Intelligent Transportation System (ITS) Technologies for Motorcycle Crash Prevention and Injury Mitigation

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Abstract

This paper presents findings from research conducted to identify existing and emerging Intelligent Transportation Systems (ITS) technologies for all vehicle types, including motorcycles, and examine the potential application of these technologies to improve motorcycle safety. Findings are based on a review of the existing literature, including published studies and industry-produced reports, and compiled according to the potential of the technology to 1) prevent motorcycle crashes (crash prevention), and 2) reduce motorcyclists' injuries incurred in a crash (injury mitigation).

Introduction

Numerous Intelligent Transportation System (ITS) technologies have been developed and adapted to improve the safety of passenger vehicles. Some of these technologies have the potential to actively prevent crashes involving motorcycles or passively lessen the severity of injuries when a motorcycle is involved in a crash. Examples include electronic stability programs; collision warning and avoidance systems; and visibility enhancing systems, among others. Motorcycles pose a particular problem when it comes to the technical adaptation of certain ITS systems because of the dynamics of motorcycles differ from those based on a four-wheel platform.

This paper presents findings from research conducted by the Texas A&M Transportation Institute to identify existing and emerging ITS and other advanced technologies that can potentially improve motorcycle safety. Researcher reviewed and synthesized literature, including published studies and industry-produced report, and compiled findings based on the potential of the technology to 1) prevent motorcycle crashes (crash prevention), and 2) reduce motorcyclists' injuries incurred in a crash (injury mitigation). This research was conducted as part of the larger

effort to develop the *Texas Strategic Action Plan for Motorcycles, 2013-2018* (http://tti.tamu.edu/documents/0-6712-P2.pdf). The authors thank the Texas Department of Transportation for funding this research.

CRASH PREVENTION

The following technologies are intended to prevent run-off-road crashes, in which the vehicle driver or motorcycle rider departs a lane or roadway or the motorcycle overturns, without colliding with an object or another vehicle.

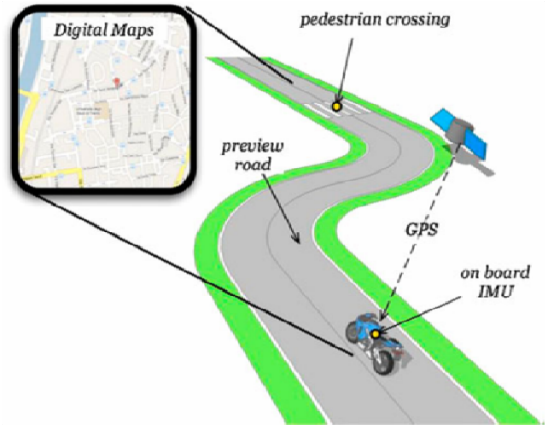
Electronic Stability Program-Passenger Vehicles

Electronic Stability Control (ESC), also referred to as electronic stability program (ESP) or dynamic stability control (DSC), improves the safety of a vehicle's stability by detecting and reducing loss of traction. ESC allows for stability to be maintained when the vehicle runs into maneuvering that requires over-correction, under steering, or over steering. ESC is common in most passenger vehicles, but it is unknown whether the technology can be applied to motorcycles [1, 4].

Curve Speed Warning

Curve-speed warning (CSW) technology warns the vehicle driver regarding an approaching curve and its recommended speed using GPS and digital maps. Vehicles can perform additional warning actions if the actual speed through the curve exceeds the recommended speed. [2, 4].

Benefit to Motorcycles: Riders would be alerted to decrease speed on an approaching curve which can help to prevent a crash.



Typical scenario and main sensors used in the curve warning function.
Source: (Biral, et al. An intelligent curve warning system for powered two wheel vehicles, 2010)

Lane Keeping and Departure Programs

These programs use forward facing cameras to scan the roadway and determine if the vehicle is migrating toward the lane markings. All systems will vibrate the wheel to ensure the driver is awake, while some will also lightly apply the brakes to keep the vehicle in line. These programs are currently active in passenger vehicles and are used in many car companies such as Volvo, Audi, and BMW. [3,4].

Benefit to Motorcycles: Collisions with motorcycles and other smaller vehicles could be avoided as the driver is kept from drifting into a lane and possibly causing the motorcycle to run off the road.

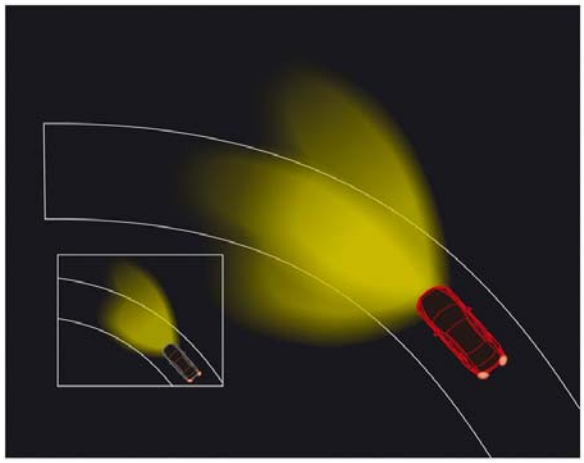
Volvo's lane departure warning system scans the road ahead to identify lane markings.
Source: http://carbuzzard.com/2011/11/extra-eyes-automotive-lane-departure-warningkeeping-technologies/

Roll Stability

Roll stability systems monitor the motorcycle's speed and yaw rate (i.e., the rate at which the motorcycle is tilting away from vertical), and warn the rider if the motorcycle is in danger of tipping over [4].

Adaptive Front Lighting System (AFS)

Adaptive Front Lighting is an emerging technology that uses the angle of the steering wheel and the speed of the vehicle to ensure that the headlight is illuminating the roadway in front of the driver. In motorcycles, the speed and angular velocity is calculated, signaling the headlight to rotate with the movement of the motorcycle [4].



2014 Mazda 6 Adaptive Front-lighting System (AFS) photo Source: http://www.bing.com/images/search?q=Adaptive+Front+Lighting+System+(AFS)&FORM=HDRSC2#view=detail&id=316096632B2331CA36737DA9BF712B178935F1B8&selectedIndex=0

Road Surface Condition Monitoring

This emerging technology uses laser scanning linked to the ABS or speed limiting systems, which scans the road and alerts the driver of any potential hazard on the road's surface. This system can be combined with information from roadside beacons or other sources of data [4].

Braking Systems

Advanced braking systems increase a driver or rider's ability to stop quickly and safely without losing control of the vehicle or motorcycle.

Anti-Lock Braking System

Anti-lock braking system is an existing technology that monitors wheel speed and adjusts braking pressure evenly among wheels to ensure that the brakes do not lock when applied in an emergency situation (6).

Benefit to Motorcycles: Riders are able to regain control of their motorcycles to prevent skidding or collision with an object.

Brake Assist

This existing technology in passenger vehicles was developed to help prevent a collision, under sudden braking, by applying maximum pressure to the brakes (7).

Benefit to Motorcycles: The combination of the brake assist and anti-lock brakes can prevent impact or the severity of motorcycle crashes. Braking motion is maintained.

Linked Braking Systems

Linked Braking Systems is an existing motorcycle technology that applies pressure to both brakes simultaneously to ensure balance (4).

Collision Warning and Avoidance Systems

Using radar, Collision Warning Systems monitor the forward roadway and warn the driver both audibly and visibly that they are nearing an object or vehicle in their lane. As the object gets closer, the warning becomes more intense (8).

Pedestrian Detection System

This emerging technology, currently used in Volvo, uses radar sensors and data from an on-board camera, which allows the vehicle to automatically apply the brakes in order to reduce or mitigate the risk of hitting a pedestrian (9).

Benefit to Motorcycles: Collisions with pedestrians and/or quick maneuvering of the motorcycle to avoid pedestrian causing spill out will be prevented.

Animal Detection

Animal Detection, currently used in Volvo, uses the same radar and camera technology combination as the pedestrian detection system to determine if the vehicle is in line to strike an object. An audible warning will be displayed, and then the brakes will automatically be applied (10).

Driver Assistance and Monitoring

These technologies include advanced displays, speed warnings, and limiters, driver/rider monitoring to prevent crashes caused by alcohol impairment or drowsiness, and systems to prevent riding by unlicensed riders.

Advanced Driver Assist

This emerging technology, currently used in Yamaha ASV-2s, will "employ a range of telematics and vehicle control systems to reduce driver workload and error" (4).

Benefit to Motorcycles: Advanced driver assist systems provide riders with more information to counteract behaviors that may lead to crashes.

Alcohol Detection/Interlock

Alcohol Detection, also known as Interlock, is an active technology currently used in passenger vehicles that requires drivers to blow into a device in order to start their vehicle. If no alcohol is detected on their breath, then the vehicle will start, but drivers will be required to blow into the device periodically on their trip (11).

Driver Status Monitoring

This emerging technology uses facial detection software, which monitors and analyzes facial features of the driver to ensure driver alertness (12).

Electronic Licenses or Smart Cards

Electronic Licenses are an emerging technology currently used in Honda products that prevents unlicensed riding and ensures all operators have the proper safety training. Electronic licenses would require 'smart cards' to be placed into the ignition to operate the motorcycle. This would also allow the ability to monitor drivers who are inexperienced or deemed "at-risk" (4).

Helmet Mounted Displays

Helmet Mounted Displays is an emerging technology that projects information from the instruments to a display inside the operator's helmet, reducing the need to fully take their eyes off the road and look at their panel (13).

Rearview Displays

Rearview displays are an emerging technology, currently present in Honda ASV-3s and Yamaha ASV-2s, which uses backward facing cameras (mounted on the helmet or vehicle) to project real time images of the road environment behind the motorcycle to increase visibility over traditional rear-view mirrors (4).

Speed Alert/Limiting Systems

Speed Alert Systems is an existing technology that warns drivers when they have exceeded the posted speed limit, or exceed the maximum limit set by the motorcycle operator, in order to minimize the role that excessive speed plays in motorcycle crashes (14).

CRASH INJURY MITIGATION

These following technologies are intended to reduce injuries when a crash occurs, and/or to bring emergency responders to the site of a crash more quickly.

Airbag System

The Airbag System is an existing technology such as those used in Yamaha ASV-2s and the Honda motorcycle airbag introduced on the 2006 Gold Wing that will deploy an airbag in the case of impact at a certain intensity level and can assist in keeping the rider from being thrown (4).

Airbag Vest

An Airbag Vest is an existing technology that is worn by the rider to protect the front and back of the body if thrown off the motorcycle (15).

Automated Crash Notification System

This system is an emerging technology actively being utilized in many car companies, such as Lexus and Toyota, that uses sensors, airbag deployment, and other cues to automatically notify emergency personnel of a crash; ensuring help can arrive more quickly while simultaneously collecting crash severity data (16).

Crash Data Recorder

Currently used in car companies such as Ford, Fiat, and Chrysler, this system is located in the airbag control, or power-train control on automobiles, and can record information such as driver's pre-impact speeds, whether the seatbelt was on or off, the driver's brake or throttle position pre-crash, and `crash severity (17).

SUMMARY

This review has identified several existing and emerging ITS technologies that could potentially improve the safety of motorcyclists. Research findings were presented based on whether the technology addressed crash prevention or crash injury mitigation. A matrix was prepared (see Table 1) and used to help identify technology countermeasures for inclusion in a five year strategic motorcycle safety plan for the State of Texas. The full report can be downloaded at http://tti.tamu.edu/documents/0-6712-1.pdf. The strategic plan can be downloaded at http://tti.tamu.edu/documents/0-6712-P2.pdf. For additional information, please contact the Patricia Turner at motosafety2013@gmail.com.

Table 1. ITS Matrix.

Crash Type	Technology to Address	Definition	Status	Active/ Passive	Companies Using	Ref.
Technologies to Prevent Run Off Road Crashes	Electronic Stability Program	"An on-board car safety system that enables the stability of the car to be maintained during critical maneuvering and to correct potential under steering or over steering."	Existing in passenger vehicles	Active		(1)
	Curve Speed Warning	Technology allows for assessment of hazard levels when driving is quickly approaching a curve in the road by using GPS and digital maps.	Emerging	Active	Yamaha AVS-2	(2)
	Lane Keeping and Departure Warnings	Uses forward facing cameras to scan to roadway and determine if the vehicle is migrating toward to the lane markings. All systems will vibrate the wheel to ensure the driver is awake, while others will also lightly apply the brakes to keep the vehicle in line.	Existing in passenger vehicles	Active	passenger: Volvo, Audi, BMW, Mercedes-Benz, Infiniti, Lexus, Cadillac, Ford in 2012	(3)
	Roll Stability	Roll stability systems monitor the motorcycle's speed and yaw rate (i.e., the rate at which the motorcycle is tilting away from vertical), and warn the rider if the motorcycle is in danger of tipping over.		Active		(4)
	Adaptive Front Lighting	Uses the angle of the steering wheel and the speed of the vehicle to ensure that the headlight is illuminating the roadway in front of the vehicle operator.	Emerging (for moto)	Active	Yamaha ASV-2 Model 1	(5)
	Road Surface Condition Monitoring	Using laser scanning technology linked to the ABS or speed limiting systems, technology scans the road and alert the driver to any potential hazard in the road surface. Can be combined with information from roadside beacons or other sources of data.	Emerging			(4)
Braking Systems	Anti-lock Braking Systems	Monitor wheel speed and adjust braking pressure evenly among wheels to ensure that brakes do not lock when applied in an emergency situation.	Existing	Active		(6)
	Brake Assist	To help prevent a collision, under sudden braking, brake assist systems will apply maximum pressure.	Existing on passenger	Active	Yamaha ASV-2 Model 1	(7)
	Linked Braking Systems	Applies pressure to both brakes simultaneously to ensure improved braking performance.	Existing on motorcycle	Active		(4)

Crash Type	Technology to Address	Definition	Status	Active/ Passive	Companies Using	Ref.
Collision Warning and Avoidance Systems		Using radar, collision warning systems monitor the forward roadway and warn the driver audibly and visibly that they are nearing an object or vehicle in their lane. As the object gets closer, the warning becomes more intense.	Emerging	Active		(8)
	Pedestrian Detection System	Using radar sensors and data from a n on-board camera, the vehicle will automatically brake to reduce or mitigate the risk of hitting a pedestrian.	Emerging	Active	Volvo	(9)
	Animal Detection	Uses same radar and camera technology combination as pedestrian detection system to determine if the vehicle is in line to strike an object. An audible warning will be displayed and then brakes will automatically be applied.	Emerging	Active	Volvo	(10)
Driver Assistance and Monitoring	Advanced Driver Assist	"Employ a range of telematics and vehicle control systems to reduce driver workload and error."	Emerging	Active	Yamaha ASV-2 Model 1, BMW	(4)
	Alcohol Detection/ Interlock	Drivers blow into device in order to start the vehicle. If no alcohol is detected on their breath, then the vehicle will start but drivers will be required to blow into the device periodically on their trip.	Existing on passenger	Active		(11)
	Driver Status Monitoring	Using facial detection technology, facial features of the driver are analyzed to ensure driver alertness.	Emerging	Active		(12)
	Electronic Licenses or Smart Cards	In order to prevent unlicensed riding and ensure all operators have the proper safety training, electronic licenses would require smart cards to be placed into the ignition to operate the motorcycle. This would also allow the ability to monitor drivers who are inexperienced or deemed at-risk.	Emerging	Active	Honda	(4)
	Helmet Mounted Displays	Projects information from the instruments to a display inside the operator's helmet, reducing the need to fully take their eyes off the road and look at the panel.	Emerging	Active		(13)
	Rearview Displays	Helmet or vehicle based, rearview displays use backward facing cameras to project real time images of the road environment behind the motorcycle to increase visibility over traditional rear-view mirrors.	Emerging	Active	Reevu, Honda ASV-3, Yamaha ASV-2	(4)

Crash Type	Technology to Address	Definition	Status	Active/ Passive	Companies Using	Ref.
	Speed Alert/ Limiting Systems	System warns drivers when they have exceeded the posted speed limit or exceed the maximum limit set by the motorcycle operator in order to minimize the role that excessive speed plays in motorcycle crashes.	Existing	Active		(14)
Injury Mitigation	Airbag System	Airbag systems will deploy in the case of impact at a certain intensity level and can assist in keeping the rider from being thrown.	Existing	Passive	Yamaha ASV-2 Model 1, and Honda motorcycle airbag system	(4)
	Airbag Vest	Worn by the rider to protect front and back of the body if thrown off the motorcycle.	Existing	Passive		(15)
	Automated Crash Notification System	Using sensors, airbag deployment and other cues, this system will automatically notify emergency personnel of a crash so that help can arrive more quickly; advanced systems also collect crash severity data from sensors on the vehicle.	Emerging		eCall (Europe), onStar, Ford Sync 911 Assist, Lexus Link, Toyota Safety Connect, BMW Assist, next generation 9-1-1	(16)
	Crash Data Recorder	Located in the airbag control or powertrain control on automobiles, the crash data recorder can record information such as driver's pre-impact speeds, whether the seatbelt was on or off, the driver's brake or throttle position pre-crash and crash severity.	Existing in some passenger vehicles	Passive	Bosch CDR system in select GM, Ford, Chrysler, Fiat, Toyota	(17)

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