Method for Detecting Operation Mistakes with Accelerator Pedal

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ABSTRACT: Since the sudden acceleration (SA) accidents in the 1980’s, unintended acceleration has been an accelerator pedal operation mistake without a definitive solution. Recent advanced driver assistance system (ADAS) technologies are hoped to save victims from this kind of accident, but their effectiveness is limited. Drivers who have caused this kind of accident have stated that they pressed the brake pedal. An investigation of pedal operation by citizen drivers showed a characteristic action that could be the cause of the accident. This characteristic is also hoped to be an effective method to detect the accelerator pedal operation mistake and prevent unintended acceleration accidents.

KEY WORDS: Safety, Accident avoidance, Driver Monitoring, Driver behavior, Driver state detection control system, Driver intention recognition, Driver Support, Human Interface, Accelerator pedal [C1]

1. Background

Every year in Japan, about 6,000 car accidents caused by accelerator pedal operation mistakes resulting in injury or death occur. The total number of all categories of accidents is decreasing, and accidents caused by accelerator pedal operation mistakes are no different.

However, the proportion of this kind of accident to all types of accidents is steadily increasing (Fig. 1). In total number, younger age groups have more accidents. But the number of pedal operation mistake accidents is higher among the elderly (Fig. 2).

Elderly drivers are the cause of more accelerator pedal operation mistake accidents among both total accident numbers and the licensed driver population (Fig. 3). This suggests that the necessity to come up with measures to prevent this kind of accident is increasing as Japan’s elderly population increases (Fig. 4).

2. The issue to be solved

Mistaking the accelerator pedal for the brake pedal does not always lead to an accident. From our research, which discovered 93 random posts on the Internet, we found that in more than 60% of cases in which drivers made this kind of mistake, they were able to reselect the correct pedal to decelerate the car and prevent an accident. At the same time, it was seen that no drivers who caused an accident stated that they had pressed the pedals slightly, although drivers who did not cause an accident said that they had pressed pedals hard or slightly, depending on the case (Fig. 5).

Fig. 1 Number and proportion of accelerator pedal operation mistake accidents [1]
To understand why drivers pressed the accelerator pedal so firmly, we looked at the company’s users’ complaint database and found 10 reports (Table 1).

In those reports, drivers claimed that the brakes did not work, but after investigations of the cars were concluded with the drivers’ consent, no failures were found in the cars’ functions and the causes of the accidents were judged to be the drivers’ mistake in operating the accelerator pedal. According to remarks by the drivers, they mistook the accelerator pedal for the brake pedal at the time of the accidents. They believed that their vehicles were not decelerating, even though they were braking (as they thought), and felt the necessity to apply more pressure to the brake. As a result, they pressed the accelerator pedal harder. The accelerator pedal became wide-open stroke quickly, and the car accelerated powerfully. The drivers might have panicked because they felt that the vehicles’ brakes were not working and the vehicles were accelerating out of control, and/or they might have had no mental preparation for coping with such a situation and froze, so that they continued driving for a certain distance until the vehicles crashed (Fig.6). In this way, the vehicles accelerated and sustained more damage in crashes.

Table 1 Report on search of user complaint database

| Period           | Apr. 2013 to Sept. 2015 |
|------------------|--------------------------|
| Total number     | About 100,000             |
| Search keyword   | Brake/Sudden/Start/Accelerate/ Unintended/Deceleration/Dust/ Pedal/Out of control |
| Reports searched | Concluded as pedal operation mistake |
| Reports found    | 10                        |
| User’s complaint | Unintended acceleration out of control 4  
                      Brake failure 5, Sudden acceleration 1 |
3. Investigation of countermeasures

Such crashes are eye-catching topics, and this type of accident has been discussed since the 1980’s SA problem. However, it cannot be said that a decisive solution has been discovered. Recently, more vehicles have been equipped with an unintended starting prevention function as part of autonomous emergency braking (AEB). Functions such as these prevent powerful acceleration at low car speeds or when the car is stationary if obstacles are detected in the direction the car is driving. We estimated the effectiveness of this unintended starting prevention function in previous accident situations using data from the ITARDA J-TAD Macro Database (Table 2).

The unintended starting prevention function has a speed limitation of 0 to 10 or 15 km/h. It has shown to be effective in fewer than about 50% of all accidents, and in 20% of fatal accidents (Fig. 7).

Most recent AEB systems recognize the accelerator pedal being deeply pressed as the driver’s intention to accelerate. Even if pedal has been pressed by mistake, the system releases the brake, even if an obstacle has been detected in the way of the vehicle.

We performed another study using ITARDA J-TAD Micro Data. This study showed that AEB was estimated as effective in 13 (18%) of 71 crashes from 50 accident reports (Table 3, Fig. 8).

An AEB system’s effectiveness with accelerator pedal operation mistakes is limited by the vehicle’s speed, material, shape, and the direction of the obstacle. In addition to AEB systems, trials of other systems to reduce the occurrence of pedal operation mistake accidents have also been attempted, some of which change the conventional pedal operation system by separating acceleration from braking (Fig. 9).

### Table 2 ITARDA J-TAD Macro Database

| Period     | 2011 to 2015 |
|------------|--------------|
| Accident damage | Injury or death |
| Total accidents     | 2,638,283 |
| Pedal operation mistakes | 3,064 (1.15%) |
| Crash direction    | 1, 3, 5, 8 |

### Table 3 ITARDA J-TAD Micro Data research

| Period     | 1990 to 2002 |
|------------|--------------|
| Number of reports found | 50 |
| Number of crashes | 71 (Including multiple crashes) |
| AEB effectiveness estimation | Estimated speed < 10km/h |
| Crash angle     : 1, 3, 5, 6, 7, 8 |
| Detectable obstacles: Vehicle, Construction, Wall, Pedestrian, Bike |
| Estimated Crash Speed | Qty. | Qty. | Qty. | Qty. | Qty. | Qty. | Qty. | Qty. | Qty. | Qty. | Qty. | Qty. | Qty. |
|-----------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 0 to 10km/h           | 29   |      |      |      |      | 1    | 18   |      |      |      |      |      |      |
| 10 to 30km/h          | 24   |      |      |      |      | 1    | 20   |      |      |      |      |      |      |
| 30 to 60km/h          | 11   |      |      |      |      | 1    | 4    |      |      |      |      |      |      |
| Over 60km/h           | 7    |      |      |      |      | 1    | 2    |      |      |      |      |      |      |

Object Other: Pole, Tree, Fence, Grate, Hedge, Canal, Bank, Gate, Cable, Curb, Lake, Traffic sign, Car stop, Field, Hollow

Fig. 8 AEB effectiveness in accelerator pedal operation mistakes

Fig. 9 Naruse One-Pedal

Fig. 10 Accelerator limiters

Fig. 11 Pedal operation mistake solution patent classification in Japan, 1991-2011 (Total 231)

4. Conventional technology

Various types of detection and prevention methods for pedal operation mistake accidents have been developed. They are meant to recognize when sudden hard pedal operation is a sign of an unusual driving pattern, different from normal acceleration. Contrary to expectations for the effectiveness of these methods, unfortunately, the realization techniques were not sophisticated enough to be a practical solution to the problem in mass production cars. Some involved the problems of secondary risk, disadvantages in cost, weight or size, inconvenience of use and so on. The most prevalent negative concern is the possibility of false (excess) detection, due to lack of a reasonable justification to detection threshold.
5. Characteristics of pedal operation mistakes

Even if drivers are very conscious of driving safety, it is not possible to eliminate all unintended mistakes while driving. Mistakes in applying pressure to the accelerator pedal is one of such driving mistake, and it does cause a certain number of accidents, but all of these mistakes do not result in serious accident. Many drivers recover from this mistake without any damage by correcting their actions before their cars crash. In case in which applying the accelerator incorrectly results in accident, the drivers tend to mistake their accelerator pedal for the brake pedal. Many drivers who have such accidents state that their car did not stop even though they were pushing the brake pedal. This means they believed they were braking.

We verified this situation using a driving simulator (Table 4, Fig. 12). While subject drivers were following the preceding vehicle, we made the car lost brake without notice and let the car accelerate according to the brake pedal as the accelerator pedal. During the experiment, we measured and logged foot force, operation stroke of the pedals and driving operation parameters by data measurement function of driving simulator facility. Many drivers just continued to push the brake even harder when they thought that the brakes weren’t working and the car wouldn’t stop, and few drivers reacted effectively to prevent a virtual accident. In more than 80% of all 40 test attempts, drivers very quickly increased the pressure on the pedal. Distinctive 14 examples are shown on Fig. 13. They pressed the pedal so hard that the force neared their physical limits.

| Table 4 Citizen Drivers’ test |
|-------------------------------|
| Date | May 20-23, 2014 |
| Place | JARI, Tsukuba Japan |
| Age | 20s-50s |
| Male subjects | 10 |
| Female subjects | 10 |

Fig. 12 Driving simulator test of general drivers

With the same subject drivers, we also measured accelerator and brake pedal operation of their daily driving style in public road and unusual hard pedal operation in closed test track. In public road, 4 to 5 hours’ driving route for each driver was decided to include various possible situations in daily driving. In closed test track, drivers were instructed to make so hard acceleration and braking as possible that subject drivers rarely experienced on the road. It was found that drivers applied strong pedal pressure when the brakes stopped working. Pedal force for accelerator operation was very lower and spread of data was separated from that of lost brake, even while strong acceleration on test track (Fig.14). The experiment and data collection described in this section and section 7 were carried out with the approval from bioethics committees of Japan Automobile Research Institute, Randstad K.K. (Japan) and Honda R&D Co., Ltd. Subject drivers were called by general invitation. Objective and method of the measurement were explained beforehand by oral explanation and written document, and they made written consent.

(a) Driving simulator in JARI
(b) Test scenario

Fig. 13 Pedal operation when brakes become ineffectual

Fig. 14 Pedal force distribution
6. Countermeasure

By detecting this unusually strong force on the pedal, it is possible to determine between an unintended operation mistake and usual accelerating operation. But cars are not usually equipped with pedal force detection. We designed a simple device, comprising a steel spring and switch that outputs a signal when the accelerator pedal is pressed with more than a certain amount of force (Fig. 15).

![Fig. 15 Accelerator pedal switch](image)

7. Effective range of this method

We measured pedal force in Japan and in Indonesia, using 500 and 516 subject drivers in each country (Fig. 16, Table 5). In both countries, pedal force were measured by force sensor on the pedal surface on the stationary car and logged to the onboard data logger. The results indicate that the physical maximum pedal force applied by citizen drivers to the brake pedal has the same spread as described before. It is possible to practically detect when a pedal operation mistake is made because the driver is pressing on the acceleration pedal, thinking that it is the brake pedal.

![Fig. 16 Brake pedal force distribution](image)

| Table 5 Pedal force measurement |
|-------------------------------|
| **Indonesia** | **Japan** |
| **Date** | Aug. 7 to Sept. 5, 2015 | Apr. 6 to May 15, 2015 |
| **Place** | Bekasi Jawa Barat, Indonesia | Utsunomiya, Tochigi, Japan |
| **Age** | 17 to 69 | 18 to 79 |
| **Male subjects** | 250 | 257 |
| **Female subject** | 250 | 259 |

8. Effectiveness of this method

During a pedal operation mistake, the force on the pedal increases beyond the detection threshold (200N for exp.) in 0.5 to 1 second after drivers began to decelerate the car. This can be used by a car control system to inform drivers of unusual operation, or to control the cars to prevent unintended acceleration. It is estimated from investigations of past accident examples that 70% to 80% of pedal operation mistake accidents could be prevented or that the damage could be reduced (Fig. 17).

This method does not cover accidents that occur in a short time from the operation mistake before pedal force detection. The remaining approximately 20% of such accidents need further solutions.

![Fig. 17 Recognition to crash time of 23 accidents from ITARDA Micro data](image)

9. Evaluation of excessive detection

The detection threshold may seem to be a trade-off between the detection of excess, which sees very strong accelerative pedal force as unusual force caused by an operation mistake, and omission of detection, which sees a very small force applied due to a pedal operation mistake as normal accelerating pedal force. It seems generally impossible to eliminate such excessive detection and omission from this method. However, in acceleration reduction control activation triggered by the detection of a pedal operation mistake, it was found that the prevention of harsh deceleration, keeping the car from stopping, prevention of regression on a slope, recovery from acceleration restriction within a certain time limit, and a cancel switch for the function, etc., effectively minimized the secondary risks while maintaining the benefits. With these measures, excessive detection would not be such a critical issue, because it is not necessarily required to brake forcefully in order to prevent unintended acceleration.

An advance notification warning when the pedal force increases greatly before the deployment of SA prevention measures can reduce the incidence of excessive detection. Drivers can learn how to operate the pedal correctly in order to prevent excessive detection from halting acceleration. Excessive detection is predictable and avoidable. A way for the driver to adjust the pedal force detection threshold will also help make the function more convenient for various kinds of drivers.

10. Future tasks and outlook for the method

There are many different kinds of drivers in traffic. Not all drivers are always careful to prevent pedal operation mistakes nor are they all skilled enough to be prepared to correct such
unexpected driving mistakes. No matter what kind of car, this fact is inescapable, and preparations should be made for all cases.

Ideally speaking, not only cars for drivers who want to pay for cars with such a function, but also all the cars from any OEMs should be equipped with certain functions to prevent unintended acceleration accidents caused by a pedal operation mistake. We must continue our work to develop and promote good solutions to prevent such accidents.

11. Conclusions

Pedal operation mistakes caused by drivers accidentally pressing the accelerator pedal tend to result in accidents when the drivers mistake the pedal for a brake pedal.

AEB’s are estimated to be effective for about 30% of this kind of accident, as the AEB system is programmed to recognize firm pedal operation as the driver’s intent to accelerate and release the brake.

In a pedal operation mistake, the driver presses on the pedal with extreme force. When the driver thinks he has pressed on the brake pedal, but the car continues to accelerate, the driver instinctively presses harder on the pedal with a distinctive amount of force that is different from normal acceleration force. This unusually strong pedal force is a phenomenon that can be used to detect operation mistakes with the accelerator pedal.

Based on a pedal force investigation of general drivers, the pedal force was found to be a practical index for preventing unintended acceleration. When the car is controlled by an SA prevention system triggered by pedal force detection, it is estimated that 70-80% of such accidents can be avoided or the damage can be reduced.

With suitable acceleration restriction control, SA prevention using pedal force detection can be realized without secondary risks. This method can be one possible solution that allows every car driver to prevent accidents caused by operation mistakes with the accelerator pedal.

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