Some Considerations of Age Estimation Method for "Augmented TV" Based on Posture of Gripping Tablet PC

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Abstract. Augmented TV is an augmented reality system for making TV video to appear to come out of the screen. With Augmented TV, a television program is viewed through the camera of a tablet PC, and related content such as three-dimensional computer graphics (3DCG) is overlaid and displayed on the tablet PC. To provide users with age-targeted content, we have developed a height-estimation method based on the posture estimation method of Augmented TV, in which the height of the user is estimated from the elevation of the tablet PC off the ground. The estimated user height is then used to estimate his/her age. A public testing was carried out with around 90 elementary school students, and the data acquired was used to formulate a relationship between the elevation of the tablet PC and the height of the user. In the age estimation method proposed, the most statistically likely age for a given height was used. Therefore, we created a table containing the most statistically likely age for a given height, and the age of the user was estimated using the table. We evaluated the accuracy of both the height and age-estimations based the results of the public testing. The error in the age estimation based on the height-estimation was about 2 years of age. A rate of the age estimation in the case of using the age estimation method was about 60 %. In addition, developing a prototype application, we confirmed the effectiveness of both methods.

Keywords: Augmented TV · Context aware computing · Augmented reality · Age estimation

1 Introduction

Recent years have witnessed the appearance of services – such as that described in Ref. [1] – that use tablet personal PCs or smartphones (hereafter simply "tablets") as second screens to accompany TV screens. The field of "Augmented TV" [2] is among the areas of research that study this type of audiovisual experience. In Augmented TV, a television is watched through a tablet's built-in camera, thereby allowing the use of AR techniques to display data synchronized to television programs, such as 3DCG, in a way that accounts for position data.

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Meanwhile, context-aware computing systems such as that described in Ref. [3] – which automatically deliver content appropriate for a user's current situation – have been a focus of recent attention. This suggests the attractive possibility that Augmented TV methods might be used to automatically estimate a user's age, and then provide age-appropriate content. To this end, we apply an Augmented TV method for posture estimation in order to develop a technique for estimating the height of a user in a standing position, as well as a method for estimating the user's age based on height.

2 Development of Height Estimation Method

In this paper, we report on the development of a height-estimation method that utilizes the elevation of a tablet and is based on the posture-estimation technique described in Ref. [2]. We assume that the elevation of the center of a television screen is known in advance. The elevation of the tablet is defined as the distance from the floor to the tablet's built-in camera. Based on the posture-estimation technique described in Ref. [2], we determine the coordinate of the vertical component of the tablet's built-in camera in a coordinate system whose origin is the center of the television screen, then add the elevation of the television-screen center from the floor in order to compute an estimate of the tablet's elevation.

Using pre-measured values of the tablet elevation in standing positions, together with subject height information, we perform a regression analysis to obtain a formula describing the relationship between the measured values of tablet elevation and subject height, then insert our estimate of the tablet elevation into this formula in order to estimate the user's height. Section 2.1 describes the public test we performed to obtain formulas expressing the relationship between the subject height and tablet elevation. Our results, and the observations drawn from them, are discussed in Sects. 2.2 and 2.3.

2.1 Public Testing

Public test was conducted to obtain formulas expressing the relationship between subject height and tablet elevation. Figure 1 shows a side view of the environment in which our public test was conducted, while Table 1 lists the experimental conditions.

To test our method for estimating height, we require measured values of tablet elevation and webcam images used to compute heights. To generate webcam images, we used two webcams to capture images of the tablet held by the test subject and top of the test subject's head.

When conducting our public tests, we ensured that the posture of test subjects was identical to the posture exhibited while experiencing Augmented TV, and prepared experimental content consisting of a sequence of rapidly switched static images on the television screen.

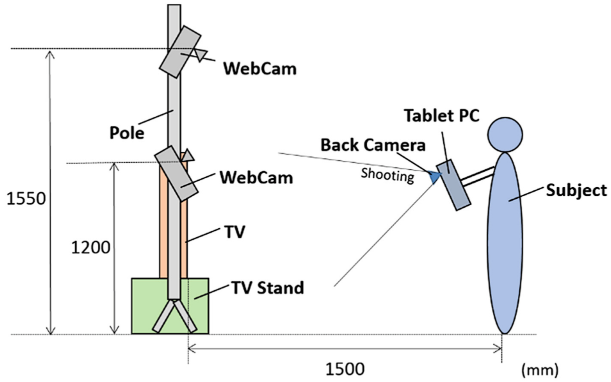

Fig. 1. Side view of public testing environment

Table 1. Experimental conditions

Number of test subjects	90
Age of test subjects	3–21 (70 % between 6 and 12)
Webcam model	Microsoft LifeCam Studio Q2F-00020
Webcam resolution	1280 × 720 (px)
Webcam image angular coverage	60.5 degrees
Distance between TV and test subject	1500 (mm)
Tablet PC model	Acer Iconia W700
Tablet PC dimensions	295 × 191 × 11 (mm)
Tablet PC weight	0.955 (kg)
Resolution of tablet PC built-in camera	2592 × 1944 (px)
Size of television	40 (in.)
Elevation of television screen center	778 (mm)

2.2 Result of Public Testing

Although we conducted public test on a total of 90 test subjects, we could only successfully obtain measurements of both tablet elevation and subject height for 71 of them. This reflects the impact of false identifications in our image processing procedures, which were designed to protect the privacy of test subjects. The results of the public tests described in Sect. 2.1 yielded graphs like that shown in Fig. 2 which characterize the relationship between tablet elevation and measured values of subject height. The regression formula obtained via the least-squares method is given by Eq. (1) below. In this equation, x is the measured value of the tablet elevation and y is the subject height. The contribution ratio was 0.84.

$$y = 1.30x - 84.6 \quad (1)$$

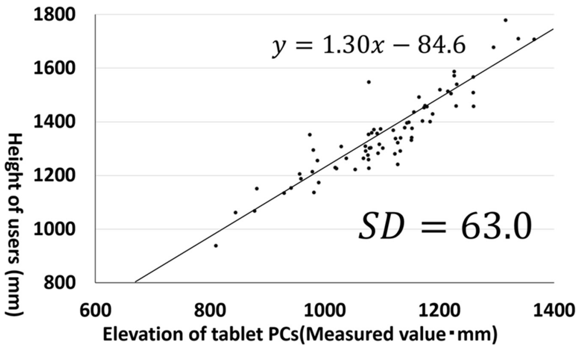

Fig. 2. Relationship between height of users and height of tablet PCs

2.3 Evaluation of Height Estimation Accuracy Supposing the Age Estimation

In this section we discuss the accuracy of our height-estimation procedure method based on the errors in our height estimates. From Fig. 2, the standard deviation of the estimated height values from the predictions of the regression formula using the tablet elevations was 63.0 mm. On the other hand, in the height data tabulated in Ref. [4] for children of ages between 6 and 12, the average height differential between children separated by one year of age is 59.9 mm. Thus, the standard deviation of our formula for the relationship between tablet elevation and subject height corresponds to an age uncertainty of approximately 1.1 years.

Based on this, we conclude that accuracy achieved by our method is sufficient for cases in which estimates are to be attributed certain widths – as is true for estimations of grade levels, which correspond to age ranges segmented by academic mastery based on achievement degree of learning.

3 Development of Age Estimation Method Based on the Height

Next, we will report on the development of an age-estimation method based on height estimates obtained using the procedure of Sect. 2. Our proposed age-estimation method begins by creating a table describing correspondences between heights and estimated ages, then estimates the age of a subject based on an input value of the subject's height. In what follows, highest estimation tables A, B, and C refer to data for male, female, and a mixed-gender population, respectively.

Tables A-C contain age estimates for each of various height values, together with values quantifying the accuracy of the estimates. Our process for constructing these tables is discussed in Sect. 3.1. In Sect. 3.2 we discuss experiments conducted to determine whether or not ages are estimated within a ±1-year accuracy range. Our results are discussed in Sect. 3.3.

3.1 Table that Shows Correspondence Between Height and Estimated Age

We constructed Tables A-C to serve as benchmark values for estimating age from height. First, following Ref. [4], for each of various height values separated by 1-cm intervals, we make test subject age-estimations based on the most common age for particular heights, and then take the ratio of estimated ages for each height value to determine the accuracy of the estimation.

Our procedure for producing age estimates and their accuracy levels are shown in Fig. 3. We augmented the data for the one to four-year age range with numerical values and probability density functions from Ref. [5]. In order to create the mixed-gender data in Table C, we used the average of the values for male and female subjects in the data of Ref. [4].

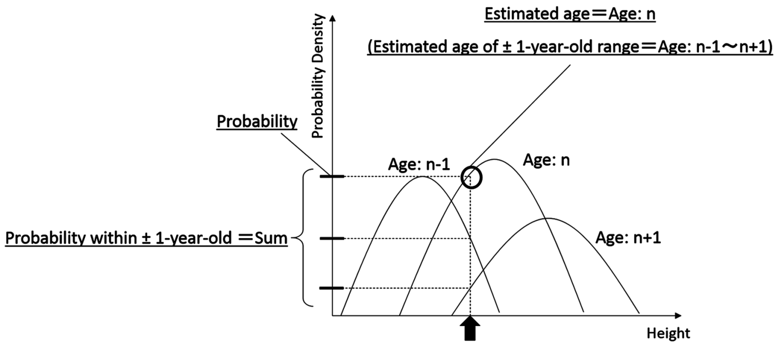

Fig. 3. Definition of estimated age and accuracy

3.2 Experiment of Age Estimation

To test the accuracy of the age-estimation method described in the previous section, we conducted experiments aimed at estimating ages based on heights using tables A-C constructed as described above. For height values, we used the estimated heights of test subjects computed via Eq. (1), as discussed in Sect. 2.2. We then applied these values to Tables A-C and estimated the age of each test subject. For the purposes of these experiments we consider an age estimate to be correct if it lies within ±1 year of the actual age of the test subject. To determine the accuracy needed to estimate ages within ±1 year, we considered the number of subjects of each age who exhibited a given height value in the data of Ref. [4]. Then, for each height value, we totaled the values of the three ages for which that height value appears most frequently.

3.3 Results and Discussion of Age Estimation

The results of the experiments described in the previous section revealed that the fraction of all test subjects for which our age estimates were correct was 60.0 % for cases in which we used the highest estimation tables (A and B), and 61.2 % for cases in which we used the gender-mixed table (C). This level of accuracy cannot be considered adequate for purposes in which accurate ages must be estimated, but we consider it sufficient for the purpose of switching content appropriate for one of three academic grade levels, as discussed in the previous section.

4 Age Estimation Function to Embed in Augmented TV

Next, we developed age-estimation functionality for Augmented TV in which the age-estimation method of Sect. 3 is used to estimate a user's age via a tablet in an Augmented TV system. This age estimate is then used to determine an appropriate academic grade level. We first estimate the elevation of a tablet held by the user, then use this value to estimate the user's height via the height-estimation method described in Sect. 2. From this height estimate, we use the age-estimation method described in Sect. 3 to estimate the user's age in the range from one to 17 years. Finally, we select one of three predefined academic grade levels appropriate for the user. We prepared trial content for display via 3DCG that may be switched in real time based on the results of this determination, and then confirmed that the 3DCG were can be switched based on academic grade level.

5 Conclusion

In this study, we considered an extension of Augmented TV functionality that provides content appropriate to a user's academic grade level. We developed a height-estimation method utilizing an Augmented TV posture-estimation technique and an age-estimation method in which the age of a user is inferred from his or her height. Tests of our two estimation methods demonstrated that they achieve accuracy sufficient to ensure no difficulties for applications requiring estimates of academic grade level. Finally, we demonstrated the effectiveness of our method in an actual implementation of our system by successfully switching trial content through conditional branching based on academic grade levels.

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