Rtcevkecn'Cur gevu'qh'Vtktqvqt 'O CX'F gxgnqr o gpv'

Cpft| gl'T{ś.'Tqo cp'E{ dc.'I{ gi qt' 'U{ chtcńumk"

Unrgukcp'Wpkxgtukv{ 'qh'Vgej pqnqi {.'38'Cncf gm kec\U0'66/322'I nky kee.'Rqncpf

ABSTRACT

This paper outlines the mechanical architecture, hardware components, and software structure for an unmanned micro aerial vehicle (MAV) trirotor. It focuses on the practical approach to the design and assembly of an aerial platform with three rotors. Furthermore, an embedded microcontroller-based navigation and control system is proposed to provide efficient angular stabilization and stable hover during the different flight conditions. The design, analysis and the validation tests have been undertaken on the experimental aerial platform.

1 INTRODUCTION

Y kj kp" vj g" rcuv" {gctu. "tcr kf " f gxgnqr o gpv" qh" uo cm" cpf " r qy gthwn" o ketqeqpvtqmgtu. "ceeguu" vq" ej gcr " cpf " tgncvkxgn{ " ceewtcva" kpgtvkcn'ugpuqtu. "tgnkcdng" y ktgmguu" nkpmu" cpf " hkpcn{ " ghhkekgpv'eqo r wvgtu'uvo s" cmoy gf " vq" cf xcpea" uo g "hqto gt{ " gzkunkpi "cetf {pco ke"eqphki wtcvkqpu'vj cv'y gtg"xgt{ fkhhkewn" vq" eqpvtqn'd{ "j wo cp"r knqvu"qpn{. "nkmg" s wcf tqvqtu0'Vj g" o quv" r qr wnct "o wnkktqvqt "eqphki wtcvkqp'ku" wpf qwdvgfn" s wcf tqvqtu0'K{" dgeco g"y kf gur tgcf "vj cpmu"vq"ku" o gej cpkecn'uko r nkekv{ "cpf " gcukn{ " wpf gtuvcpf cdng" f {pco keu0' J qy gxgt." hqt" uqo g" cr r nkecvkqpu'c'us wcf tqvqt'o ki j v'dg" pqv'r ctvkewntn{ 'uwkvcdng'f wg" vq"tgnkcdkng" j ki j "o cuu'ecwugf "d{ "hqwt"o qvqtu.'y j kej "tgf wegu" vj g"r qy gt"ghhkekgpe{0'Vj gtghqtg.'vj g"r ytr qug"qh'vj ku"r tqlgev" y cu'vq"f guki p"cpf "cuugo dng"c'xgj keng"y kj "vj g"pwo dgt"qh" o qvqtu'tgf wegf "vq"vj gg"cpf "ecr cdng"qh'uvcdng"j qxgt"hlki v0' Vj ku" ku" cp" o wnkf kuekr nkpct{ " r tqdngo " y kj " xctkqwu" tgswktgo gpvu'hqt"o gej cpkeu."j ctf y ctg"cpf "uqhy ctg0'Vj gtg" ctg"o wnkr ng"r wdnkecvkqpu'qp'WCXu"pcxki cvkqp'cpf "eqpvtqn"]3_.]4 "dcugf "qp"eqo o gtekc{ "cxckncdng"r ncvhqto u."vj gtg"ku" cnuq" c" pwo dgt" qh" r cr gtu" hqewukpi " qp" y jggtgvkecn' eqpukf gtcvkqpu']5_."]6_0'Vj gug"r wdnkecvkqp'f q"pqv'r tqxkf g"' eqo r gj gpukxg" qxgtxkgy " qh" vj g" WCX" cuugo dnkpi " htqo " eqpegr v'vq"hlki v0'

Vj g"o ckp'i qcn'y cu'vq"f guki p"c'uko r ng. "nki j v'cpf "f wtcdng" ckthtco g" ecrt{kpi " go dgf f gf " o gcuwtgo gpv'cpf " eqpvtqn" u{ uvgo ."uwdhfkekgpv'hqt"hktuv'uguvu'cpf "hngzkdng"gpqwi j "vq"cf cr v" gcukn{ "vq"hwwtg"f gxgnqr o gpv'y kj qw"o clqt"ej cpi gu0'Vj g" o ckp'kpvgpvkqp'y cu'vq"f gectgcug"vj g"pwo dgt"hlo qvqtu"vq"vj tgg0' K{"ku"qdxkqwu'vj cv'uwej "c"o qf khkecvkqp'kpvtqf wegu'egtvckp" ej cpi gu'vq"vj g"i gpgtcn{ "uvo "f {pco ku"cpf "tgswktg"xctkqwu" o qf khkecvkqpu'kp'vj g"o gej cpkecn'f guki p0'Vj g"kuuwg"vj cv'pggfu" vq" dg" f gcn'y kj " ku" vj g" wpdcncpeg" qhtqswg" qp" vj g" xktqtqt" ecwugf "d{ "wpgxgp"pwo dgt"qh'o qvqtu0'Cnvgtcvkqpu"kp"vj g" o gej cpkecn'f guki p"r tqr qugf "kp'vj ku"r cr gt"kpvtqf weg" c"vkn{ " o gej ckuo "hqt"qpg"qh'vj g"o qvqtu0'Vj g"vkn{ o gej ckuo "cmoy u"

cf lwuvkpi "qtkgpvcvkqp'qh'qpg"qh'vj g"o qvqtu'r tqxkfkpi "c'o gy hqd " qh'eqo r gpucvkqp'qh'gzeguukxg"vqts wg"cu'y gm'cu'eqpvtqn'qh'vj g" {cy "cpi ng0'Vj g" vtktqvqt" hlki j v'r tkpekr ng" ecp" dg" gzr nckpgf " hqnqy kpi]7_< "

$$(3B) \quad = *f_4 - f_3 + l_3$$

$$(304) \quad = f_5 n_4 equ \; - m_5 i \; n_4 + \; + *f_4 + f_3 + l_3 \; ukp \; - 4m_{34} g \; ukp$$

$$(305) \quad = f_5 l_4 \; ukp$$

y j gtg<

. . ó'i gpgtcnk{ gf 'o qo gpvu"

$f_3 . f_4 . f_5$ ó'hqtegu'i gpgtcvgf 'd{ 'o qvqtu"

l_3 ó'fkuvcpeg'htqo "vj g"o qvqtu'3'cpf '4'vq"vj g'z-czku"'

l_4 ó'fkuvcpeg'htqo "vj g"o qvqt'5'vq"vj g'egpvgt'qh'i tcxkv{ "

 ó'vkn{ 'cpi ng'qh'vj g"o qvqt'5"

 ó'cpi ng'dgwy ggp'ukfg'dqqo u'cpf 'czku'{ "

$o_{34} . o_5$ ó'o qvqtu'o cuugu"
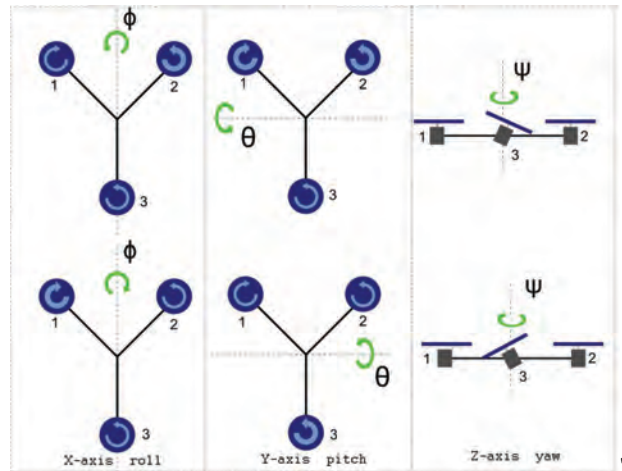
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Vj ku'r cr gt'r tgugpvu'c'uj qtv'qxgtxkgy "qh'hqwt'uvci gu'qh'vj g" r tcevkecn'ko r ngo gpvcvkqp'qh'c'vtktqvqt0'Vj g'ugeqpf "ej cr vgt"

kpvtqf wegu'o gej cpkecn'f guki p"cpf "f gf kecvkqp" 'hnki j v'eqo r wgt0'
O gcuwtgo gpv'u{uvgo "kpenwfkpi "f cvc'hkngtkpi "ku'f guetkdgf "kp"
yj g"yj ktf'ej cr vgt0Ej cr vgt"6'dtkpi u'kp"yj g"pcxki cvkqp"gs wcvkqpu"
cpf "ku'hqnqy gf "d{"eqpvtqn'u{uvgo "f guki p"kp"ej cr vgt "70'Vguvu"
tguwnvu"ctg"r tgugpvgf "kp"ej cr vgt "80'

2 MECHANICAL DESIGN

2.1 Airframe

Vj g"htco g"ku"yj g"ng{"gngo gpv'qh"cp"WCX0'K{'uj qwrf "dg"
r qqukdn{"f wtcdng."uvkhh'cpf "rki j v'cu"y gn'cu"chhqtf cdng"y kij kp"
r tqlgev'dwf i gv0'Vj gtghqte."yj g"o cvgtkcn'ugngevgf "vq "wug"y gte"
qh"yj g"r qqukdn{"hkpguv'swcnkv{"k" o kdg{'qpn'd{"r tkeg0'C "etwekcn'
hcevqt"hqt"htco g"f guki p"ku"yj g"o cvgtkcn'uvtgpi yj 0'J qy gxgt."yj g"
y qtf " õuvtgpi vj ö" j cxg" f khhgtgpv" o gcpkpi " hqt" f khhgtgpv"
o cvgtkcnu0'Hqt" o gvcnu." uvtgpi vj " o gcpu" {kgnf " uvtgpi vj ." hqt"
eqo r qukgu"kv'ku"yj g"vgpukng'hcknwtg"uvtgpi vj 0'Vj g"o cvgtkcnu"
ugngevkqp"hqt"yj g"ckhtco g"y cu"dcugf "qp"]8_"y j kej "cpcn{ugu"
yj gkt "uvtgpi vj "tgncvkxg'vq "equv'cpf "f gpukv{0'Vj g"o cvgtkcn'
ej qqgp"hqt"yj g"r tqlgev'y gtg"ectdqp'hkdtg'tgkphqtegf "r qn{o gt"
*EHTR+"cnwo kpkwo ."cpf "r qn{co kf g'RC"880'EHTR"y cu"wugf "
hqt"ukf g"dqqo u'y kng"yj g"eqo dkpcvkqp"qh'cnwo kpkwo "cpf "RC"
88"y gtg"wugf "hqt"o qvqtu'j qnf gtu."ko'o gej cpkuo "cpf "egpvtcn'
r ctv0' Vj g" ckhtco g" f guki p" kp" 5F " ECF " ku" uj qy p"
kp'hki wtg'4 cpf "50'
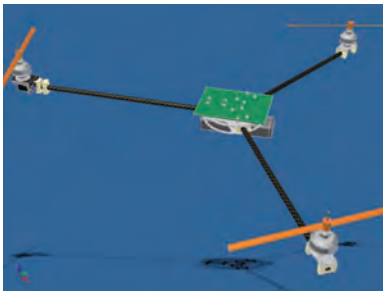
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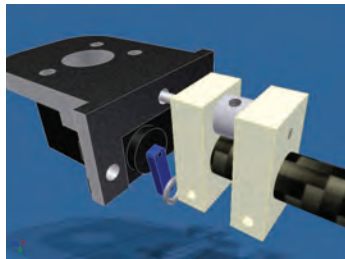
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Hki wtg"6<'Cuugo dngf "'vktqvqt0'

2.2 Components

Vj g"eqo r qpgpvu"wugf "hqt "cuugo dn{"qtki kpcvg"htqo "TE "
o qf gm0'Dcwt{."ugtxq."o qvqtu'cpf "r tqr gngt"y gtg"cf qr vgf "
y kij qw'ej cpi gu0'Vj g"dtwuj nguu'o qvqtu'ugngevgf "hqt"yj g"f guki p"
tgs wktg"gngevtqpke'ur ggf "eqpvtqngtu"*GUE+0'Vj gug"eqpvtqngtu"
ctg"cxckncdng'vq "dw{"cu"TE "o qf gm'gs wkro gpv. "wphqtvwpcvgn{."
kp"yj ku"eqphki wtcvkqp"yj g{ "ctg"pqv'r ctvkewrctn{"wughwr'hqt'uwej "c"
f go cpf kpi " ucuk'cu" uvcdkr cvkqp" qh" c" tqvqtetchv0' Vj g"o ckp"
nko kcvkqp"ku'yj g"uvcpf ctf "TE "o qf gn'kpvgthceg."uq "ecnngf "r wtug"
r qukkqp"o qf wrcvkqp"RRO ."yj cv'qr gtcvgu"y kyj "htgs wgpe{ "cu"
nqy "cu"72J | 0'Vj gtghqte."c"f gf kecvgf "GUE"y kij "K4E"qt"WCTV"
pggf u"vq "dg"wugf "kp"qtf gt "vq "qdvckp"c"j ki j gt "uco r ng"tcvg'qh"yj g"
eqpvtqn'uki pcnu0'Uqo g"ej cpi gu"y gte"o cf g."uq "yj cv'yj g"f gxkeg"
chvgt "eqpxgtukqp"eqwrf "dg"eqpvtqngf "xkc'K4E"kpvgthcec"y kj "wr "
vq "322mJ | "'tcpuo kuukqp'htgs wgpe{ "cpf "ku'eqo r cvkdng'y kyj "4. "5 "
cpf "6/egm'Nk'Rqn'dcvvgtkgu"*9.6X"ó"36.: X+0'Vj g"eqpxgtukqp"
r tqeguu"y cu"r gthqto gf "ceeqtf kpi "vq "yj g"kphqto cvkqp"htqo "]9_"
y j gte"yj g"pgy "hkto y cte"qtki kpcvgu'htqo "cu"y gm0'

2.3 Hardware

C "f gf kecvgf . "o ketqeqpvtqngt/dcugf "hnki j v'eqo r wvgt"j cu"
dggp"f gxgnqr gf 0'Vj g"egpvtcn'wpkv'qh"yj g"hnki j v'eqo r wvgt"ku"cp"
Cvo gn'CVo gi c"34: "y kij "r gthqto u'f cvc'eqmgevkqp."uqnxgu"
pcxki cvkqp"gs wcvkqpu."tgcf u'cpf "kpvgtr tgvu'qtf gtu'htqo "TE "
tgegkxgt."twpu'uvcdkrk cvkqp'cni qtkyo u'eqpvtqn'yj g"o qvqtu"
cpf " ugtxq0' CVo gi c "o ketqr tqeguuqt" y cu" ej qugp" f wg" vq "
pwo dgt "qh"cxckncdng"eqo o wpkecvkqp"r tqvqeqnu"*URK "K4E. "
WUCTV+"" mq{ " r qy gt " eqpuwo r vkqp." cpf " wpeqo r rkecvgf "
r tqi tco o kpi 0'Vj g"f guki gf "ekteww u'cpf "RED'ecp'dg"wugf "hqt"
dqyj "tkktqvqt"cpf " swcf tqvqt"cgtkcn'r ncvhqto u0'K{'j cu"hqwt"
uqemgu'hqt"K4E"dwu'cpf "y q"RY O "qwr ww0'Ku'kpvgpf gf "vq "
y qtm'y kj "CF KU38622"dww"f wg"vq "hngzkdng"ctej kgewtg"ecp"
cnuq "eqo o wpkecvg"y kj "qyj gt"ugpuqtu'v{r gu0'

3 MEASUREMENT SYSTEM

3.1 Sensors array

Cpcnqi "F gxkegu"CF KU38622"y cu"ugngevgf "cu"yj g"o ckp"
o gcuwtgo gpv'wpkv0'K{'ku"cp"kpvgi tcvgf "f gxkeg"eqpvckpkpi "
vtkczkcn'O GO U"i {tqueqr g."vtkczkcn'O GO U"ceegngtqo gvgt."
vtkczkcn'o ai pgvqo gvgt" cpf " cwzkrkct{ " cpcnqi " ó "f ki kvcn'
eqpxgtvgt0'K{'yj g"uo cm'*45z"45z"45"o o +"cpf "nki j v."38i "
r cemci g"yj gtg"ctg"cnuq "o go dgf f gf "go r gtcwtg"cpf "xqnci g"
ugpuqtu'cmqy kpi 'r tgekug'dkcukpi 'qh'tgcf kpi u0'Eqo o wpkecvkqp"
y kij " yj g"kpuvtwo gpv'ku'r gthqto gf "wukpi "URK'kpvgthceg0'Vj g"
u{uvgo " r tqxkf gu" hwm{ " cwqqo qwu" qr gtcvkqp." cpf " f cvc'
eqmgevkqp'tcvg"cu'hkuvv'cu'442o u'ncuvó"vr "ko g"cpf "6o u'unggr "
o qf g"tgeqxgt{"ko g0'Ceeqtf kpi "vq "yj g"f cvcuj ggv."ecrkdtcvkqp"
qh'ugpukkxkv{."dkcu'cpf "czkcn'cnki po gpv'y cu"r gthqto gf "hqt"
- 47ÅE0' Vj g" u{uvgo " r tqxkf gu" cnuq " c "Dctngw'y kpf qy "HKT "
f ki kvcn'hkngtkpi 0'

3.2 Filtering

F wg'vq "yj g"O GO U"ugpuqtu'pcwtg. "c'pqkug'kp"qwr ww'uki pcnku"
wpcxqkf cdng0' Cf f kvkqpcm{. " twppkpi " o qvqtu' i gpgtcvg"
xkdtcvkqpu'qh'y kf g"ur gevtwo 0'Vj gug"y q"uqwtegu'qh'pqkug"ecp'
dg"o qf gngf "cu"y j kvg'pqkug"ugs wgpeg0'Vj g"y j kvg'pqkug"ecp'dg"
tgo qxgf " htqo " ugpuqtu' tgcf kpi u" qpn{" d{ " f guetkdkpi " ku"
uvcvkuvkecn'ej ctcevgtkuvkeu'cpf "cr r n{kpi "cr r tqr tkcvg'hkngtkpi "
]: _0'F ki kvcn'kpgct. "ko g/kpxctkcpv'*NVK4'hkngtu'ecp'dg"f ghkpgf "

d{"c"f khhgtgpeg"gs wcvkqp"qh"vj g"hqmqwy kpi "hqto <

$$(5(B+"" \quad \sum_{i=3}^{M} a_i y]n-i\_=\sum_{j=3}^{N} b_j x]n-j\_"$$

y j gtg."

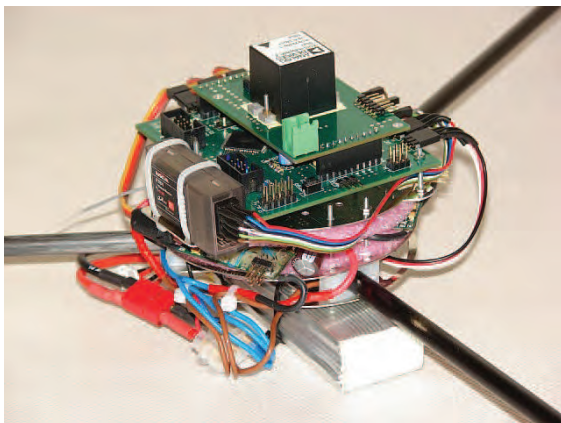a_i ó"hggf dcem"eqghhekgpvu"

b_i ó"hggf "hqty cf "eqghhekgpvu"

Vj g" ej ctcevgtkuvkeu"qh" kpr w"uki pcnu" o wuv" dg" mpqy p" vq"
f guki p"c"r tqr gt"hknqgt0'Vj g"o gcuwtgo gpvu. "uco r ngf "cv"422J | ."
y gtg"eqmgevgf "htqo "ugpuqtu"r ncgf "qp"vrkvtqtqr"y j krg"o qvqtu"
y gtg"twppkpi "vq"r tqvkf g"r ouukdn{"emqug"cr r tqzko cvkqp"qh"tgcn"
hnki j v'eqpf kvkqpu0'C"r gthgev"qvgtvkxky "qh"uki pcnu"eqo r qpgpu"
y cu"qdvckpgf "wukpi "c"j ki j "tguqnwvkqp"RUF "*Rqy gt"Ur gevcn"
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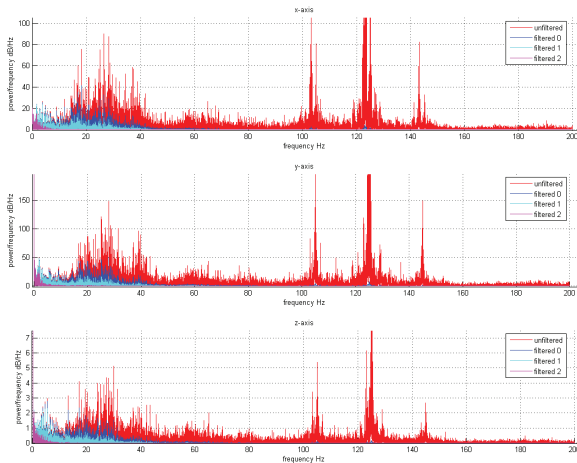
Hki wtg"7<'RUF "guvko cvg"qh"i {tqueqr gu'qwvr wvu0'

"	HKNVGT "2" $_c$ = 42Hz"		HKNVGT "3" $_c$ = 32Hz"		HKNVGT "4" $_c$ = 7Hz"	
	c"	d"	c"	d"	c"	d"
3"	30222"	20[589"	30222"	20[952"	30222"	20[377"
4"	/2[9487"	20[589"	20[952"	20[952"	/20[;3"	20[377"

Vcdng"3<'Hknvgtu"ewv"qhh"htgs wgpekgu"cpf "eqghhekgpvu0'

Hki wtg"8<'Egpvtcn"r ctv"qh"vj e"vtktqtqt"y kvj "f gf kecvgf "engevtqpkeu."'
CJ TU'CF K38622."TE "tgegkvgr"cpf "dcwtg{0'

Hki wtg"7"uj qy u"RUF "qh"o gcuwtgo gpvu"eqmgevgf "f wtkpi "vj g"
gzr gtko gpv0' Vj gtg" ctg" wy q" o ckp" htgs wgpe{" kpvgtxcnu"
eqpvckpkpi "o qvu"qh"vj g"pqkug"eqo r qpgpvu0'Vj g"vj gg"r gcmu"

dgy ggp"322J | "cpf "372J | "ctg"ecwugf "d{"xkdtcvkqp"vj tgg"uki f g"
dqqo u.'o qvqtu"cpf "r tqr gmgtu0'Vj g"gzcev"nqecvkqp"qh"vj gug"
r gcmu"ku"f gr gpf gpv'qp'o qvqtu'tqvcvkqpcn'xgnqekv{'P qkug"kp"vj ku"
htgs wgpe{ "tcpi g"ku"pqv"r ctvkewrctn{"j cto hwn'hqt"vj g"pcxki cvkqp"
dgecwug"kv'ecp'dg"xgt{'gcukn{"hknvgtgf "qwv'd{ "c"nqy /r cuu'hknvgt"qh"
tgncvkxgn" " j ki j " eww" qhh"htgs wgpe{0' Vj g" pqkug" eqo r qpgpvu"
ngecvgf "dgy ggp"32J | "cpf "72J | "j cxg"o wej "ncti gr"r gi e cvtg"
ko r cev"qp"vj e"pcxki cvkqp"u{uvgo 0'Hkngtkpi "r gthqrm gf "y kj "c"
nqy /r cuu'hknvgt"qh"ewv"qhh"htgs wgpe{"dgmqy "32J | "unqy u"f qyp"
vj g"u{uvgo "uki pkhkecpvn{.'qp'vj g"qvj gr"j cpf "qq"j ki j "ewv"qhh"
htgs wgpe{ "ecwugu"vj e"pcxki cvkqp"u{uvgo "eqmgev'tgm ctmcdg"
pqkug." uq " vj g" UPT " *uki pcn/vq/pqkug" tcvkq+" f getgcugu"
o gcpkpi hwn{0'

Gzeguukxg"guvu'qh'xctkqwu'hknqgtu'f gvgto kpgf "vj cv'hktuv'qtf gr"
Dwwgty qrvj " KKT " hknqgtu" y kj " ewv'qhh" htgs wgpe{ " kp " tcpi g"
32/42J | "ctg"o quv'uwkcdng"hqt"vj g"vktktqvqt0'Vj g"r gthgevn" "
hknqgt" qw" vj g" uki pcn'eqo r qpgpvu" qh" htgs wgpe{ " : 2/382J | " "
ecwugf " d{ " tqvcvkpi " o qvqtu"cpf " uki pkhkecpvn" " tgf wecf " nqy "
htgs wgpe{"pqkug"cr r gctkpi "dgy ggp"42J | "cpf "62J | 0'Y j cv'ku"
ko r qtvcpv.'vj g"f gnc{"kpvtqf weaf "d{ "hknqgtu"qh"vj gug"qtf gr "ku"
ceegr vcdng"d{"pcxki cvkqp"cpf "eqpvtqn'cnri qtkj o u0'

4 NAVIGATION

F wtkpi "vj g"tgugctej "qp"KP U."cp"ghhhekgpv'pqxgn'cnri qtkj o "
hqt"O CTI "u{uvgo "y cu"hqwpf "kp"]_0'Kv'y cu'c"r gthgev'uqnwvkqp"
f wg "vq "xgt{ "nqy " eqo r wvcvkqpcn'nqcf ." s wctgtpkqpu"kpvgrcn'
ko r ngo gpvcvkqp" cpf " j ki j " ceewtce{ " eqo r ctcdng" y kj " MH"
*Mcno cp'Hknvgr+'uqnwvkqpu0'Vj g"cnri qtkj o "j cu"dgqp'o qf khgf "kp"
qtf gr "vq"r tqvkf g'j ki j gr"uucdknkv{ "cpf "r gthqto cpeg0'F wtkpi "vj g"
hktuv'twp'vj g"cnri qtkj o "ucxgu'vj g"kpkkcn'qtkgpvcvkqp"y kej "y knt"
dg "c"dcuku'hqt "hwtvj gr "ecnewrcvkqp0'

4.1 Orientation

Vj g" cnri qtkj o " hktuv{ " ecnewrcvgu" vj g" qtkgpvcvkqp" wukpi "
i {tqueqr gu"tgcf kpi u" /" $_E^S\mathbf{q}\_{,k}$ 0' Cv" vj ku" uvci e" vj gtg" ku" pq"
eqttgevkqp'hqt 'f tkhv'uq'vj g"gttqt"ku'ceewo wrcvkpi 0'Cv'vj ku'ugeqpf "
uvci e"kv'ecnewrcvgu'vj e"qtkgpvcvkqp"wukpi "xgevqr'o gcuwtgo gpvu"
htqo " ceegrgto gvgtu" cpf " o ci pgqo gvgtu0' Vj g" qtki pcn'
cnri qtkj o "htqo "]; _'wugu'c"eqo dkpcvkqp"qh'ceegrgto gvgtu"cpf "
o ci pgqo gvgr " tgcf kpi u." j qy gxgr " vj g" o qf khecvkqp"
kpvtqf weaf "kp'vj ku'tgugctej "cuuwo gu'cv'c"f kuvkpevkxg"vtkr ng"qh"
o gcuwtgo gpvu'ku'r tqvkf gf "hqt"cp{'qtkgpvcvkqp'kp'ur ceg"d{ "dqvj "
vtkczkcn" ceegrgto gvgr " cpf " " " vtkczkcn" o ci pgqo gvgr0'
Vj gtghqtg.'vj g"qr ko k|cvkqp'r tqdngo "htqo "]; _'ecp'dg"gzvgpf gf "
gxgpvwcm{ "vq<

$$(6(B+"" \quad _E^S\mathbf{q}\_{,v.k+3+}= _E^S\mathbf{q}\_k - {}_k \frac{\nabla f *_E^S\mathbf{q}.^E \mathbf{g}.^S \mathbf{a}.^E \mathbf{b}.^S \mathbf{m}+}{\left\| \nabla f *_E^S\mathbf{q}.^E \mathbf{g}.^S \mathbf{a}.^E \mathbf{b}.^S \mathbf{m}+ \right\|} \cdot "$$

$$k = 2.3.4.(0]n$$

y j gtg<

$_E^S\mathbf{q}\_{,v.k+3+}$ "qtkgpvcvkqp'ecnewrcvgf "htqo "xgevqtu"" " " " "

" " " " " o gcuwtgo gpvu"

$_E^S\mathbf{q}\_k$ " " ncuv'cvkwf g"guvko cvkqp"

U.'G'ô'ugpuqt'cpf 'Gctyj 'htco g"
m'ó''pq0'qh'kvgtcvkqp"

cpf "

(4.1) $f *^S_E \mathbf{q}.^E \mathbf{g}.^S \mathbf{a}.^E \mathbf{b}.^S \mathbf{m}+= \begin{bmatrix} f *^S_E \mathbf{q}.^E \mathbf{g}.^S \mathbf{a}.+ \\ f *^S_E \mathbf{q}.^E \mathbf{b}.^S \mathbf{m}+ \end{bmatrix}$ "

y j gtg<

"

(4.3) $f *^S_E \mathbf{q}.^E \mathbf{g}.^S \mathbf{a}+= \begin{bmatrix} 4g_x *\frac{3}{4} - q_5^4 - q_6^4 ++ \\ 4g_x *q_4q_5 - q_3q_6 ++ \\ 4g_x *q_3q_5 + q_4q_6 ++ \end{bmatrix}$ "

$$\begin{bmatrix} +4g_y *q_3q_6 + q_4q_5 ++ 4g_z *q_4q_6 - q_3q_5 +- a_x \\ +4g_y *\frac{3}{4} - q_4^4 - q_6^4 ++ 4g_z *q_3q_4 + q_5q_6 +- a_y \\ +4g_y *q_5q_6 - q_3q_4 ++ 4g_z *\frac{3}{4} - q_4^4 - q_5^4 +- a_z \end{bmatrix}$$

"

(4.4) $f *^S_E \mathbf{q}.^E \mathbf{b}.^S \mathbf{m}+= \begin{bmatrix} 4b_x *\frac{3}{4} - q_5^4 - q_6^4 ++ \\ 4b_x *q_4q_5 - q_3q_6 + \\ 4b_x *q_3q_5 + q_4q_6 ++ \end{bmatrix}$ "

$$\begin{bmatrix} +4b_y *q_3q_6 + q_4q_5 ++ 4b_z *q_4q_6 - q_3q_5 +- m_x \\ +4b_y *\frac{3}{4} - q_4^4 - q_6^4 ++ 4b_z *q_3q_4 + q_5q_6 +- m_y \\ +4b_y *q_5q_6 - q_3q_4 ++ 4b_z *\frac{3}{4} - q_4^4 - q_5^4 +- m_z \end{bmatrix}$$

y j gtg<

$^S \mathbf{a} =]2 \ a_x \ a_y \ a_z \_^T$ "ceegngtqo gvgtu'pqto cnk| gf 'tgcf kpi u'"

$^S \mathbf{m} =]2 \ m_x \ m_y \ m_z \_^T$ o ci pgvqo gvgtu'pqto cnk| gf 'tgcf kpi u"

$^S \mathbf{g} =]2 \ g_x \ g_y \ g_z \_^T$ i tcxkv{ 'hkgnf 'kpkvkcn'qtkgpvcvkqp'xgevqt"

$^S \mathbf{b} =]2 \ b_x \ b_y \ b_z \_^T$ "o ci pgvke'hkgnf 'kpkvkcn'qtkgpvcvkqp'xgevqt"

"

y j kej "encko u"

(4.5) $\nabla f *^S_E \mathbf{q}.^E \mathbf{g}.^S \mathbf{a}.^E \mathbf{b}.^S \mathbf{m}+=$ "

$= J^T *^S_E \mathbf{q}.^E \mathbf{g}.^E \mathbf{b}+ f *^S_E \mathbf{q}.^E \mathbf{g}.^S \mathbf{a}.^E \mathbf{b}.^S \mathbf{m}+=$

$= \begin{cases} J^T *^S_E \mathbf{q}.^E \mathbf{g}+ f *^S_E \mathbf{q}.^E \mathbf{g}.^S \mathbf{a}+ \\ J^T *^S_E \mathbf{q}.^E \mathbf{b}+ f *^S_E \mathbf{q}.^E \mathbf{b}.^S \mathbf{m}+ \end{cases}$

"

y j gtg<

(4.6) $J^T *^S_E \mathbf{q}.^E \mathbf{g}+=$ "

$$= \begin{bmatrix} 4g_yq_6 - 4g_zq_5 & 4g_yq_5 + 4g_zq_6 \\ -4i_xs_6 - 4i_zs_4 & 4i_xs_5 a\{ -6i_ys_4 - 4i_zs_3 \\ 4i_xs_5 - 4i_ys_4 & 4i_xs_6 - 6i_zs_4 - 4i_ys_3 \end{bmatrix}$$

$$\begin{matrix} -6g_xq_5 + 4g_yq_4 - 4g_zq_3 & -6g_xq_6 + 4g_yq_3 + 4g_zq_4 \\ 4i_zs_6 - 4i_xs_4 & -6i_ys_6 - 4i_zs_5 - 4i_xs_3 \\ 4i_ys_6 - 6i_zs_5 - 4i_xs_3 & 4i_ys_5 - 4i_xs_4 \end{matrix}$$

cpf "

(4.7) $J^T *^S_E \mathbf{q}.^E \mathbf{b}+=$ "

"

$$= \begin{bmatrix} 4d_ys_6 - 4d_zs_5 & 4d_ys_5 - 4d_zs_6 \\ -4d_xs_6 - 4d_zs_4 & 4d_xs_5 - 6d_ys_4 - 4d_zs_3 \\ 4d_xs_5 - 4d_ys_4 & 4d_xs_6 - 6d_zs_4 - 4d_ys_3 \end{bmatrix}$$

$$\begin{matrix} -6d_xs_5 - 4d_ys_4 - 4d_zs_3 & -6d_xs_6 - 4d_ys_3 - 4d_zs_4 \\ 4d_zs_6 - 4d_xs_4 & -6d_xs_6 - 4d_zs_5 - 4d_xs_3 \\ 4d_ys_6 - 6d_zs_5 - 4d_xs_3 & 4d_ys_5 - 4d_xs_4 \end{matrix}$$

"

Vj g" qtkgpvcvkqpu" tguwnkpi " htqo " ceegngtqo gvgtu" cpf " o ci pgvqo gvgtu'tgcf kpi u'ctg'cxgtci gf 'cpf 'f gpqvgf 'cu'$^S_E \mathbf{q}_{v.k}$0"

4.2   Fusion

Vj g"ctg" w q "kpf gr gpf gpv"uqwtegu'qh'wr f cvgu'hqt"pgy " cwkwf g" guko cvkqp<$^S_E \mathbf{q}_{.k}$ "cpf $^S_E \mathbf{q}_{v.k}$ 0' Hwukqp" qh " vj g" w q " guko cvgu'y cu'r gthqto gf "d{ "c'eqo r ngo gpvct{ 'hknvgr<

$(4.)$ $^S_E \mathbf{q}_k = *3 - +^S_E \mathbf{q}_{*.k+} + ^S_E \mathbf{q}_{*v.k+}.2 \le \le 3$ "

Vj g'eqo r ngo gpvct{ 'hknvgr 'ctguvgt'f gtkxcvkqp'r gthqto gf 'kp']; _' j cu'c'hqmqy kpi 'hqto <

$(4.)$ $^S_E \dot{\mathbf{q}}_k = ^S_E \dot{\mathbf{q}}_{*.k+} - ^S_E \dot{\mathbf{q}}_{*v.k+}$ "

Y j kej 'ku'gs wcn'vq<

(4.32) $^S_E \dot{\mathbf{q}}_k = ^S_E \dot{\mathbf{q}}_{*.k+} - \frac{\nabla f}{\|\nabla f\|}$ "

Cpf 'ngcf u'vq<

(4.33) $^S_E \mathbf{q}_k = ^S_E \mathbf{q}_{*k-3+} + ^S_E \dot{\mathbf{q}}_k \Delta t$ "

Vj g" r ctco gvgt" β " y cu" hqwpf " f wtkpi " vj g" gzr gtko gpvu." r tqxkf kpi 'cu'c'i qqf 'tcf kpi ' 'tgcev kqp'hqt'tcr kf 'ej cpi gu'cnqpi 'y kj ' i qqf 'f tkhv'eqttgev kqp'kp'nqpi 'twp0'

"
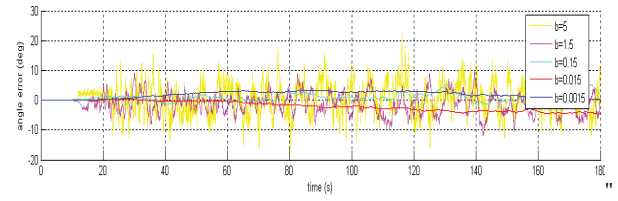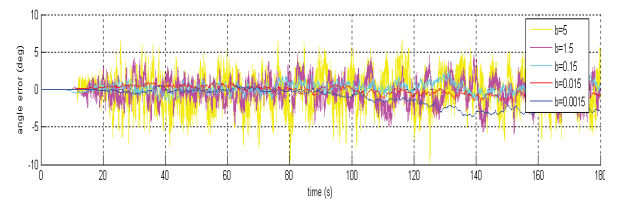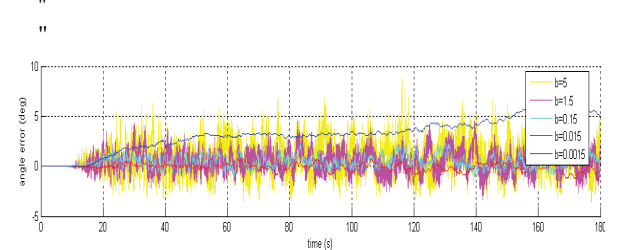
Hki wtg'7<'Kphwgpeg'qh'r ctco gvgt'β'qp'''
r gthqto cpeg'qh'pcxki cvkqp'cni qtkj o 0'

"

Vguvu'y gtg'r gthqto gf "y j krg''CFKU38622''y cu''o qwpvpf ''qp''
vtktqvqt''htco g.''b qvqtu'y gtg''uppplkpi ''cpf ''hkngtkpi ''y cu''cr r nkgf 0'
Vj g''b gcuwtg''uwgf ''tq''gxclwcvg''cri qtkjo ''r gthqto cpeg''y cu''tqqv''
o gcp''us wctg''gttqt *TO UG+0'K'y cu''ecnewncvgf ''qxgt''y g''kpvgtxcn'
2/3: 2u''hqt''gcej ''czku''ugr ctcvgn{0'Gxgpvwcn{."y g''ctkjo gvke''
o gcp''qh'y jug''xclwgu'y cu''eqo r wgf ''cpf ''y cu'r tgugpvgf ''kp''y g''
vcdng''4<'

"
"

	RMSE			
	z/czku"	{/czku"	|/czku"	o gcp"
0.0015	340.7369"	40.7284"	60.839; "	80.7685"
0.015	20.3523"	20.; 76"	80.4929"	40.4876"
0.15	20.8445"	20.6695"	40.894; "	30.4697"
1.5	30.553; "	40.5648"	340.8923"	70.4: 37"
5	50.2995"	60.7; 26"	470.3; 64"	320. 762"

Vcdng''4<'TO UG''qh'xctki cvkqp''cri qtkjo ''y kj '''
xctkqwu'xclwgu'qh'r ctco gvgt''β0'

"

Vj g''r ctco gvgt   'f gvgto kpgu''j qy ''dki ''ku''y g''kphnwgpeg''qh''
xgevqt''o gcuwtgo gpvu''qp''y g''hkpcn'tguwn0'Hqt''um cnn'xclwgu''qh.''
y jg''pcxki cvkqp''r gthqto cpeg''y cu''chhgevgf ''d{''i tqu''ftkhv''y cv''
eqwf ''pqv''dg''eqo r gpucvgf ''d{''cduqnwg''xgevqt''o gcuwtgo gpvu0'
Hqt''ncti g''xclwgu''qh''   ."y j g''ftkhv''eqttgevkqp''qxgtuj qqvu''y g''
gzcev''uqnwvkqp''ecwukpi ''y g''pr vko k| cvkqp''cri qtkjo ''qp r gtcvg''hct''
htqo ''y g''pr vko cn'uqnwvkqp0Vj g''uguvu''j cxg''uj qy p''y cv''y g''xclwg''
qh''   'uj qwf ''dg''enqug''tq''2.37''kp''qtf gt''tq''r tqxkf g''j ki j guv''
pcxki cvkqp''u{uvgo 'r gthqto cpeg0'

5   CONTROL SYSTEM

U{uvgo ''uvcvg''ku''guvko cvgf ''cceqtf kpi ''tq''y g''o gcuwtgo gpvu''
qdvckpgf ''htqo ''c ''O OTI ''ugpuqtu''cttc{0'Cu''kv''y cu''cltgcf {''
uj qy p.''CFKU38622'' r tqxkf gu''kphqto cvkqp''cdqwv''ewttgpv''
cpi wnct''xgnqekv{.''nkpgct''ccegngtcvkqp''cpf '' o ci pgvke''hkgnf ''
qtkgpvcvkqp.'y kj ''uco r ng''tcvg''wr ''tq''3; ,.4J '/0Vj cy 'tgcf kpi u''
ctg''r tqeguugf ''d{''c ''pcxki cvkqp''cri qtkjo ''y j kej ''qwr wvu''y g''
kphqto cvkqp''cdqwv''ewttgpv'WCV''qtkgpvcvkqp0'

Hki wtg''; <'I gpgtcn'u{uvgo ''uvtwewtg0'

"
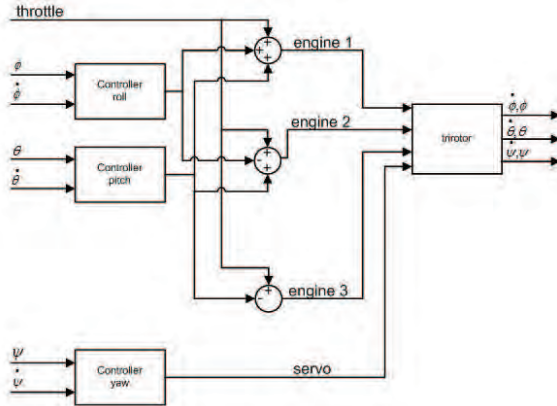
K'' ku'' ko r qtvcpv'' tq'' pqvg.'' y jcv'' y g'' tcy ''o gcuwtgo gpvu.''
gur ekcnm{''cpi wnct'xgnqekvkgu.''"ctg''qh''o wej ''hcuvgt''f {pco ke''
yj cp''y g''cvukwf g''qtkgpvcvkqp''tguwtpgf ''d{ 'pcxki cvkqp''cri qtkjo 0'
Vj g''tgcuqp''ku''cv''y g{''ctg''o gcuwtgf ''f ktgevn{''d{ 'ugpuqtu.''y krg''
y g''pcxki cvkqp''cri qtkjo '' kpvtqf wegu''uqo g ''gzvtc''f {pco keu0'

Vj g''eqpvtqn''cri qtkjo '' hqt'' vtktqvqt'' y cu''
uncdnkk{ cvkqp''qh''cpi ngu.''kp'qtf gt''y cu''y qtf u.''cdknk{ ''tq''vtcen''cpf ''
o ckpvckp'i kgp'tqro' r kej ''cpf ''{ cy ''cpi ngu0Vj g''eqpvtqn'u{ugo ''
y cu''f geqwr ngf ''cpf ''cu''c''tguwn''gcej ''qh''czgu''j cu''c''ugr ctcvg''
eqpvtqn''cri qtkjo 0'Vj gg''eqpvtqn''cri qtkjo u''tgwtp''ugr ctcvg''
kpr wu''hqt''y jgg''o qvqtu''cpf ''ugtxqo gej cpkuo ''y j kej ''pggf ''tq''dg''
eqo dkpgf ''tq'i gyj gt''y kj ''y j tqwg''uki pcn'c''o kzgf 0Vj g''i gpgtcn''
u{uvgo ''uvtwewtg''ku''r tgugpvgf ''kp''y g''hki wtg''; 0'

"

Ccegqtf kpi ''tq''y j g''tgugctej ''qp''gzkuvkpi ''eqpvtqn'u{ugo u''hqt''
WCXu''cpf ''kpxguvki cvkqp''qh'o gcuwtgo gpvu''ej ctcevgtkuvkeu''c''
RKF ''ecuecf g''y cu''ej qugp''hqt''tgcnk| cvkqp''qh''''vtktqvqt''eqpvtqn''
cri qtkjo 0'Cp''gzco r ng''qh'y g''eqpvtqn'u{ugo ''qh'tqm''cpi ng''ku''
r tgugpvgf ''kp''y g''hki wtg''; 0'

"

Hki wtg''; <'Eqpvtqn'uej go c''hqt''tqm'uncdnk'cvkqp0'

"
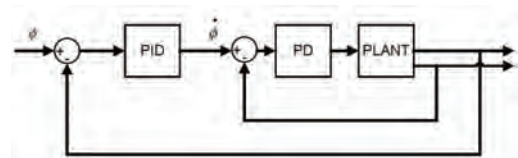
Vj g''uvtwewtg''qh'eqpvtqnkge''ej ququp''hqt''y g'kpvgtpcl'nqqr ''ku''qh''
v{r g''D''y kj ''hknngtgf ''f gtkxcvkxg'']32 0'Vj g''v{r g''D''uvtwewtg''y cu''
ugngevgf ''kp''qtf gt''tq''cxqkf ''uuf fgp''xqnvugg''eqtttgcvkqpu''qp''ej cpi gu''
kp''ugvr qkpv0O qtgqxgt.''c'hknngt''kp''y g''f gtkxcvkxg''tgto ''r tqxkf gu''
cf f kkqpcl'eqpvtqn'u'wr kv''ko r qxgo gpv0Vj ku''nqqr ''i uctcpvggu''
s wkem'ttgcevkqp''qp 'f kuuwtdcpegu'kp''y g'u{ugo ''cpf ''gcukgu''wpkpi ''
qh'y g''kpj tgpgpy ''wpuvcdng'u{ugo 0Vj g''wug''qh'y{r g''D''y kj ''hknngtgf ''f gtkxcvkxg.''j qy gxgt.''
y jgtg '' ctg'' uqo g '' o qf khkecvkqpu'' kpvtqf wegf 0 Vj g ''hktuv''
o qf khkecvkqp''eqpegtpu''y g''y c{''y g''ugvr qkpv''ej cpi gu'' ctg''
cr r nkgf ''tq''y g''u{ugo 0'Vj cu''kp'eqpegtp'dgj kpf ''kv'ku''tq''tgf weg''
y g''qxgtuj qqv'y j gp''y g''ugvr qkpv'xctkgu''tcr kfn{0Qpg''o gyj qf ''tq''
cxqkf ''y ku''r tqdngo ''y qwf ''dg''tq''wug''v{r g''E''RKF ''eqpvtqnngt0'
Cnj qwj ''kv''tgo qxgu''y g''qxgtuj qqv''kv''o ki j v'dg'q'unqy ''hqt''
cgtqcr ctx gj keng.''dgecuwg''y g'f guktgf ''xcnwg''ku''dgkpi ''tcemgf ''qpn{''
d{''y g''kpvgi tcn'vgto 0'Vj cu''o gyj qf ''cv''y cu''ko r qug gpvgf ''kp''y g''
vtktqvqt''cri qtkjo ''ku''c''qy /r cuu'hknngt''y kj ''tgduy eug''y g'r ggf ''
qh''ej cpi g''qh'y g''ugvr qkpv''tq''32f gi 1u''y kej ''ku''unqy ''gpqwj ''tq''
cxqkf ''r gcm'tgcevkqp''qh'r qr qtvkqpcl'vgto .''cpf ''qp''y g''qy gt''
j cpf .''hcuv''gpqwj ''tq''r tqxkf g''j ki j ''WCX''r gthqto cpeg0'Vj g''
ugeqpf '' cri qtkjo '' gpj cpego gpv''ku'' c '' f qwdng '' cpk'y kpf wr ''
r tqvgevkqp''u{ugo 0'K''ko ku''y g''o czko cn'xcnwg''qh'gttqt''y cv''
uwr r nkgu''y g''kpvgi tcn'ctv''cpf ''f ghfgpgu''nqy gt''cpf ''wr r gt''dqwpf ''
hqt''y g''kpvgi tcn'vgto '' xcnwg0Vj g''y kf ''gpj cpego gpv''qh''y g''
cri qtkjo ''ku''c''hknngt''kp''f gtkxcvkxg''vgto 0'

6   TESTS RESULTS

Vj g''vguvu'y gtg''r gthqto gf ''kp''qtf gt''tq''gzco kpg''y j gyj gt''cnn''
eqo r qpgpvu''ctg''y qtmkpi ''r tqr gtn{''cpf ''uvcdknk| cvkqp''qh''tktqvqt''
cvukwf g''ku''r quukdng0'Vj g''cdknk{ ''tq''o ckpvckp''i kigp''ugvr qkpv''
hqt''cv''ngcuv''82''ugeqpfu''y cu''uguvgf ''hqt''gcej ''czku''ugr ctcvgn{''
wukpi ''c''ur gekcln gf ''uvcpf ''y cv''ko kvgf ''y g''pwo dgt''qh'f gi tggu''qh''
htggf qo ''tq''qpg0Vj g''uuukpi ''r tqeguu'hqmqy gf ''ecuccf g'u{ugo u''
uwpkpi ''twngu0Kp0y g''kppgt''nqqr ''y cu''uupgf ''tq''j cxg''r quukdn{'j ki j ''
r tqr qtvkqpcl''cpf ''f gtkxcvkxg'i ckp0Vj ku''uguwkpi ''r tqxkf gf ''i qqf ''
tglgevkqp''qh''f kuuwtdcpeg''cr r gctkpi '' kp'' kp''y g''kppgt''nqqr 0'

Ugeqpfn{."yjg"qwegt"nqqr"jcxkpi "unqy gt"f{pco keu"ycu"wpgf"
uq."yjcv"yjg"vtkdpvqt"ycu"cdng"vq"o ckpvckp"c "ikxgp"ugvrqkpv0'
Vguvu"tguwnu"ygtg"ucvkuhcevqt{."yjg"vtktqvqt"ycu"cdng"vq"jqnf"c"
ikxgp"ugvrqkpv"hqt"wpnko kgf "ko g0'Vjg"guvu"tguwnu"ctg"uj qy p"
kp"hki wtg"320'

Qpeg"yjg "vtktqvqt"ycu"ecrcdng"qh"o ckpvckpkpi "c "ikxgp."
eqpuvcpv" ugvrqkpv" kv" ycu" vguvgf " ci ckpiut" utgr " ej cpi gu" kp"
ugvrqkpvu0'Vjg"g ikpu"tgswktgf "unki j v"o qf khkecvkqpu"kp"qtfgt"vq"
r tgxgpv" c "qxgtujqqv" vq "ceewt" cpf " r tqxkf g" f co rkpi " qh"
quekncvkqpu0'Vjg"\guvu"cxg"r tqxgp"yjcv"yjg"vtktqvqt"ku"r tqr gtn{"
vtcemkpi "ej cpi gu"kp"ugvrqkpvu"kp"cm"czgu0'Vjg "tguwnu"ctg"
r tgugpvgf "kp"yjg"hki wtg"330'

Hki wtg"32<'Gwrgt"cpi gu"f wtkpi "yjg"j qxgt"hnki j v0'

Hki wtg"33<'Vtcemkpi "qh"yjg"Gwrgt"cpi gu"f guktgf "xcnwgu0'

Cp"cr tqpcej "yq"j ctf y ctg"ko r ngo gpvckqp"qh"yjg"pcxki cvkqp"
cni qtkjo ."cu"y gm"cu"eqpvtqn'cni qtkjo ."j cu"dggp"f guetkdgf 0'
Vj g" pcxki cvkqp" cni qtkjo " dcugf " qp" ceegngtqo gvgtu."
i {tquecr gu"cpf "o ci pgvqo gvgtu"eqo dkpgf "y kj "yjg"ecuecfg"
eqpvtqn" uvtwewwtg " r tqxkf gu" i qqf " uvcdkk| ckqp" f wtkpi " yjg"
f khhgtgpv"hnki j v"eqpf kkqpu0'Vjg"vtktqvqt"ku"cdng"vq"o ckpvckp"
i kxgp"qtkgpvckqp"cu"y gm"cu"vtcem"yjg"ej cpi gu"qh"yjg"Gwrgt"
cpi ngu0'Vjg"r ctckck"tgcnk| ckqp"qh"yjg"cwkwf g"uvcdkk| ckqp"
u{uvgo "ku"cp"ko r qtvcpv"uvgr "kp"yjg"f gxgnqr o gpv"r tqeguu"qh"
o qtg" cf xcpegf " hwpevkqpcik{" qh" yjg" cwvqpqo qwu" hn{kpi "
xgj kengu0Hktuv/cwgo r wu"vq"qwvf qqt"hnki j wu"y gtg"xgt{"r tqo kukpi "
cpf "cej kgxgf "tguwnu"ctg"ucvkuhcevqt{0'

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"
]3_ Ko o cpwgn'Cuj qmctcl."Cpvqpkqu"Vuqwtf qu."Rgvgt"O 0'I 0Uknuqp"("
Dtkcp" C0' Y j kg0' C" Tqdwuv" Cr r tqcej " " vq " O wnkr ng" Ugpuqt " Dcugf "
P cxki ckqp"hqt "cp"Cgtkcn'Tqdqv."Proceedings of the 2006 IEEE/RSJ,
International Conference on Intelligent Robots and Systems, Beijing,
China."r ci gu'5755/575: 0'

]4_ Uco kt"Dqwcdf cmcl ."Cpf m'Pqvj "cpf "Tqrord"Ukgi y cp0'RKF "xu'NS "
Eqpvtqn' Vgej pkswgu " Cr r nkgf " vq " cp " Kpf qqt " O keto " Swcf tqvqt0'
Proceedings of 2004 1EEElRS.J Internationel Conference On
Intelligent Robots and Systems, Sendal, Japan, xqwo g'5."r ci g'4673"

]5_ J qrr gt" Xqoqu0' Pqpnkpgct" Uvcv/Fgr gpf gpv' Tkeecvk' Gswckqp"
Eqpvtqn' q" c "Swcf tqvqt" WCX, Proceedings of the 2006 IEEE
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r ci g'4769"

]6_ Vctgm'O cf cpk'cpf "Cdf gmc| k| "Dgpcmgi wg0'Dcemuvgr r kpi "Eqpvtqn'
hqt" c "Swcf tqvqt" J gnkeqr vgt, Proceedings of the 2006 IEEE/RSJ
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China."r ci g'5477"

]7_ Ucmc| ct"U0"Nq| cpq"T0"Guectq° q"L0'Uvcdkk| ckqp"cpf "pqpnkpgct"
eqpvtqn'hqt'c'pqxgn'vtktqvqt'o bpk'cketcthv."Proceedings of the 2005 IEEE
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Spain."r ci g'4834/4839"

]8_ Cuj b{."O kej cgl'H0'O cvtkcn'Ugpcevkqp"kp"O gej cpkecn'F guki p"'*5tf "
Gf kkqp+."Dwwgty qtvj /J gkpgo cpp"4227"

]9_ j wr <lly y y 0teitqwr u0eqo lhqtwo ulujqy yj tgcf 0r j r A?9887: ; (r c
i g?43."ncuv'ceeguu'qp"O c{"37yj ."4233"

]: _ Nkw'Twk'J wc."Nkkcpi "Tqpi skcpi ."\j cpi "Ngk0'Hkngtkpi "Cni qtkjo "
Tgugctej "qp"O GO U'I {tquecr g"Fcvc, 2008 International Conference
on Computer Science and Software Engineering, Wuhan, Hubei."
r ci gu'3: 8/3: ; "

]; _ O ci c y kenn'Ugdcuvkcp"Q0J 0'J cttkuqp"Cpf tgy "L0N0'Xcki{cpckcp"
Tcxk0Cp"ghhkekgpv'qtkgpvckqp"hkngt'hqt "KO Wu'cpf "O CTI "ugpuqt'cttc{u0'
Cr tkn'; ."4232."wpr wdnkuj gf "

]32_ Mkco "J gqpi "Cpi ."Tgi q'Ej qpi ."[wp"N0'RKF "Eqpvtqn'U{uvgo "
Cpcn{uku."F guki p."cpf "Vgej pqnqi {0Lwn{."4227."KGGG"Vtcpucevkqp"qp"
Eqpvtqn'U{uvgo u'Vgej pqnqi {."xqn035"pq060'

7 CONCLUSIONS

Kp"yjku"r cr gt"y g'j cxg"r tgugpvgf "yjg"yjqng"vtktqvqt"u{uvgo ."
dgi kppkpi "y kj "yjg"o ej cpkecn'eqpuvtwevkqp"cpf "yjgp"yj tqwij "
yj g'gngevtqpkeu'\knn'yjg'eqpvtqn'cni qtkjo "ko r ngo gpvckqp'cv'yjg"
ncuv" uvci g0'Vjg "vtktqvqt" cgtkcn'tqdqv" ecp "o cng" r quukdng" qh"
r ngpv{"qh'r qvgpvkcn'cr r nkecvkqpu'hqt "wpo cppgf "cgtkcn'xgj kengu0'