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3D Head Orientation Estimation and Expression Influence Minimization using Characteristic Points of Face

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Introduction

Face and head gestures are important cues in communication between humans. The face first attracts our attention, when we meet somebody, because it transfers the identity information, emotions are expressed by facial expressions, head gestures are used to show approval or disapproval. Because these reasons head gestures and facial expression are alternative input modalities in human – computer interaction. Methods of head detection and face analysis were enabled because of rapid development of information technologies. The need for training of algorithms to recognise humans and objects appeared. From the late eighties more attention was committed for head and face analysis systems.

Head detection and characteristic points of face localisation are initial steps of whole process. Knowing that the head or face is in the video frame let make next conclusions from basic to sophisticated ones: the persons head (faces) is in frame, the face belong to woman or man, how much in the frame is children's and adults, where they look and what are their face expressions.

Possibilities to evaluate head 3D rotation accurately allow to implement divers tasks on control, investigation and acquisition. Research was carried out with goal to develop method for head 3D rotations evaluation and investigated its errors and their dependencies on various factors as noise, frame resolution, face expression, size of rotation angle.

The most robust to user's head movement are remote gaze tracking systems that are using an algorithm of pupil centre and several corneal reflections for estimation of user's gaze direction [1]. The additional infrared light sources are used to obtain corneal reflections. The cameras, used in such systems, must be sensitive to infrared light. The light sources must be close to a user that to form a detectable glint at eye image. All these features are disadvantages of the system.

Gaze tracking in visible light is an alternative approach for low cost gaze trackers [2]. User's head orientation in space must be estimated in such case. It is accepted to divide head tracking methods into two types: appearance-based [3] and model based [4].

Previously we proposed a model based method [2,5] for 3D head orientation estimation from a single monocular camera. Coordinates tracking of several characteristic facial points (facial features) is used in the method. The coordinates of facial features obtain the shifts not only after head translation or rotation but also after a change of face expression. The way to minimize influence of facial expression is proposed in the current paper. The method was examined using computer simulation and analysis of the images from CMU PIE database [6].

Computer simulation of head pose estimation errors caused by a face expression

Initially, we need to select characteristic facial points for an algorithm implementation. We analysed 18 points–candidates, which can be detected automatically. All of them coordinates shift with a face expression [7]. The goal is to find a minimal number of the points, which are the most stable versus different expression and ensure small head angles estimation errors.

A geometrical model of 18 points arrangement on head was build. Further, we refer to it as a 3D head model. A head rotation center can be chosen arbitrary. We chose a point on the midline between user's eyes because it is seen on the acquired images. The facial points, which coordinates have minimal shifts versus different expression and are easy detectable, were selected. Firstly, the points having the longest distance from the center of rotation were included into set. The points were included by the next order: a nose tip, mouth corners, outer corners of eyes, inner corners of eyes. Then we simulated angle estimation errors versus a number of characteristics face points (Fig.1).

We defined from the plot in Fig. 1 that the optimal number of points is 6 – 8. In such case angle estimation error is less than 3 degree. The face characteristic points, which coordinates least change versus expression, are shown in Fig.2.

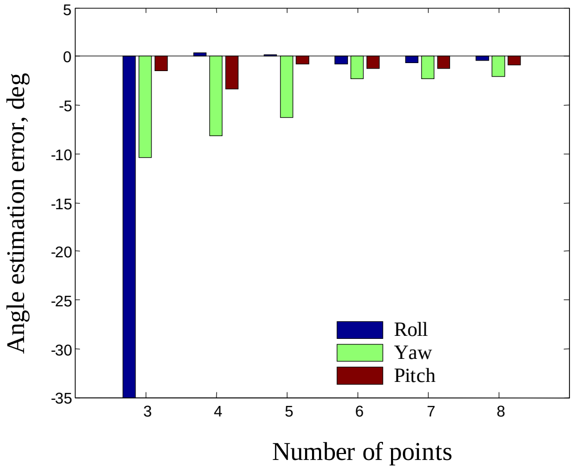

Fig. 1. Angle estimation errors versus number of characteristic points of face

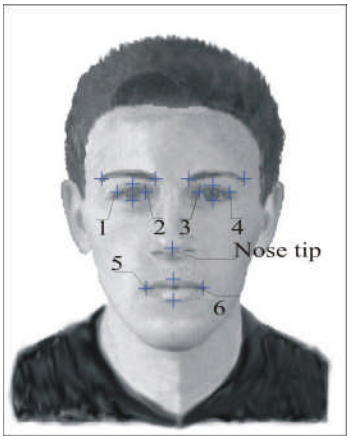

Fig. 2. Location of characteristic points, which least changes versus different expression

Previously [7] we defined the coordinates shifts of 6 characteristic points in five different face expressions (see. Table 1).

Table 1. Name of expression and code

Code of expressions	Expression name
1.	Angry
2.	Happy
3.	Neutral
4.	Sadness
5.	Surprise

Now, simulation of errors based on 3D head model was done. Rotations of head by 10 degree around all axis were simulated. This yielded new coordinates of selected face points. Random shift values according to expression were added to all coordinates before rotation. Afterward, head rotation angles were calculated from obtained coordinates by our suggested method. The differences between estimated by method values and initial rotation value (10 deg.) are angle estimation errors, caused by face expression. The bar plot of mean angle estimation error versus different expression is show in Fig. 3. Similar simulation results are shown in Fig. 4. Only now, after expression caused random shifts were added, the mean shifts values for expression were subtracted. The situation was simulated, when facial points coordinates shifts were compensated by recognized expression mean shifts. We can see that errors in Fig. 4 are some times smaller than in Fig. 3. Error ranges are presented in Table 2.

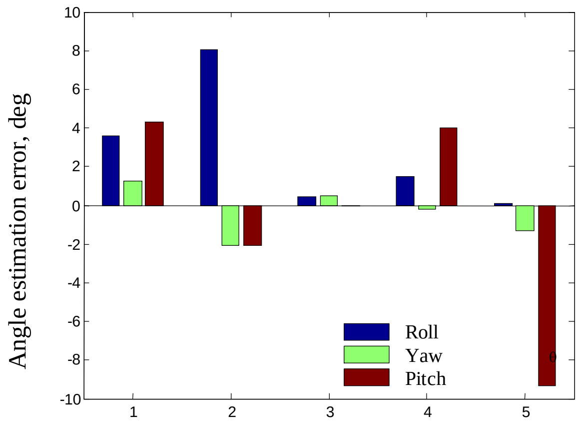

Fig. 3. Mean angle estimation error without expression compensation after head rotation about three axis by 10 degrees

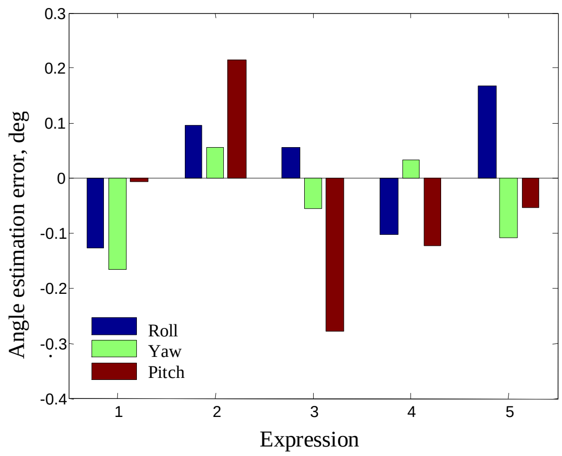

Fig. 4. Mean angle estimation error with expression compensation after head rotation about three axis by 10 degrees

Table 2. Intervals of head orientation angles estimation errors with expression compensation

Expression	Roll, deg	Yaw, deg	Pitch, deg
1. Angry	[–1.77 ; 1.26]	[–1.94 ; 1.28]	[–2.60 ; 2.58]
2. Happy	[–1.33 ; 1.72]	[–1.84 ; 2.06]	[–1.69 ; 2.55]
3. Neutral	[–1.55 ; 1.78]	[–1.22 ; 1.00]	[–2.73 ; 1.61]
4. Unhappy	[–2.02 ; 1.61]	[–1.36 ; 1.49]	[–2.36 ; 1.87]
5. Surprise	[–1.23 ; 1.91]	[–1.45 ; 1.02]	[–2.01 ; 1.79]

Head pose estimation errors obtained from database images

It is impossible to rotate a head accurately by a desired angle. Consequently we used CMU PIE database [6] of head images acquired from several cameras simultaneously. Because the cameras looked at face with different angles, heads in images seem as rotated by different angles. In addition, the faces in database were acquired with different expressions. Our expression elimination method gives angle estimation errors, presented in Fig. 5.

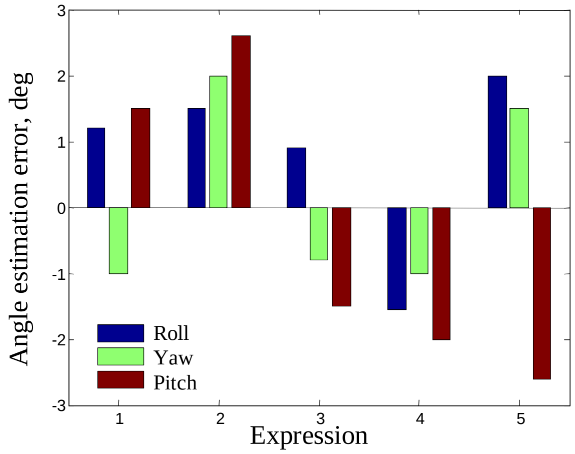

Fig. **5.** Mean head angle error with expression compensation for CMU PIE images

Simulation and experimental errors has tested and match 78-90% versus expression (Fig. 6).

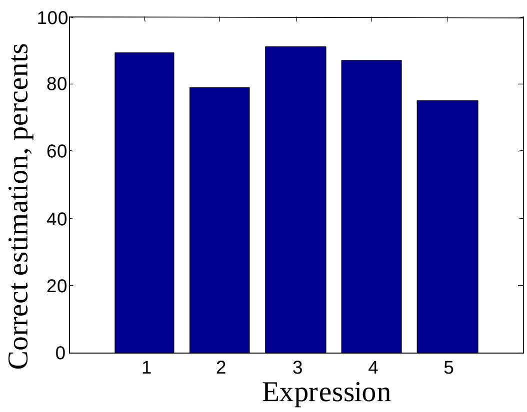

Fig. 6. Percentage of correct experimental estimation which belong to simulation intervals

Conclusion

The optimal number of facial features for tracking is 6-8. The points are: a nose tip, mouth left and right corners, both eyes outer and inner corners. A computer simulation gives that angle estimation error without expression compensation after head rotation around three axis by 10 degrees could reach maximal value13 degree (in surprise expression) and mean value of error is in range 6-8 degree. After expression compensation mean value of error is in range 0,1-0,3 degree. Simulated and experimentally obtained errors have been compared. Their match 78-90% is established. A proposed compensation method significantly reduces angle estimation error for tested expressions.

Acknowledgement

This research is supported FP6 NoE project COGAIN (contract No. 511598), EUREKA Programme (EUREKA project E!3807 EKO-FACTORY), and Agency for International Science and Technology Development Programmes in Lithuania (contract No. 10V-130).

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The method of minimization face expression influence for evaluation of head orientation in space is proposed and investigated. In our previous works 18 characteristic face points were selected for the head orientation evaluation. It is difficult to track all 18 points in real time. It was found by way of mathematical simulation that number of points 7 is optimal number for head orientation tracking. The points were selected at the face places which obtain minimal changes because of face expression. Mathematical simulation helped to establish that errors for head rotations could reach value 13 degrees (for surprised expression), and mean error is about 6-8 degrees. After correction of face specific points coordinates by mean value of change caused by face expression the errors were reduced until range 0.1-0.3 degrees. Intervals of possible errors for every expression and some head orientation angles were calculated. The method was tested using CMU PIE database of face images. The obtained interval for head orientation angles errors is 1.5-2.8. The correspondence of 78-90% was obtained between results of experimental errors and results of mathematical simulation. Ill. 6, bibl. 7 (in English; summaries in English, Russian and Lithuanian).

Д. Дервинис, Г. Даунис, Н. Раманаускас. Оценка ориентации головы в трехмерном пространстве и уменьшение влияния выражения лица, используя характерные точки лица // Электроника и электротехника. – Каунас: Технология, 2008. – № 6(86). – С. 47–50.

Предложен и исследован метод минимизации влияния выражения лица на оценку ориентации головы в пространстве. В наших предыдущих работах 18 характерных точек лица были отобраны для оценки ориентации головы. Трудно следить за всеми 18 точек в режиме реального времени. Посредством математического моделирования было найдено, что число точек 7 – оптимальное число для прослеживания ориентации головы. Точки были отобраны в местах лица, которые получают минимальные изменения из-за выражения лица. Математическое моделирование помогло установить, что ошибки углов поворота головы могут достигнуть значений 13 градусов (для удивленного выражения), а средняя ошибка – приблизительно 6–8 градусов. После коррекции координат характерных точек лица на среднее цзначение изменения, вызванного выражением лица, ошибки были уменьшены до диапазона 0,1–0,3 градуса. Интервалы возможных ошибок для каждого выражения и некоторых главных углов ориентации были вычислены. Метод был проверен, используя базу данных изображений лиц PIE университета Карнеги-Меллона. Полученный интервал для ошибок углов ориентации головы – 1,5–2,8 градуса. Соответствие 78–90 % была получена между результатами экспериментальных ошибок и математического моделирования. Ил. 6, библ. 7 (на английском языке; рефераты на английском, русском и литовском яз.).

D. Dervinis, G. Daunys, N. Ramanauskas. Veido išraiškos įtakos sumažinimas nustatant galvos erdvinę orientaciją pagal būdinguosius veido taškus // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 6(86). – P. 47–50.

Šiame darbe aprašomos galimybės sumažinti veido išraiškos įtaką nustatant galvos erdvinę orientaciją pagal būdinguosius veido taškus. Anksčiau atliktuose darbuose buvo nustatyta 18 būdingųjų veido taškų. Kadangi realiu laiku detektuoti 18 taškų yra sunku, šiame darbe matematinio modeliavimo būdu buvo nustatymas optimalus 7 taškų skaičius bei parinktos būdingųjų taškų vietos (akių vidiniai ir išoriniai kampai, nosies galas, lūpų šoniniai kampai), kurios mažiausiai keičiasi kintant veido išraiškoms. Matematinio modeliavimo būdu nustatyta, kad erdvinio galvos posūkio kampų nustatymo klaidos, kai galva pasukta apie tris ašis po 10 laipsnių, maksimali klaida siekia iki 13 laipsnių (esant nuostabos išraiškai), vidutinė klaida – 6–8 laipsnius. Po kompensavimo klaidos sumažėja iki 0,1–0,3 laipsnio. Matematiškai apskaičiuoti klaidų intervalai esant kiekvienai išraiškai ir kampui. Naudojant CMU PIE duomenų bazę buvo gauti eksperimentiniai duomenys – erdvinio galvos posūkio kampų nustatymo klaidos, kurios siekia 1,5–2,8 laipsnio. Gautas 78–90% matematinio modeliavimo ir eksperimentinių rezultatų atitikimas. Il. 6, bibl. 7 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).