Poster Abstract: Don't Wait For Weight: Towards Weight Inference of Passengers and Luggage using Smartphone Camera

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ABSTRACT

Proposals on weighing passengers and their carry-on luggage prior to flights are gaining traction in the airline industry for fuel efficiency purposes. Adoption of such proposals are difficult in practice, however, as requiring passengers to step on weighing scales would incur significant overhead heavily affecting already busy airports. To solve this problem, we propose *CamWeight*, a novel vision-based weight inference system that takes video feed of off-the-shelf elastic mat (e.g., yoga mat) placed on the floor as the passenger walks over it while pulling his/her wheeled carry-on luggage. *CamWeight* makes use of inherent properties including amplitude and recovery time of *strain*, or mat deformation caused by footsteps and luggage wheels. Due to the inherent design of *CamWeight*, it incurs no additional time for weighing, while being cost effective. We present a preliminary proof-of-concept evaluation by varying weights in a luggage from 2.5 kg to 20 kg to achieve prediction mean absolute error of approximately 2 kg.

1 INTRODUCTION

Estimating correct amount of fuel prior to a flight is an important problem in airline industry for fuel efficiency purposes. Overestimation degrades fuel efficiency due to added weights of extra fuel, while underestimation is detrimental as the plane needs sufficient fuel to reach its destination [1]. Hence, proposals to weigh passengers and their carry-on luggage have gained traction as such information is crucial to accurate fuel estimation. Such proposals are difficult to be adopted in practice, however, due to increasing overhead in already extremely busy airports. One can only imagine the additionally incurred overhead of weighing hundreds of passengers for every flight.

While there are other proposals to infer body weights without using scales, they have shortcomings that are not applicable for the aforementioned problem. For example, vision-based systems focus on measuring volume [4, 6], hindering accuracy as weights of carry-on luggage cannot be accurately inferred simply from their volumes. In addition, passenger weight inference may have reduced accuracy due to inherent noise such as thick clothes. Pressure mats may also be used, but incurs significant cost [5].

In light of this problem, we propose *CamWeight*, a novel vision-based weight inference scheme that is augmented by the use of an off-the-shelf elastic mat (e.g., yoga mat). This scheme enables a commodity smartphone camera to take a video feed of the mat as a passenger walks on it while pulling his/her wheeled carry-on luggage. Specifically, *CamWeight* utilizes the amplitude and recovery time of *strain* – or deformation of the mat caused by footsteps and luggage wheels – depicted on the video signal to infer the weight of the passenger and the luggage. *CamWeight* has the following inherent advantages. First, it does not incur any additional weighing time (as opposed to traditional weighing scales). Second, it is cost effective and scalable as it only requires a smartphone camera with an off-the-shelf elastic mat, rendering it easy-to-install across all gates or security checkpoints. We present a proof-of-concept experiments utilizing a wheeled carry-on luggage and a yoga mat to demonstrate the feasibility of *CamWeight* as we vary weights from 2.5 kg to 20 kg and achieve weight prediction mean absolute error of approximately 2 kg.

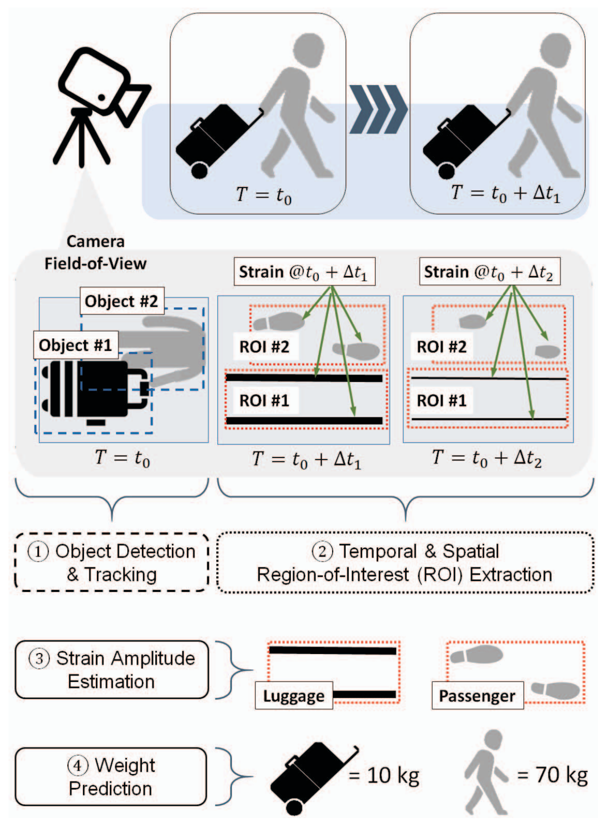

Figure 1: Figure depicts *CamWeight*'s system overview. A smartphone camera focuses on an elastic mat and records video footage and performs: ① object (i.e., passenger feet and luggage) detection and tracking; ② Region-of-Interest (ROI) extraction to identify the area with strain (i.e., deformation) on mats; ③ estimation of amplitude of strains; and ④ weight prediction utilizing recovery time and amplitude.

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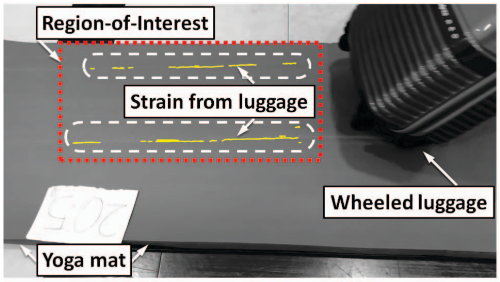

Figure 2: Figure depicts carry-on luggage being pulled on an elastic mat and extraction of Region-of-Interest (ROI) and amplitude estimation of strain due to luggage wheels.

2 DESIGN AND IMPLEMENTATION

We now present system design and implementation of *CamWeight*, namely how it utilizes computer vision analysis on strain caused by footsteps and wheeled luggage on the elastic mat to infer the weights, as depicted in Figure 1.

First, *CamWeight* detects and tracks objects of interest, which are footsteps and wheeled carry-on luggage (Figure 1①). We implement this step using state-of-the-art frameworks such as Faster R-CNN object detection [7] and IOU tracker [2], respectively. Upon detecting the objects, *CamWeight* identifies the region-of-interest (ROI) that contains resulting *strains* – or deformations left on the mat – as a consequence of the walk and pulling motion (Figure 1②). Note that the amplitude of strain decreases over time as the mat gradually returns to its original state. Hence, we apply image processing techniques to estimate the changes of amplitudes (Figure 1③). Specifically, we first reduce the the noise from camera sensor and video compression by applying non-local means denoising [3]. This is effective because it averages the pixels weighted by the similarity of their neighborhoods and has minimal effects on edges from the strain. Subsequently, we apply Canny edge detection and Hough transformation to detect edge segments from deformation of the mat caused by luggage wheels. *CamWeight* infers the amplitude of strain by counting the total number of pixels of the edge segments detected in the ROIs. Finally, we predict weight of an object by applying regression models with two dependent variables of time and strain. Specifically, we utilize support vector regression model using Radial basis function (RBF) kernel because of the non-linear characteristics of strain over time (Figure 1④).

3 PRELIMINARY EVALUATION

We present the preliminary evaluation to demonstrate the feasibility of *CamWeight*. We perform proof-of-concept experiments by utilizing a wheeled carry-on luggage (340 x 250 x 525 mm) and a yoga mat (1800 x 600 x 20 mm) as illustrated in Figure 2. We mount an iPhone X on a tripod to record video footage at 1920 x 1080 resolution and 30 FPS. We vary the load inside the luggage with dumbbells with five different weights – 2.5, 5, 10, 15, and 20 kg – across different trials.

We focus on strain amplitude estimation and weight prediction. First, we compute the number of detected pixels over time as we vary the weights across different trials. Figure 3 depicts the results

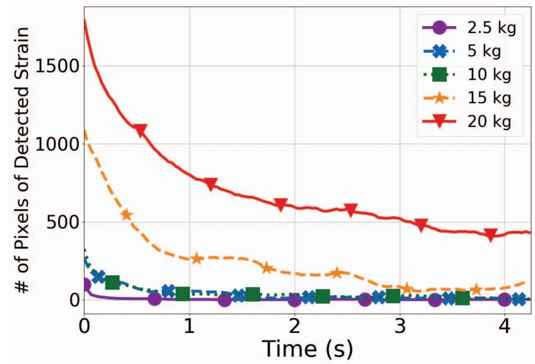

Figure 3: Plot depicts changes of number of pixels of strain as the mat recovers to its original state. Different curves depict trials with varying weights, and heavier loads leads to higher strain amplitudes.

where the luggage with heavier loads tends to exhibit higher amplitude especially in the earlier phases. Second, we utilize the collected data of 1281 samples and perform luggage weight prediction by training and testing multivariate support vector regression model with RBF kernel by 5-fold cross validation with 20 repetitions, yielding mean absolute error of 1.92 kg.

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