Automation tool for home fire safety check

1. How the image sensors should be set to guarantee the coverage of the indoor area?

Step 1. For the given indoor area, set a minimum bounding box to cover it.
Step 2. Find the center point of the bounding box.
Step 3. Place the camera at the center point with half height of floor.
Step 4. Rotate the image sensor and take an image every θ until the sum of the rotating angles is equal to or larger than 360°. We will describe how to decide θ later.
We here prove the feasibility and reproducibility of our approach.

Proof: There are two limitations in our approach.

The first is that the position of image sensor is fixed at the center point of the indoor area. With the size of the room, the minimum object distance is formed which is the shortest distance from the wall to the center point.

The second is that the vertical angle of the image sensor is fixed. Therefore, the vertical field of view (FOV_V) which is the object height, has to be at least equal to the floor height. The floor height is the distance between the ceiling to the floor and usually is 3 m.

We take a common room as an example, shown in Figure 1. The room is a 5m×3m rectangle. Its floor height is 3 m. The camera is set at the center point and the shortest distance between wall to the center point which is the minimum object distance is 1.5 m.

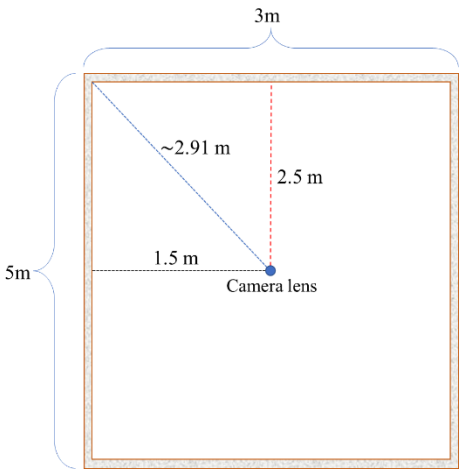


Figure 1. An example of calculating the horizontal field of view (FOV_H)

To satisfy the limitations, the focal length has to be at most 18mm. Most common mobile phones on the market are embedded with focal lengths ranging from 12mm~24mm. They are able to be the image sensors of our approach.

The rotating angle θ is limited by FOV_H which can be computed by given the object width and object distance. The object width can be computed by given object height and the ratio of film height to film width that is 16:9 for most general mobile phone. In the example of Figure 1, the horizontal field of view (FOV_H) is about 58.72°.

The rotating angle has to be equal to or less than FOV_H to ensure the room is fully covered by the images. In our experiment, we use the phone Asus Zenfone 5 with focal length ranging from 12mm to 24mm, which satisfied the requirement of the limitations.

2. What are the environmental models in this study? What are their differences with other models? What are the used metrics?

To prove that our automation tool is feasible, we adopted two common approaches of building environmental models, *manual reality* and *manual images*, for comparison.

Here are the descriptions of how the environmental models are built.

(1) *manual reality:* This environmental model was built by human observed and measured all objects in the real environment and the number, size, and material of the objects are the closest to the real environment so this model is considered as ground truth.

(2) *manual images:* This environmental model was built by human observed the images and based on his knowledge and experience. The accuracy of the model is affected by the quality of images and the ability of human. Therefore, the quality of the environmental model is unstable and errors on the number, size, and material of the objects are unavoidable.

(3) *automatic images:* This environmental model was built by our automation tool. The accuracy of environmental model raises with the improvements of recognition technologies and their datasets. The localization and size measurement results of the object are affected by the camera's angle, angle of view, and the camera's shooting position.

To evaluate the correctness of the automation tool, PyroSim [9] was used along with three input models for the experiments. We use two outputs of PyroSim, *variations in temperature* and *smoke over time*, for evaluating the feasibility of our automatic images model.

1. In terms of variations in temperature, the fire simulation results of automatic images model are close to the manual reality model which is the

ground truth.

2. In terms of smoke over time, the three models have the same trend of smoke spreads although the speed of smoke spread of automatic images model is a bit faster than the manual reality model. However, it is acceptable because the speed of smoke spread is less important for home fire safety check.

The two fire simulation results demonstrate that our automatic images model extracted the critical objects and their features that indeed impact the fire spreads. In other words, our automation tool is feasible.

3. The authors add the experimental scene at home. How is it different from the laboratory scene?

To address this problem, we added an experiment. There are two indoor experiments in this revision. One is the laboratory to represent public offices and the other is a home to represent private houses. Their inside objects are different. In addition, two different fire-starting points are simulated. One is at the central position of the laboratory, and the other is at the corner position of the home. According to our experimental results, although there is difference between the environmental models built by our automation tool and the environmental model built by manual operation, their fire simulation results are similar. Here is the comparison of the two experiments.

Field	Number of objects	Density of objects	Type of Windows	Compartment
Laboratory	A lot	Low	Large	Yes
Home	Few	High	Small	No

The added experiment and its results are described in the fifth paragraph of the Section III.

4. What is the difference between the existing environmental modeling used in Taiwan and the automation environmental modeling presented in this study?

We have not found any other automation tools for home fire safety check. As we know so far, the home fire safety check relied on manual examination in Taiwan. The disadvantages of manual examination include burden of labor, time-consuming, inconsistent results, and poor resident's privacy. Our automation tools relieve these cons, especially for processing time. Here is the table to present the processing time to build the three models.

	Manual reality	Manual images	Automatic

			images
Processing time	more than 2 days	more than 8 hours	within 10 minutes

5. Why do the authors regard the proposed method as a twin-based fire prevention system?

Digital twin refers to the establishment of a digital analogy through the integration of physical feedback data, artificial intelligence, machine learning and software analysis. Its analogy is self-learn based on the feedback data, and presents the real situation of the real world by the digital world.

Digital twin has the advantages of shortening the product development cycle and cost, reducing the maintenance cost and improving the service quality. So far, the definition of digital twins, recognized and used by most people, consists of three parts; the physical products, the virtual products and the associated data that connects the physical and the virtual products.

In fact, the fire cannot be simulated in a real environment. In addition, several existing fire simulation tools have many problems, such as relying on manual operation, longer modeling time, inconsistent environmental model owing to a manual operation, privacy problems and high difficulty of using the software. This decreases the willingness of using such factors. The automation method proposed in this study can highly attenuate the above-mentioned problems.

To avoid confusion among readers, we have changed the "fire prevention system" to "fire safety check".

6. What is the novelty of this study? Is it necessary to adopt an iPhone?

The work described here makes two contributions: First, our work is among the first, if not the first, to design automation tools for home fire safety check by image sensors. Characterize and extract environments from images to capture the critical features that affect the spread of fires. Our design decreases the cost, complexity, and time of home fire safety check system.

The second contribution is that the implement of home fire safety check system by exploiting fire simulation tools combined with existing recognition technologies and our developed measurement technologies. In our system, multiple image processing modules, data fusion modules and converters, that only use image data generate environmental models and relevant parameters for fire simulation. The experimental results reveal that the accuracy rate is similar to the ground truth.

We thank the reviewer for pointing out the problems with the hardware of experiment. The main reason of adopting i-phone as image sensor in the experiment is to demonstrate the feasibility of using general mobile devices instead of specific fixed camera. Owing to the popularity of mobile devices, this presents our approach is applicable to private houses.

In the revision, an experiment of the home bedroom scene with other mobile devices was added. The added experimental setting and results are in the fifth paragraph of the Section III. More details are described in the online documents.

7. Why was the system name changed from "fire prevention system" to "fire safety check"?

To address the above question, we rewrote the paper and modified the title from “An automatic fire prevention system” to “Automation tool for home fire safety check”. In the revision, we addressed the contributions on developing automation tools with existing fire simulation tools for replacing manual home fire safety inspection.

8. Can the authors give more details about the object properties table?

The object properties table stored the properties of objects affecting fire spread, including name, material, location and size. These properties are automatically generated by our automation tools based on image recognition, localization and size measurement technologies. According to the object properties table, a single object following FDS6 syntax is created. In addition, the number of OBST commands is determined by the composition of the object. Here, we listed several common objects with their compositions in Table 1. Take a bed as an example, it is composed of a headboard, a bedstead and a mattress.

Object	Number of compositions
Bed	3 (headboard x 1, bedstead x1, mattress x1)
Table	3 (desktop x1, leg x2)
Chair	6 (chair back x1, seat surface x1, leg x4)
Sofa	2 (chair back x1, seat surface x1)
Television	2 (LCD panel x1, outside frame x1)
Refrigerator	1 (body x1)

Table 1. Composition of each object

Generally, an object is composed of multiple materials, especially for the surface. By matching the components of object properties table the material table, as Table 2, can determine the fire-resistance coefficient of the object which is the critical factor for fire spread.

Material	Composed objects
Wood	headboard, bedstead, desktop, table leg, chair back, seat surface, chair leg
Plastic	outside frame
Steel	desktop, chair leg, chair back, seat surface, table leg
CRT	LCD panel

Fabric + Foam	Mattress, chair back, seat surface
Steel + Plastic	refrigerator body

Table 2. Object and surface material matching

Owing to the four pages limitation of “IEEE Sensors Letter” and the suggestions of other reviewers, the object properties table and its explanations were moved to the online document which was created as a supplement. We added its hyperlink in the end of the first page of this revision.