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ElSayed A ElNashar [1]* and Zlatin Zlatev [2]

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)DFXOW\ RI 7HFKQLFV DQG 7HFKQRORJLHV 7UDNLD 8QLYHUVLW\ %XOJDULD

Abstract

7KH UHSRUW UHSUHVHQWV WKH SHFXOLDULWLHV RI XVLQJ LQWHOOLJHQW DLUE
WR DFWLYDWH WKH DLUEDJ V\VWHP LQ WHUPV RI WKHLU GYDQWDJHV DQG GLVD
XVLQJ WKH FDSDELOLWLHV RI WKH KDUGZDUH RI VHQVRU GHYLFHV LQ RUGHU WH
OLWHUDWXUH LV GHYHORSHG D VRIWZDUH VHQVRU IRU DLUEDJ GHSOR\PHQW GHS
ZRUN RI WKLV VHQVRU LV VWXGLHG LQ FDVH RI LQWHUXSWHG DQ\ RI WKH LQSX
GDWD IURP WKUHH KDUGZDUH VHQVRUV LV UHFHLYHG HUURU XS WR LQ GLVWL
VHDW RI WKH FDU 7KH GURSSLQJ RI WKH VLJQDO LQ KDUGZDUH VHQVRUV DIIHFW
SDVVHQJHU VHDW

Keywords: Automotive active safety; Smart airbags; So ware sensor

Introduction

e technology of application of airbags has proven successful over time as compared to other ways of ensuring safety in vehicles as headrests and seatbelts. e older models airbags, but also some new and intelligent ones also can cause injuries in children and adults people. e combination of side and front airbags signi cantly reduce the risk in anaccident [1] but these safety systems are not universal. is suggests the use of speci c airbag systems associated with the materials of which are made, their location in the vehicle interior, systems for their operation associated with sensor technology and actuators included in this area. e systems for activation of the airbags are not so sophisticated, they can be activated at wrong moment. For example, weight sensors are activated by the pressure exercised by the passenger, when he sits on the seat. In this case, the airbag is activated in an accident. If on the passenger seat is placed capacious object with greater weight it will also lead to activation of the airbag [2].

Most of the developments related to airbags are related to safety of the driver and front passenger, and those in the back seat against the direction of movement of the car. 40% of collisions and 30% of the causes of injury to passengers are in a side collision [1,3,4].

In the literature [5-7] states that the development of side airbags is much harder than front it depends of textile materials, sensors used and time for deployment. Much of the energy in a frontal collision is absorbed by the bumper, the bonnet and the engine, the reaching blow wave to the driver and passengers going for 30-40 ms. In a side blow the time to reach blow wave is 5-6 ms as the only barrier is the door of the car. ese times are critical in the development of systems for control of airbags.

e aim of this report is a comparative analysis of sensors used to activate the airbags in terms of their advantages and disadvantages and to analyze a so ware sensor for activation of airbags for active safety in the car.

Exposure

Using intelligent airbag systems improves the sensing functions and control options for the airbag in ation process. Such improvement functions are [1]:

- Impact severity detection through improvement of triggering algorithm;
- Seat belt usage detection;
- Occupant presence, position and weight;
- Seat position and back rest inclination detection;
- Introduction of up to ten and more di erent triggering thresholds;
- Depowered airbag: it use reduced gas in ator power, which leads to a reduced in ation speed, in ation severity and risk to occupants.

e application of sensors and actuators for activation of air bags must meet certain restrictions [2,5]: a small amount of equipment including airbag control system; reducing the cost of production and installation; improve safety; enhancing ergonomics.

Di erent types of sensors measuring wheel speed, seat occupant status, brake pressure and impact, and other vehicle status indicators are monitored by the airbag control unit located in the front portion of the cabin. e sensors relay signals to the airbag control unit, which analyzes the data and can control safety features like seat belt lock automatic door locks, as well as airbag deployment. e advantages and disadvantages of airbag deployment sensors are described in Table 1

e choice for suitable sensors for smart airbag application has to be taken in consideration of the following criteria [3]: System cost; Bandwidth; Latency; Determinism; Safety; Recovery actions; Physical layer.

*Corresponding author: (O6D\HG $ (O1DVKDU)DFXOW\ RI 6
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6KHLNK (J\SW 7HO VPDUW#HOQD HG X HJ

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XQGHU WKH WHUPV RI WKH &UHDWLYH &RPPRQV $W
XQUHVWULFWHG XVH GLVWULEXWLRQ DQG UHSURG
RULJLQDO DXWKRU DQG VRXUFH DUH FUHGLWHG

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Sensor	Advantages	Disadvantages	Reference
$FFHOHURPHWHU	6LPSOH GHVLJQ HDV\ WR XVH XVLQJ GLIIHUHQW SULQFLSOHV RI DFWLRQSLH]RHOHFWULF FDSDFLWLYH	6HQVLWLYH WR QRLVH DQG PHFKDQLFDO LQIOXHQFH	>@
&DSDFLWLYH	$ ODUJH RXWSXW VLJQDO ZLWK VPDOO FKDQJHV LQ FKDUDFWHULVWLFV	5HTXLUHV FDUHIXO VKLHOGLQJ DQG FDOLEUDWLRQ EHIRUH XVH	>@
8OWUDVRQLF	,QGHSHQGHQFH RI WKH RSWLFDO SURSHUWLHV RI WKH REMHFW /LQHDU UHODWLRQVKLS EHWZHHQ RXWSXW OHYHO DQG GLVWDQFH	1HHGV DQ RSHQ VXUIDFH RI WKH REMHFW DQG LWV ORFDWLRQ	>@
,QIUDUHG	:LGHO\ DYDLODEOH	/LPLWHG UHOLDELOLW\ RI IDOVH DODUPV GXH WR FRQGLWLRQLQJ KHDWLQJ	>@
7HPSHUDWXUH	&RQWLQXRXV WHPSHUDWXUH PRQLWRULQJ LQVWDOODWLRQ DQG PDLQWHQDQFH	1RQOLQHDU characteristic	>@
9LGHR FDPHUD	6HSDUDWLRQ RI WKH REMHFW IURP WKH EDFNJURXQG DQG WKH SRVLWLRQ RI WKH ERG\ KHDG	/DUJHU FRPSXWDWLRQDO DQG data VWRUDJH SURFHVVLQJ	>@
6WHUHR FDPHUD	7KH REMHFW LV UHFRJQL]HG LQ GHSWK	1HHG ODUJHU FRPSXWDWLRQDO DQG data VWRUDJH SURFHVVLQJ	>@
,QIUDUHG FDPHUD	(DVLO\ GLVWLQJXLVK SDVVHQJHU SRVLWLRQ KHDG DQG ERG\ /HVV DIIHFWHG E\ VXQOLJKW DQG IRJ	3UREOHP LQ GLVWLQJXLVKLQJ WKH KXPDQ ERG\ DW WHPSHUDWXUH +LJK FRVW RI HTXLSPHQW	>@
:HLJKW	(DV\ WR XVH TXLFN UHVSRQVH	1RQ OLQHDULW\ RI WKH RXWSXW ,W FDQ EH DFWLYDWHG ZKHQ D KHDY\ REMHFW LV RQ VHDW	>@
0LFUR VZLWFK	(DV\ WR XVH TXLFN UHVSRQVH	7ZR VWDWHV RI RXWSXW EH DFWLYDWHG ZKHQ D KHDY\ REMHFW LV RQ VHDW	>@

Table 1: $GYDQWDJHV DQG GLVDGYDQWDJHV RI WKH VHQVRUV XVHG WR DFWLYDWH WK

7 years old child   22 years old man   Dog laying

Figure 1: ([DPSOHV RI VLJQDOV RI WKUHH VHQVRUV

Systems using video sensor have proven over the years as successful in identifying persons determining the position of the body and the head of the driver or passenger, which is proven by numerous studies [8-12]. Despite the fact that systems using video sensor have proven their advantages in the study of triggering systems, they are not adopted by the automotive industry [13]. One of the reasons is that many consumers do not want to be photographed by cameras.

In recent years there has been entering in mobile devices, industrial automation, so ware-based sensors that are not technically feasible, but actually retrieve data from one or more hardware-based sensors and based on their values made its own result [14]. Interesting problem in the operation of the sensors is the reconciliation of data derived from multiple hardware sources, in which can be generated synthetic indications of new characteristics. A typical example of such a combination is the result of the data, those which develop the so ware sensors.

Material and Methods

Data from [13] is used, where the author analyzes the work of developed by him activation system for intelligent airbag. e system consists of three sensors - ultrasonic for distance, temperature and passive infrared sensor PIR. e author is investigated raw data from the three sensors for objects on passenger seat-Empty seat, 1 year old child, 2 years old child, 7 years old child, 13 years old child, 22 years old man, Box, Dog laying.

Examples of the operation of the the three sensors are presented in Figure 1.

In this study the data were processed with Kalman lter [15]. Combining of the data is done through a central limit theorem [16] and Fraser-Potter xed-interval smoother [17,18].

e output signal y_c and its dispersion c is calculated by:

$$y_c = \sigma_c^2\left(\sigma_1^{-2}x_1 + \sigma_2^{-2}x_2 + \sigma_3^{-2}x_3\right)$$

$$\sigma_c^2 = \left(\sigma_1^{-2} + \sigma_2^{-2} + \sigma_3^{-2}\right)^{-1}$$

where X_1, X_2 and X_3 simultaneously measured signals with their dispersions 1, 2 and 3.

e results are processed with discriminant classi er using non-linear separating function. e classi cation is evaluated by common error of classi cation.

In the combining of the data from sensors may be obtained falling or improper reading of the one of the sensors. In the study [13], such are the ultrasonic and temperature sensors, whose signals vary widely or entirely eliminated depending on the object standing on the passenger seat.

Results and Discussion

Based on the literature study and requirements for building so ware sensors [19-21] is proposed solution to a so ware sensor. In Figure 2 is a block diagram of the developed so ware sensor. e signals from the three sensors are precisely ltered with Kalman Filter.

e ltered signals are fed to a program block for combining, the output of which gives the total signal.

e results of the so ware sensor that combine signals from three sensors-ultrasonic, PIR and temperature are presented in Figure 3. A visible di erence is observed between the signals of the so ware sensor depending on the object on the vehicle seat.

In Figure 4 are examples of separability between objects on the passenger seat by signals from so ware sensor.

In Table 2 are presented the results of the classi cation using the combined signal of the three sensors.

A research is done on the work of developed so ware sensor in case of interruption of one of the input signals.

In Figure 5 are presented output signals from the so ware sensor using data from the two sensors – temperature and PIR. ere is less identi ability of signals compared to variants using combined data from three sensors.

Figure 2: %ORFN GLDJUDP RI D VRIWZDUH VHQVRU

Empty seat

2 years old child

Dog laying

Figure 3: ([DPSOHV RI VLJQDOV IURP WKH VHQVRU VRIWZDUH

1 year old child – 2 years old

1 year old child – 7 years old child,

Figure 4: ([DPSOHV RI GLVWLQJXLVKLQJ WKH VLJQDOV IURP WKH VHQVRU VRIWZ

In Figure 6 are examples of Severability between objects on the passenger seat by signals from the so ware sensor in case of failure of the ultrasonic sensor.

In Table 3 are presented the results of the classi cation using the combined signal of the two sensors, in case of interruption of the ultrasonic one.

In Figure 7 are presented output signals from the so ware sensor using data from the two sensors – ultrasonic and PIR. ere is less identi ability of the signals compared to the variant using the combined data from the three sensors, but better compared to the use of temperature and PIR sensors.

In Figure 8 are examples of separability between objects on the passenger seat by signals from the so ware sensor in case of interrupted temperature sensor. Table 4 summarize all of the results in this case.

In Figure 9 are summarized the results of the study. With the "+" are marked ability to separate object with an error of less than 5%, and with "-" results with higher error.

e results show that the separation of objects is able by using the combination of the signals of the three sensors. e greatest impact on the performance of the so ware sensor has the fall of the ultrasonic sensor (Table 5).

Conclusion

e presented material considered prerequisites and techniques for the application of sensors to activate the intelligent airbags depending on the position and characteristics of the occupants. e principles

Ages	Empty seat	1 year old child	2 years old child	7 years old child	13 years old child	22 years old man	Box	Dog laying
(PSW\ VHDW	[							
\HDU ROG FKLOG		[						
\HDUV ROG FKLOG			[					
\HDUV ROG FKLOG				[				
\HDUV ROG FKLOG					[			
\HDUV ROG PDQ						[		
%R[							[	
'RJ OD\LQJ								[

Table 2: 5HVXOWV RI FODVVL¿FDWLRQ XVLQJ WKH FRPELQHG VLJQDO RI WKH WKU

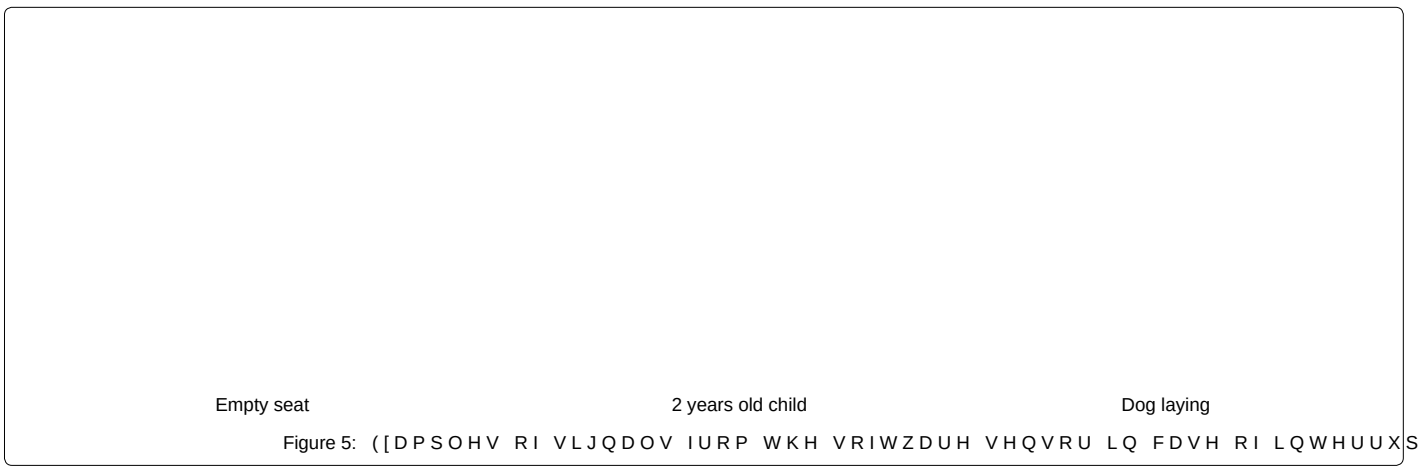

Figure 5: ([DPSOHV RI VLJQDOV IURP WKH VRIWZDUH VHQVRU LQ FDVH RI LQWHUUXSWLR

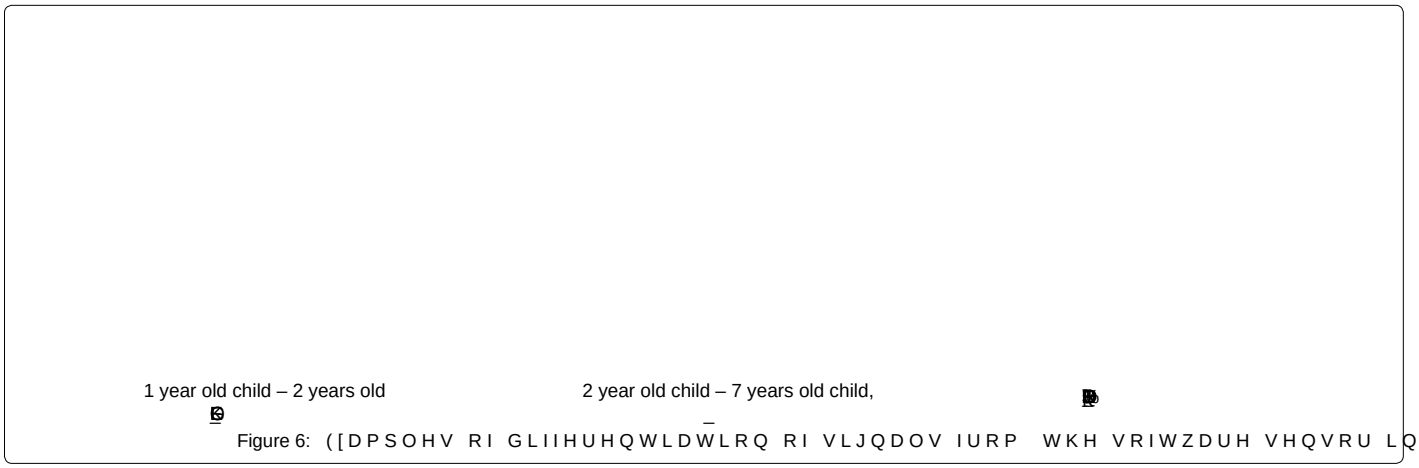

Figure 6: ([DPSOHV RI GLIIHUHQWLDWLRQ RI VLJQDOV IURP WKH VRIWZDUH VHQVRU LQ FDV

Ages	Empty seat	1 year old child	2 years old child	7 years old child	13 years old child	22 years old man	Box	Dog laying
(PSW\ VHDW	[							
\HDU ROG FKLOG		[						
\HDUV ROG FKLOG			[					
\HDUV ROG FKLOG				[				
\HDUV ROG FKLOG					[			
\HDUV ROG PDQ						[		
%R[							[	
'RJ OD\LQJ								[

Table 3: 5HVXOWV IRU LGHQWL¿DELOLW\ RI REMHFWV LQ FDVH RI LQWHUUXSWHG X

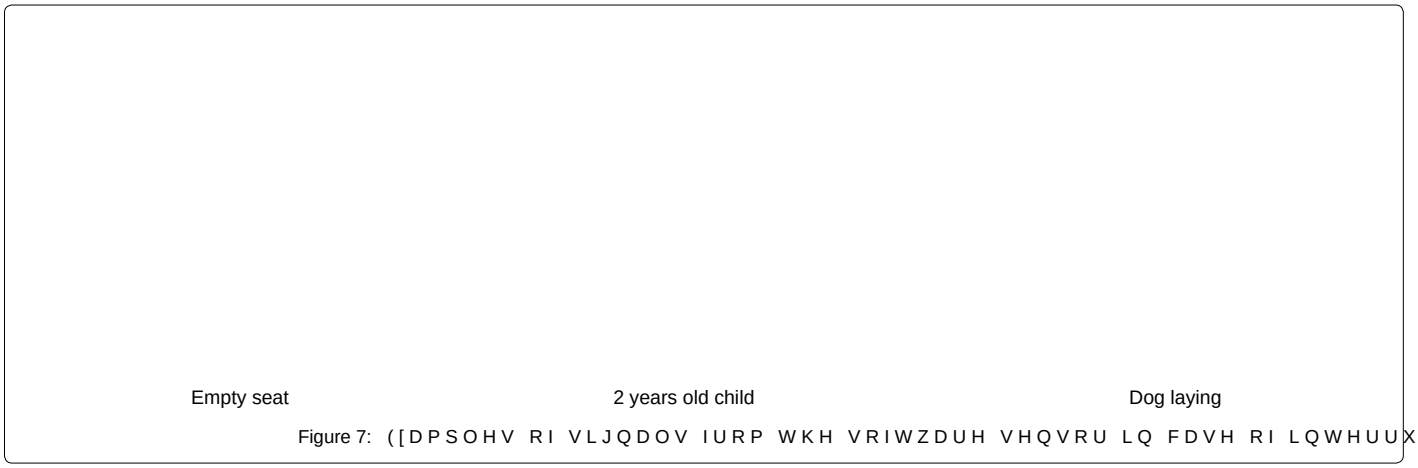

Figure 7: ([DPSOHV RI VLJQDOV IURP WKH VRIWZDUH VHQVRU LQ FDVH RI LQWHUUXSWH

Figure 8: ([DPSOHV RI GLIIHUHQWLDWLRQ RI VLJQDOV IURP WKH VRIWZDUH VHQVRU LQ FDV

Ages	Empty seat	1 year old child	2 years old child	7 years old child	13 years old child	22 years old man	Box	Dog laying
(PSW\ VHDW	[							
\HDU ROG FKLOG		[						
\HDUV ROG FKLOG			[					
\HDUV ROG FKLOG				[				
\HDUV ROG FKLOG					[			
\HDUV ROG PDQ						[		
%R[							[	
'RJ OD\LQJ								[

Table 4: 5HVXOWV IRU LGHQWL¿DELOLW\ RI REMHFWV LQ FDVH RI LQWHUUXSWHG W

of operation and characteristics of sensors is systematically presented. Presented are so ware applications using the capabilities of the and their diversity, described are their advantages and disadvantages of ware of sensor devices in order to build a common signal. e

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Figure 9: 6XPPDU\ DQDO\VLV RI WKH UHVHDUFK UHVXOWV RI D VRIWZDUH VHQVR

Ages	Empty seat	1 year old child	2 years old child	7 years old child	13 years old child	22 years old man	Box	Dog laying
7KUHH VHQVRUV	+	+	+	+	+	+	+	+
:LWKRXW XOWUDVRQLF VHQVRU	+							
:LWKRXW WHPSHUDWXUH VHQVRU		+	+					

Table 5: 6XPPDU\ DQDO\VLV RI WKH UHVHDUFK UHVXOWV RI D VRIWZDUH VHQVR

results presented illustrate the advantages and disadvantages of using a so ware sensor in case of failing of any of the signals transmitted to its input.

From the analysis of the results it is established that:

¾By combining data from three hardware sensors is received error up to 5% in distinguishing between the objects on the passenger seat of the car;

¾Dropping of the signal in the hardware sensors a ects the accuracy of identifying the object on the passenger seat;

¾e higher impact on the performance of the so ware sensor has the dropping of the signal from the ultrasonic sensor.

References

0DWWXWDW 9: $XWRPRWLYH +DQGERRN %26&+ WK HGQ

6DW]D $ +DPPHUVFKPLGWE ' 7XPSROGD ' &DSDFLWLYH SDVVHQJHU GHWHFWLRQ XWLOL]LQJ GLHOHFWULF GLVSHUVLRQ LQ KXPDQ WLVVXHV 6HQVRUV DQG $FWXDWRUV $ 3K\VLFDO

$GVXO 5 -RVKL 6 3HUIRUPDQFH 0RGHOLQJ RI $XWRPRWLYH 6HQVRUV DQG 6HQVRU ,QWHUIDFH 6\VWHPV XVLQJ 6LPXOLQN ,QWHUQDWLRQDO -RXUQDO RI 6FLHQFH DQG 5HVHDUFK ,-65

6FKUHLEHUD ' /XRE < 6HDW GHWHFWLRQ LQ D FDU IRU D VPDUW DLUEDJ DSSOLFDWLRQ 3DWWHUQ 5HFRJQLWLRQ /HWWHUV

&XQQLQJKDP . %URZQ 7 *UDGZHOO (1HH 3 $LUEDJ DVVRFLDWHG IDWDO KHDG LQMXU\ FDVH UHSRUW DQG UHYLHZ RI WKH OLWHUDWXUH RQ DLUEDJ LQMXULHV - $FFLG (PHUJ 0HG

'LQHYD 3 .D]ODFKHYD = 'HVLJQ RI ZRPHQ ZHDU ZLWK WKUHH GLPHQVLRQDO HOHPHQWV ;;,9 ,QWHUQDWLRQDO VFLHQWL¿F FRQIHUHQFH 0DQDJHPHQW DQG TXDOLW\ IRU \RXQJ VFLHQWLVWV

.D]ODFKHYD = ,OLHYD - +LVWRU\ RI WKH FRVWXPH

%DOO\ . 0LOJUDP 0 %RRVWLQJ IHDWXUH VHO UHJUHVVLRQ 1HXUDO 1HWZRUNV

%RYHULH 6 'HY\ 0 /HUDVOH) &RPSDULVRQ VWHUHRYLVLRQ VHQVRUV IRU QHZ DLUEDJ JHQHUD

'LPLWURYD $ $QDO\VLV RI 6(0 LPDJHV RI PDJ PDWHULDOV $SSOLHG 6FLHQWL¿F -RXUQDO ,QQRYD

*HRUJLHYD . *HRUJLHYD 76 .LULORYD ('DVNDOR KHDOWK\ DQG GLVHDVHG YLQH OHDYHV XVLQJ FRO

0DOGHQRY 0 3HQFKHY 6 'H\DQRY 0 &RPSOH SURGXFWV TXDOLW\ XVLQJ DQDO\VLV RI YLVXDO K\SHUVSHFWUDO FKDUDFWHULVWLFV ,QWHUQDWL ,QQRYDWLYH 7HFKQRORJ\ ,-(,7

.HH 56 'HWHFWLRQ 6\VWHPV IRU $LUEDJ 'HSO 3URMHFWV S

,YDQRY 0 6SHFL¿FV RI WKH ZRUN RI VHQVRUV $QGURLG 26 :RUNLQJ 3DSHU 6FLHQWL¿F HOHFWUR

7KH (PEHGGHG .DOPDQ)LOWHU $Q ,QWHUDFWLYH 7

:LNLSHGLD &HQWUDO OLPLW WKHRUHP

(LQLFNH * 6PRRWKLQJ)LOWHULQJ DQG 3UHGLFWLRQ (VWLPDWLQJ 3UHVHQW DQG)XWXUH 6LMHND &URDWLD ,QWHFK

0D\EHFN 6 6WRFKDVWLF 0RGHOV (VWLPDWLQJ $FDGHPLF 3UHVV S

6KLYDFKHYD * 1HGHYD 9 <DQHYD 0 *HRUJLHYD ' YLUWXDO ODERUDWRULHV ;;,9 ,QWHUQDWLRQDO V TXDOLW\ IRU \RXQJ VFLHQWLVWV SS

6WR\NRYD 9 ,QWHUDFWLYH HQYLURQPHQWV IR ,QWHUQDWLRQDO &RQIHUHQFH RQ H /HDUQLQJ H /

7DMHY * 0DQDJHPHQW DQG ([SORUDWLRQ RI PDWKHP RI IUHTXHQF\ RI GLDJQRVLV RI WKH HOHPHQWV RI WK ,QWHUQDWLRQDO &RQIHUHQFH 5HOLDELOLW\ FRPPXQLFDWLRQ /DWYLD SS