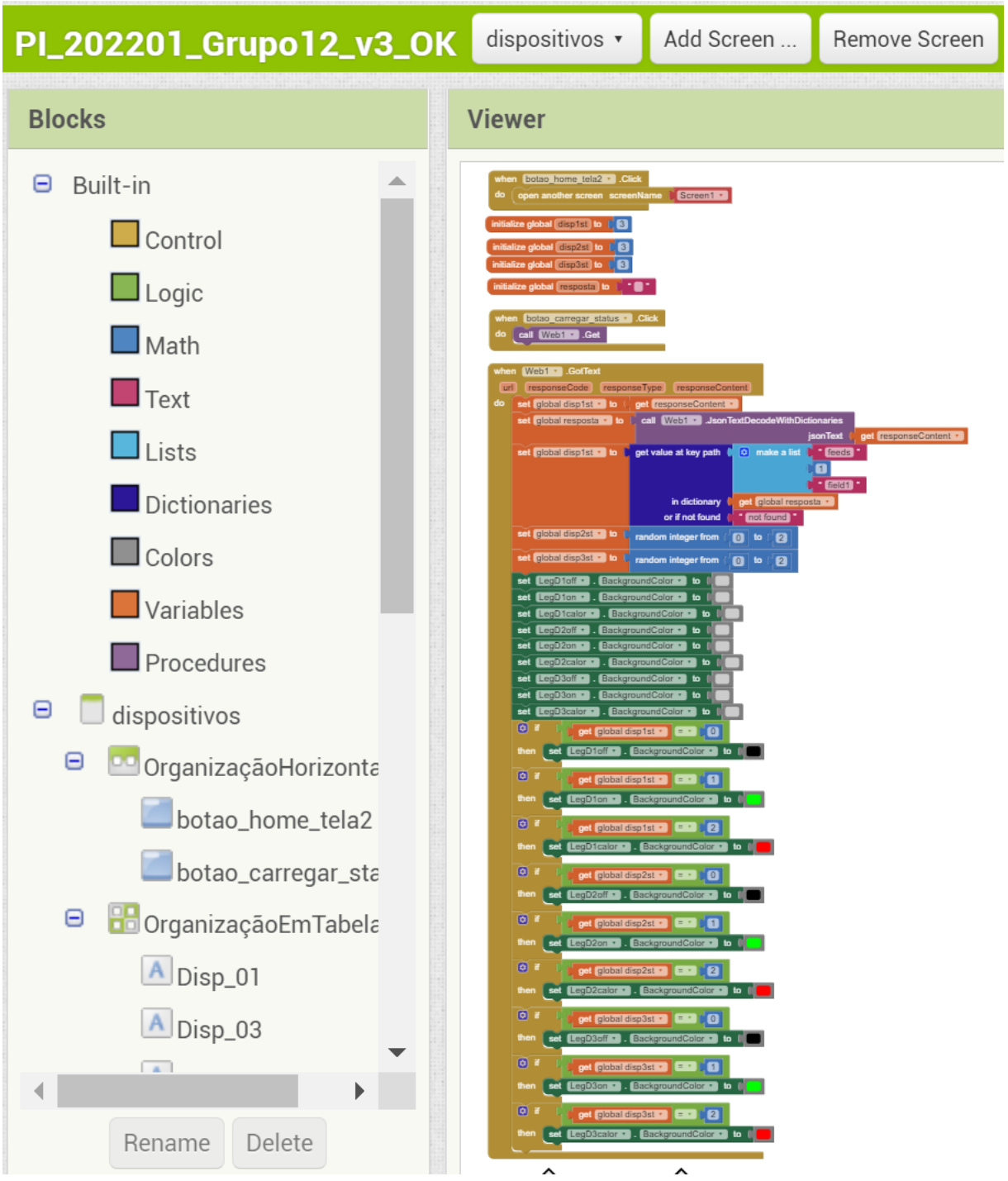

MIT
APP INVENTOR
Projects
Connect
Build
Settings
Help
PI_202201_Grupo12_v3_OK
Screen1
Add Screen ...
Remove Screen
Publish to Gallery
Blocks
Viewer
Built-in
Control
Logic
Math
Text
Lists
Dictionaries
Colors
Variables
Procedures
Screen1
OrganizaçãoHorizonta
botao_home
botao_dispositivo
botao_exemplo
OrganizaçãoHorizonta
Legenda2
Rename
Delete
initialize global logado to 0
initialize global senha to 0
when botao_exemplo .Click
do open another screen screenName exemplo_ST
when botao_log .Click
do set global senha to CaixaDeTextoLeSenha . Text
if get global senha = " 098765 "
then set Legenda5_nome_logado . Text to CaixaDeTextoLeLogin . Text
set global logado to 1
when botao_dispositivo .Click
do if get global logado = 1
then open another screen screenName dispositivos
when botao_logout .Click
do set global logado to 0
set Legenda5_nome_logado . Text to " deslogado "


9:48
HOME
CARREGAR STATUS
Disp 01
Disp 02
Disp 03
Disp 04
Disp 05
Disp 06

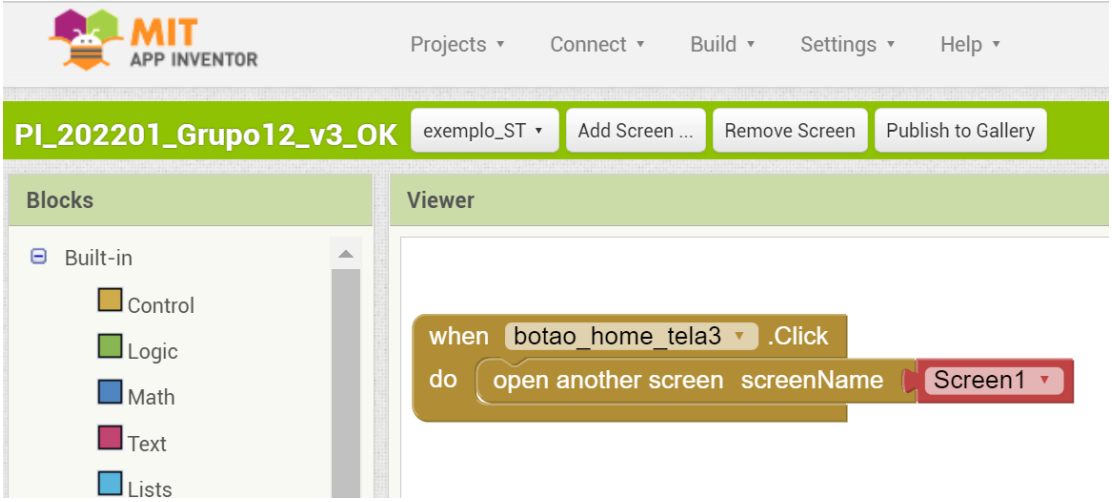

00:26
92%
HOME
CARREGAR STATUS
Disp 01 Disp 02 Disp 03
ON ON ON
CALOR CALOR CALOR
OFF OFF OFF
0
Disp 04 Disp 05 Disp 06


13:48
HOME
CARREGAR STATUS
Disp 01 Disp 02 Disp 03
ON ON ON
CALOR CALOR CALOR
OFF OFF OFF
Disp 04 Disp 05 Disp 06


13:45
HOME
CARREGAR STATUS
Disp 01 Disp 02 Disp 03
ON ON ON
CALOR CALOR CALOR
OFF OFF OFF
Disp 04 Disp 05 Disp 06


PI_202201_Grupo12_v3_OK
dispositivos
Add Screen ...
Remove Screen
Blocks
Built-in
Control
Logic
Math
Text
Lists
Dictionaries
Colors
Variables
Procedures
dispositivos
OrganizaçãoHorizonta
botao_home_tela2
botao_carregar_sta
OrganizaçãoEmTabela
Disp_01
Disp_03
Rename
Delete
Viewer


9:48
Exemplo de status dos dispositivos
HOME
Observe as cores realçadas nas mensagens abaixo do número do dispositivo. Se o dispositivo estiver desconectado, todos os campos estarão apagados.
Disp 01
ON
Disp 02
CALOR
Disp 03
OFF
Ligado e ativo
Ligado mas inativo por calor
Botão local desligado


MIT APP INVENTOR
Projects
Connect
Build
Settings
Help
PI_202201_Grupo12_v3_OK
exemplo_ST
Add Screen ...
Remove Screen
Publish to Gallery
Blocks
Viewer
Built-in
Control
Logic
Math
Text
Lists
when botao_home_tela3 .Click
do open another screen screenName Screen1