

MODELLING AND RELIABLE CLASSIFICATION OF PERSONS ON THE FRONT SEAT OF A PERSONAL CAR

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The use of air bags in the presence of bad passenger and baby seat positions in car seats can injure or kill these individuals in case of an accident when this device is inflated. A proposed solution is the use of range sensors to detect passenger and baby seat risky positions. Such sensors allow the Airbag inflation to be controlled. This work is concerned with the application of different classification schemes to a real world problem and the optimization of a sensor as a function of the classification performance. The sensor is constructed using a new technology which is called Photo-Mixer-Device (PMD). A systematic analysis of the occupant detection problem was made using real and virtual environments. The challenge is to find the best sensor geometry and to adapt a classification scheme under the current technological constraints. Passenger head position detection is also a desirable issue. A couple of classifiers has been used into a simple configuration to reach this goal. Experiences and results are described.

1. INTRODUCTION

Recent statistics have provided evidence about the risk involved when air bags are used in the presence of unbelted passengers and rear-oriented forward-placed child seats. Since the use of air bags is being extended nowadays to all personal cars, and their number increases with lateral, window and back seat air bags, occupant detection and recognition research has become more important. This problem is known as the Out of Position Detection (OPD) problem. This problem is specially difficult to solve regarding the companion seat place since the driver position is usually easier to predict and a simpler sensor can carry out driver recognition with a high-reliability classification rate. Many solutions based on different sensor technologies have been proposed to solve the OPD problem. One of them is the use of range sensors to detect dangerous passenger and baby seat positions. A new promising device –PMD– is currently under research and development. This low cost device gives the opportunity not only to detect the occupant on the companion seat of a car but also to detect the occupant head position. Occupant head position gives the chance to made a more safety use of airbags.

2. CONTRIBUTION

Three main fields of interest compose the problem under study, i.e., the technology, the classifier and the sensor configuration. These parts conform a unique problem and none of them can be solved with independence of the other two. In the *technological field* an optimal dispersion angle for pixel sensors has been found through graphic simulation.

Regarding *classification schemes* a battery of tests was performed to select an adequate classifier, *The Support Vector Machine* (SVM) with a *second order polinomial kernel* in *pairwise mode*. Bias optimization for the OPD case is proposed as a topic for future research.

From the *configuration* point of view, matrix-sensor geometry is proposed and tested, considering the technological constraints. The optimal sensor orientation has also been established.

A battery of tests using a couple of Polinomial Classifiers, a Laser camera sensor and passengers into a real cockpit were made regarding the possibility to apply range sensors to detect the passenger head position.

3. PROBLEM DEFINITION AND EVALUATION OF RESULTS

The initial approach to solve the problem is to consider the three profiles corresponding to one of three different classes, Passenger -P-, Empty Seat -E- and Child Seat -CS-.

The distances measured from the sensor to the object surface define a pattern. This pattern must be classified into one of the three above-mentioned classes. Classification results are expressed by using a confusion-matrix in which the first column shows the input classes and the first row indicates the classification obtained. From this matrix a classification factor is computed. The classification factor is a measure of the performance of the classifier. The confusion-matrix is then weighted using a cost-matrix. The cost matrix represent the risk about human injuries for each kind of error. The present approach to the Occupant Detection problem implies a multiple-class non-linear classification problem. The goal is to reach a 99 % classification rate.

4. GRAPHICAL SIMULATION

Real patterns have been obtained from real cars and from electric seats in laboratory using actual sensor prototypes.

Simulation was carried out by using a customized general-purpose CAD system which allows the user to define, store, modify and use different types of distance sensors, companion seats, cockpits, child safety seats and anthropometric models. This simulation system can elicit a desired amount of patterns. Each pattern is defined by a set of distances measured by the distance sensor.

The companion seat is moved inside this cockpit from a back to a front position with a given step. Backrest angle and the head guard position can also change with a given step. Passenger or child seats can be placed on the companion seat and carried on it during this animation. One pattern is extracted and stored for each companion seat position.

5. OBJECTS DOFS

Companion seat degrees of freedom -DOFs- are head-guard rotation and translation, backrest rotation and seat translation.

Child and baby seats have been classified into three groups. Forward Facing Child Seats -FFCS-, Rear Facing Infant Seats -RFIS- and baby seats. Different child seats can have different DOFs.

To represent the passenger and his/her position on the companion seat, an existing anthropometric program (Anthropos®, 1997) was linked with the CAD environment.

A method to compute human types called Anthropometric Data Reduction (ADR) provides a basis for the definition of human model DOFs (Geuss, 1995). The basis of this method is to consider only a few groups of human proportions as *relevant measures* in order to define human bodies.

For an initial set of human types the existing possibilities have been reduced considering the relevant measures named, i.e., corpulence, height, proportion and gender.

Based on these *relevant measures* a *set of anthropometric models* has been defined. The reduced set contains thirty anthropometric model definitions.

Similarly, a *set of human postures* has been defined. By applying the set of human postures to each model in the anthropometric set a general population of patterns has been obtained for passengers.

How to define this set of human postures and what *out of position* means are important questions. A standard has been defined at Bosch GMBH by using photographs. In this standard adult passenger positions are qualified from right to out of position through two intermediate values. This standard has been herein used to define the human posture set and to label each posture as "Out of Position" or not.

6. FIRST AND SECOND GENERATION SENSOR

Two different sensor technologies are currently under development. They are: Infrared active or first generation sensor (Spies, 1998) and Photonic Mixer Device or second generation sensor (Schwarte *et al.*, 1997). The transition from the first generation sensor to the second generation sensor was defined regarding the experiences and results described in the next section. The first generation sensor is based on light emitters and the distances are measured by triangulation. Due the sequential measurements this sensor is not adequate to be constructed with more the ten pixels or emitters. Thus there is a limit in pattern dimensionality. The PMD sensor is basically an array or a matrix of pixels arranged into a chip. It can be constructed with about thirty or forty pixels. The overhead console was selected for sensor location in both sensors because it provides an ideal exposure of the seat to the sensor and no additional wiring is required inside the cockpit of a conventional car.

From a geometrical point of view sensor models have been classified as line and matrix sensors. In line sensors all the emitters are arranged on a line and all the rays lie on the same plane.

7. FIRST GENERATION SENSOR RESULTS

Using patterns obtained from the first generation sensor –The triangulation sensor- different classifiers have been evaluated. Tested classifiers were Multi-Layer Perceptron with Backpropagation function, Supported-Vector-Machines, Polynomial Classifiers and Radial-Basis-Function.

These tests lead to the following conclusions:

- 1) The best classification factor and cost was reached using the Perceptron Backpropagation Neural Network with two hidden layers.
- 2) A pruning process was applied to this network after it was designed. After pruning all the input neurons remains active. This relevant point indicates that more inputs are necessary to perform a reliable classification.
- 3) A similar pattern was found for two different classes. For this particular case it is not possible to discriminate both classes. This is an additional hint about the need of more inputs to achieve the reliable classification.
- 4) One class (The empty seat class) was easily separable from the other two.
- 5) Radial Basis Function has shown an unstable performance and was discarded for future research.
- 6) The optimization of the Perceptron Backpropagation Neural Network is a high time-consuming task and was not appropriate to train classifiers with thirty or forty input dimension, instead its high classification performance. This was the main reason to apply SVM and Polinomial classifiers for further research.

8. SECOND GENERATION SENSOR RESULTS

A battery of tests was made to answer the following questions:

1. Is it possible to solve the OPD problem by using distance sensors? How many pixels are needed?

The matrix sensor geometry with 108 pixels was simulated. Results show, that a few inputs are enough to perform a reliable classification. After these neural nets were trained and tested, Skeletonization (Zell, 1994) was applied. MLP-BP with less than forty-five input neurons were obtained and a classification rate > 0.96 was reached.

2. Comparison between actual and simulation results

As a research tool, a laser camera sensor was used to confirm simulation results. The output, filtered with a mean/median filter yields a precise deep image. An electric seat was used to obtain the patterns. A polynomial classifier was used to avoid the long optimisation processes required by Backpropagation NNets. To train a second order polynomial classifier the *principal component analysis* (Tou and Gonzalez, 1974) was applied to reduce input dimension. Correlation between both experiences reveals a statistical correspondence between the CAD simulated data and the real world data.

3. The classification factor as a function of sensor orientation

Tests have shown that an amount of pixels smaller than one hundred can perform a reliable classification. But the remaining neurons after skeletonization correspond to different neural net topologies -the neurons were not always the same-, so it was not possible to establish an input neuron hierarchy considering the influence over the classification performance.

A similar test was performed under new initial conditions. A matrix sensor with 30 pixels and a second order PC were used. The larger errors were obtained when pixels pointing to the bottom of the companion seat were passive. Classification rates over 99 % for test-set were reached by using the *pairwise* approach.

4. The classification factor as a function of the dispersion angle

To construct the first PMD prototype, two possible designs were considered. Each option can be evaluated in terms of a different ray dispersion angle which has influence over the classification rate.

This problem is also important for the infrared active sensor development due to the fact that real light can produce an illuminated surface with a diameter of about 45 mm on objects at a distance of 900 mm. In this case uncertainty exists respect to which point over this illuminated area is taken as a reference to compute the distance from sensor to intersection point.

The illuminated area was simulated and a mean value was computed as distance sensor-intersection point. To do this, a sensor CAD model was used. It is composed of thirty pixels, but in this case, each ray is modelled using thirteen lines identified as shown in Fig. 14. These thirteen lines have been divided into four groups, each one representing a different dispersion value. These dispersion angles were taken as 0, 1.5, 3 and 4 Srad. The four different optical definitions were defined in the same simulated sensor. This ensures that the comparison is made under the same simulation conditions.

Innovación Tecnológica Transferida.

**Resultados de investigaciones realizadas para la empresa DaimlerChrysler.
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