D11 Using Object Detection to Obtain Flame Height From Experimental Video and Evaluate Predictive Models

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Learning Overview: After attending this presentation, attendees will: (1) be familiar with potential uses of flame height in the investigation and analysis of fire incidents; (2) recognize how a machine learning model for object detection can be used to obtain flame height data from experimental video; and (3) understand the capabilities and limitations of algebraic formulas commonly used to predict flame height.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by examining how, through the application of an object detection machine learning model, flame height data were collected from experimental video of free burn and compartment fires. The data were then used to assess predictive algorithms designed to estimate flame height. The discrepancy between the predicted and measured flame heights tended to be larger for fire scenarios that involved more complex fuels.

Over the years, researchers have developed a variety of techniques to estimate certain characteristics of a fire and its surrounding environment. Many fire investigation textbooks and engineering handbooks contain detailed information regarding algebraic formulas derived from empirical correlations that are used to predict different aspects of a fire.[1,2] Furthermore, training programs offered by the International Association of Arson Investigators describe a similar set of algebraic equations that can be used to estimate fire plume temperature, flame height, hot gas layer temperature, radiant heat flux from a fire source to a target fuel, time to compartment flashover, and other quantities for a given fire scenario.[3]

The vast majority of these empirically based algorithms are based on data collected from experiments involving gas burner and/or liquid pool fires, which typically have high levels of repeatability and can often be defined by the two-dimensional planar surface from which the fuel is expelled.[2,4] However, many fire scenarios involve fuel sources that are more complex than these laboratory fuels, such as a residential structure fire fueled by furnishings, appliances, and other items located inside the dwelling. These types of fuels are often composed of synthetic materials that melt, drip, and/or flow when heated and can emit fuel from multiple surfaces at any given time during the fire. Therefore, the flame geometry from a fire with a laboratory fuel may not accurately represent the flame geometry from a fire with a more complex fuel.

Over 100 full-scale experiments were conducted to examine the performance of numerous predictive algorithms for fire scenarios that used a natural gas burner, upholstered sofa, or upholstered chair as fuel. Fires from these fuels were studied under free burn conditions as well as inside a compartment with interior dimensions of 3.7m long by 3.7m wide by 2.4m high. A single ventilation opening was present in the form of a 2.0m high by 0.9m wide doorway located on the front side of the compartment. To study the effect of fuel location on fire dynamics, fuels were positioned at various locations in the compartment during the fire experiments. Additionally, experiments were performed with the compartment door in both the open and closed positions to evaluate predictive methods under conditions with different ventilation patterns.

Historically, researchers have measured flame height through various methods that include analysis of still images or video; analysis of infrared-imaged photos or video; a 500°C average centerline temperature criterion; and visual estimation by an individual.[5,6] For the majority of these experiments, flame height data were obtained through the analysis of recorded video. More specifically, a machine learning model was successfully trained and deployed to identify the fuel source, flame(s), and reference markers in the still frames of each experimental video. Knowing the vertical distance between each reference marker, the number of pixels per meter was computed for each analyzed video. Then, the object detection model was used to identify any flame(s) in each video frame, and the number of pixels between the tip and base of the flame was computed and converted to meters.

Experimental flame height data were compared to predicted values from empirical correlations. Results suggest that the magnitude of the difference between predicted and measured flame heights may depend on the fuel location within the compartment. Additionally, discrepancies between predicted and measured flame heights tended to be larger for scenarios that involved a more complex fuel, such as the upholstered chair or upholstered sofa utilized for these experiments.

As a result of this project, a new method has been developed to extract flame height data from recorded video. This procedure could be utilized by researchers and engineers in the future to effectively measure flame height during fire scenarios. Furthermore, experimental flame height data were compared to the values predicted by commonly used algebraic formulas. Results from this study provide fire investigators and engineers with credible scientific information based on data from full-scale fire experiments to better understand the capabilities and limitations of algorithms used to calculate fire phenomena.

Reference(s):

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Fire Investigation, Flame Height, Predictive Fire Models