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Technical Domain / Task Number 2 …………………………………

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Implementation of the Convolution Function to Determine Flash Duration

# Background

For many years, the IALA method of determining the flash duration has been as follows:

*“The duration of the measured flash profile should be taken from the point in time when the intensity first exceeds 50% of the peak intensity value to the point in time when the intensity finally falls below 50% of the peak intensity value. The end of a flash should be considered as when the intensity falls below 5% of the peak intensity value for more than 100ms.”*

This definition has been extracted from IALA Recommendation E200-3. There are two notable difficulties with this definition, particularly in relation to the use of LEDs. The first difficulty relates to the definition of the peak intensity. Some LED lights exhibit a spike in the intensity at switch on, and when the above definition is applied, the peak intensity is taken to be the intensity of the spike, rather than the “average peak” intensity of the flash. This can lead to a reduction in the flash duration because the 50%-ile is a higher value than expected

Secondly, some LED lights use pulse-width modulation (PWM) to control the perceived intensity of the light. Again, by the above definition, any light using PWM to ramp the LED intensity up and down will result in an incorrect flash duration.

It is apparent that the key issue with flash duration calculation given by the above definition is that it does not take into account to how the light is actually perceived by the human visual system.

# SOLUTION

The natural solution to the issue is to apply a filter to the data that removes the high frequency components such as spikes and PWM artefacts. Then, the question becomes, which filter to use?

The obvious candidate for this purpose is the Modified Allard Method (MAM). This, after all, is simply a filter that is meant to represent the response of the human visual system to flashing lights. Normally, it is only the maximum value that is considered, which is the effective intensity of a flash of light (IALA Recommendation R0204). However, the convolution method produces a series of values (shown as orange in the example in Figure 1), which represents the level of stimulation in the human visual system to the flashing light. If the maximum value of this series is the effective intensity, then it is not unreasonable to consider the width of the 50%-ile to be the flash duration, in accordance to the definition above.

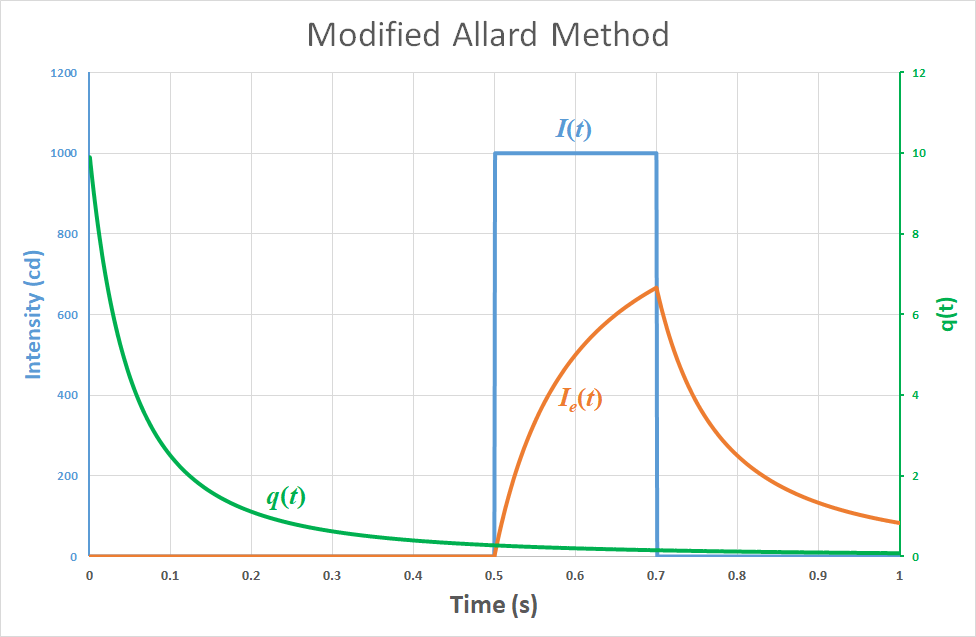


Figure 1 – Typical application of the MAM. The flash (blue) is convolved with the visual impulse response function (green) to produce the perceived flash (orange).

## Using MAM for Flash Duration

We can use MAM for calculating the flash duration using the following method:

1. Calculate the convolution of the measured intensity and Luizov impulse response function as per MAM as usual. Retain the entire series.
2. Calculate the maximum value of the series (which is also the effective intensity of the flash), and halve it.
3. Determine the length of time that the convolution result is above this value. This value is the flash duration.

Table 1 - Flash duration calculated using MAM

|  |  |  |  |
| --- | --- | --- | --- |
| **Flash Shape** | **Theoretical Flash Duration (s)** | **Convolution Flash Duration (s)** | **Difference in Flash Duration** |
| Rectangular | 0.2 | 0.213 | 6.5 % |
| 0.5 | 0.505 | 1.0 % |
| 1.0 | 1.001 | 0.1 % |
| Up Triangle | 0.2 | 0.221 | 10.5 % |
| 0.5 | 0.504 | 0.8 % |
| 1.0 | 0.986 | -1.4 % |
| Down triangle | 0.2 | 0.352 | 76.0 % |
| 0.5 | 0.773 | 54.6 % |
| 1.0 | 1.414 | 41.4 % |
| Symmetrical Triangle | 0.2 | 0.270 | 35.0 % |
| 0.5 | 0.610 | 22.0 % |
| 1.0 | 1.149 | 14.9 % |
| Gaussian | 0.2 | 0.265 | 32.5 % |
| 0.5 | 0.579 | 15.8 % |
| 1.0 | 1.092 | 9.2 % |
| PWM, 100 Hz, 50% duty | 0.2 | 0.213 | 6.5 % |
| 0.5 | 0.497 | -0.6 % |
| 1.0 | 0.994 | -0.6 % |

We can use theoretical flashes to test the method, and calculating their effective intensity and flash duration using the above method. The results are shown in .

The difference in the photometric flash length and the convolution flash length can vary significantly for complex flash shapes. In the vast majority of cases, the theoretical observed flash length is longer than that of the photometric flash length. Also, because of the filtering effect, any sharp spikes in the photometric data are smoothed out.

## Using Couzin-Tutt Model for Flash Duration

In a recent report published by R&RNAV, a different model for the impulse response function was proposed. This model was developed by Dennis Couzin, and refined by Ian Tutt through measurement, and is therefore referred to as the Couzin-Tutt model in this paper. It was found that this model deals with complex flash shapes better than MAM, especially when it is applied to triangular shapes. In this paper, we are not necessarily concerned with the amplitude of the convolution result, but rather its full-width at half maximum value, as calculated above using MAM.

Table 2 - Flash duration calculated using Couzin-Tutt Method

|  |  |  |  |
| --- | --- | --- | --- |
| **Flash Shape** | **Theoretical Flash Duration (s)** | **Convolution Flash Duration (s)** | **Difference in Flash Duration** |
| Rectangular | 0.2 | 0.216 | 8.0 % |
| 0.5 | 0.504 | 0.8 % |
| 1.0 | 1.001 | 0.1 % |
| Up Triangle | 0.2 | 0.288 | 44.0 % |
| 0.5 | 0.599 | 19.8 % |
| 1.0 | 1.100 | 10.0 % |
| Down triangle | 0.2 | 0.286 | 43.0 % |
| 0.5 | 0.665 | 33.0 % |
| 1.0 | 1.284 | 28.4 % |
| Symmetrical Triangle | 0.2 | 0.264 | 32.0 % |
| 0.5 | 0.582 | 16.4 % |
| 1.0 | 1.109 | 10.9 % |
| Gaussian | 0.2 | 0.253 | 26.5 % |
| 0.5 | 0.555 | 11.0 % |
| 1.0 | 1.063 | 6.3 % |
| PWM, 100 Hz, 50% duty | 0.2 | 0.215 | 7.5 % |
| 0.5 | 0.505 | 1.0 % |
| 1.0 | 1.001 | 0.1 % |

The results are shown in Table 2. As for the MAM results, the Couzin-Tutt model predicts the theoretical observed flash length to be longer than the photometric flash length. The differences are less than those for the MAM result, but still significantly different for some flash shapes.

# Discussion

It is evident from the results above that the flash length is dependent on the convolution function employed as a filter. Because the two convolution functions represent a low pass filter with a cut-off frequency of approximately 2 Hz, any high frequency components due to PWM or momentary spikes are removed. However, it is also evident that, regardless of the convolution function used, the flash length is almost always longer than the existing IALA method which uses the photometric flash data directly.

One should note that the results presented in this paper are entirely theoretical and have not been tested through observation to understand the after-image effect that the convolution function predicts in its results (i.e. the falling edge of the convolution function gradually fades after the flash has ended, implying that light is “observed” after the flash has extinguished).

## Further Work

GLA R&RNAV is hoping to carry out experiments to better understand what is actually observed in the period immediately after a flash has extingushed. It is hoped that this work will add to the body of work already carried out by R&RNAV to improve the effective intensity model since it is closely related to the apparent flash length.

# Action by IALA

IALA is kindly requested to note the theoretical work given above, and to discuss the merits of such an approach to flash length. This will help to inform any future experiments in this field.

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