

## USING LIFELINES FOR SPATIOTEMPORAL SUMMARIES

\$QMKRQ\ 6WHIDQLGLV 3DQD\RLV 3DUWLQHYHORV 3HJJ\ \$JRXULV  
' HSDUWPHQW RI 6SDWLDQ ,QIRUPDWLRO (QJLQHULQJ  
1DWLRODQ FHOWHU IRU \*HRJUDSKLF ,QIRUPDWLRO DQG \$QDQ\VLV  
8QLYHUVLW\ RI ODLOH %RDUGPDQ +DQD  
ZURQR O( 86\$  
'WRO\ SDQRV SHJJ\ #VSDWLDQ PDLOH HGX  
KIWS ZZZ VSDWLDQ PDLOH HGX aSHJJ\ GJL KIWPQ

### Abstract

,Q WKLV SDSHU ZH SUHVHQQW D JHQHUDO IUDPHZRUN IRU WKH DQDQ\VLV RI VSDWLRLWHPSRUDO GDWDVHW 2XU DSSURDFK PDNHV XVH RI DQ DQDQ\VLV RI VSDWLRLWHPSRUDO WDMHFWULHV GHVFULELQJ WKH SDWK LQ VSDFH DQG WLPH RI REMHFHW LQ RXU GDWDVHW : H KDYH GHYHORSHG D YDULDWLRQ RI VHOI RUJDQL]LQJ PDSV WR JHQHUDOL]H WKHWH REMHFHW OLTIHOLQHV E\ SHUPLWLLQJ YDULDEOH UHVROXLRQV WR UHSUHVHQQW FRPSOH[ VHWPHQW FRPSDUHG WR VPRRWKHU RQHV 7KLV DQDQ\VLV XV WR EHWWHU UHSUHVHQQW WKH FRPSOH[ VSDWLRLWHPSRUDO EHKDYLRU RI REMHFHW DQG WR LGHQWL\ FULWFDQ LOVWDOFHV LQ WKHLU OLTIHOLQHV ZKHQ FHUWLRQ DVSHFW RI WKHLU EHKDYLRU FKDQJH 7KH UHVXOWLQJ JHQHUDOL]HG UHSUHVHQQWLRQ LV WKH NH\ FROFHFW WKDW VXSSRUW WKH JHQHUDWLRQ RI VSDWLRLWHPSRUDO VXPPDULHV 7KH HIIHFILYHQHV RI RXU K\EULG 620 WHFKQLTXH IRU VSDWLRLWHPSRUDO JHQHUDOL]DWLRO LV GHPRQVWDWHG ZLWK HDUO\ H[SHULPHQWDO UHVXOW

### 1. Introduction

\*HRVSDWLDQ DSSOLFDMRQV WHQG WR EHFRRPH LQFUHDVLRQ\ VSDWLRLWHPSRUDO 7KH LQIRUPDWLRO WKDW DQDQ\VLV VHHN RIWHQ UHVLGHV QRW LQ D VLQJQH LPDJH RU D PDS EXW LQ D PXOWLWHPSRUDO FROOHFWLRO RI LPDJHV DQG PDSV LQVWHDG 9DULRXV SDUDOOHO DGYDQFHPHQW LQ VHOVLU WHFKQRORJ\ KDYH DQDQ\VLV XV WR FROOHFW HDVLO\ YDQXDEOH PXOWLWHPSRUDO JHRVSDWLDQ LQIRUPDWLRO 5HOLDEOH VDWLQWV DHULDO DQG JURXQG LPDJHV\ FQD EH UHGLQ\ DYDLODEOH RQ GHPDQG RU SHULRGLFDO\ \$GYDQFHPHQW LQ YLGHV VHOVLUV DUH DQV SURYLGLQJ XV ZLWK WKH RSSRUWXQLW\ WR FDSWXUH G\QDPLF HYHQW FDSWXUH LQ YLGHV GDWDVHW (YHQ EH\ROG LPDJHV\ WKH DYDLODEOLW\ RI FKHDS DQG FRPSDFW SRVLWLRQLQJ GHYLFHV DQDQ\VLV XV WR FDSWXUH REMHFHW WDMHFWULHV FUHDWLRQ D QRYHO W\SH RI VSDWLRLWHPSRUDO LQIRUPDWLRO 7KH SURFHVWLQJ DQG DQDQ\VLV RI VSDWLRLWHPSRUDO GDWD FROOHFWLRQV LV LQWURGXFLQJ VRPH LQWHUHVWLQJ FKDQJHJHV PRVW\ DVVRFDWHG ZLWK WKH VL]H DQG FRPSOH[LW\ RI WKH LQIRUPDWLRO VSDFH WKDW KDV WR EH H[SORUHG ,W DQV LQWURGXFLV LQWHUHVWLQJ FKDQJHJHV RQ PHWDGDWD DV H[LQWLQJ DSSURDFKHV DUH UDWKHU VWDNLQ LQ QDWXUH 7KLV SDSHU DGGUHVVHV WKH XVH RI VSDWLRLWHPSRUDO OLTIHOLQHV WR VXPPDUL]H WKH LQIRUPDWLRO FROOHFW RI PXOWLWHPSRUDO GDWDVHW 7KLV VXPPDUL]HG LQIRUPDWLRO FQD WKHQ EH XVHG WR FUHDWH PXOWLPHGLD VXPPDULHV RI GDWDVHW FROOHFWLRQV VHUYLQJ DV QRYHO PXOWLPHGLD PHWDGDWD IRU WKHP 7KH SDSHU GHDOV SULPDULO\ ZLWK PRQLWRULQJ DSSOLFDMRQV ZKHUH IHZ REMHFHW PRYH DQG LQWHUDFW WKURXJKRXW D UHODILYHO\ VWDQGHQ EDFNJURXQG VFHQH

,QWHUHVWLQJ ZRUN RQ VSDWLRLWHPSRUDO VXPPDUL]DWLRO KDV EHHQ SHUIRUPHG RQ YLGHV DQDQ\VLV : RUN UHODYDQW WR RXU WRSLF LQFOXGHV WKH XVH RI LPDJH WHPSDWHV VDWLQWV IHDWXUHV DQG KLVWRJUDP EDVHG UHWHUHYDO DQG SURFHVWLQJ WHFKQLTXHV >&KDJ HW DO @ 9LGHV VXPPDUL]DWLRO LV WKH REMHFILYH RI ZRUN RQ WKH JHQHUDWLRQ RI D ÷NLPL\ YLGHV WR UHSUHVHQQW D V\QRSLV RI WKH RULJLQDQ YLGHV WDLQJ LQWR FROVLGHUWLRQ ERWK YLVXDO DQG VSHHFK SURSHULHV >6PLWK . DQDQ\VLV @ 9LGHV SRVWHUHV KDYH DQV SURSRVHG DV DQWUDQILYHV WR GHVFULEH D YLGHV WURU\ FROOHFW ><HXQJ <HR @ : RUN RQ WRSLFV XVHIXOH IRU VXPPDUL]DWLRO LQFOXGHV WKH DSSURDFKHV WR LGHQWL\ GLTIHQW VHQHV ZLWKLO D YLGHV WUDHP E\ DQDQ\VLQJ D YDULW\ RI SURSHULHV >9DVFROFHORV /LSSPDQ @ DQG WKH ZRUN WR H[WUDFW DQG UHFRJQL]H PRYLOJ

REMFWW DQG FODVLI\ WKHLU PRMLRQ >OHGLRQL HW DO 5RVDOHV 6FODURII @ ,Q DGGLWLRQ WKH JHQHUDLWRQ RI VSDMLRWHPSRUDO \QWKLWLF GDWDVHW WR VLPXODWH PRYHPHQW WJDMHFWRULHV LV SUHVHQMHG LQ >31RVHU 7KHRGRULGLV @ ,Q WKH GDWDVHV GRPDLQ ZH KDYL WKH ZRUN WHPSRUDO JRRPLQJ RI >+RUQVE\ (JHQKRIHU @

,Q WKLV SDSHU ZH SUHVHQM D JHQHUDO IUDPHZRUN IRU WKH DQDO\VLV RI VSDMLRWHPSRUDO GDWDVHW )RU UHWHUHQFH ZH DVVXPH WKH XVH RI YLGR GDWD DV LOSXW IRU RXU ZRUN : H GUDZ RXU PRMLYDWRQ IURP PRQLWRULQJ DSSOLFDWRQV ZKHUH REMFWW PRYH DQG LQWUDFW WKURXJKRXW D UHODWLYHO\ VIDEH EDFNJURXQG VFHQH : H SUHVHQM D IUDPHZRUN WR DQDO\]H VXFK GDWDVHW LQ RUGHU WR SURGXFH EULHI VXPPDULHV RI WKHLU FROTHQW 2XU DSSURDFK PDNHV XVH RI DQ DQDO\VLV RI VSDMLRWHPSRUDO OLIHOLQHV WR GHVFULEH WKH SDWK LQ VSDFH DQG WLPH RI REMFWW LQ RXU GDWDVHW \$ OLIHOLQH FDQ EH EURDGO\ GHILQHG DV D VHTXHQFH RI WKH VSDWDO ORFDLWRQV [ \ ] ; RI DQ REMFWW RYHU D WLPH LQWUYDO W<sub>1</sub> W<sub>2</sub> GXULQJ ZKLFK DQ REMFWW KDV PRYHG IURP RQH ORFDLWRQ WR DQRWKHU ,Q WKH FDVH RI D YLGR GDWDVHW WKLV LQWUYDO LV VXDDO\ D YLGR VKRW DQG WKH VHTXHQFH RI VSDWDO ORFDLWRQV GHVFULEHV WKH REMFWWV ORFDLWRQ DW HYHU\ IUDPH RU DW IL[HG WLPH LQWUYDOV H J HYHU\ VHFROG \$OHUODWLYHO\ WKH WLPH LQWUYDO RI DQ REMFWWV OLIHOLQH PD\ EH D VXEVHW RI D ORQJHU YLGR VKRW DV W<sub>1</sub> DQG RU W<sub>2</sub> PD\ EH WKH WLPH WKH REMFWW HQMHUHG DQG RU H[LQHG WKH YLGR FDPHUD ILHOG RI YLZ ,QGLYLGXDO OLIHOLQHV DUH DQDO\]HG WR LGHQWL\ FULMLFDO SRLQW GHORMLQJ LQVMDQFHV ZKHUH WKH REMFWWV EHKDYLRU FKDQJHV H J DFFHOHUDWLV RU PDNHV DQ DEUXSW WXUQ 7KHVH LQVMDQFHV GHORWH HYHQW LQ DQ REMFWWV WJDMHFWRULHV DQG DUH LPSRUDQW LQIRUPDWRQ IRU VXEVHTXHQW DQDO\VLV : H FDQ PRYH IURP VLQJOH WR PXOWLSOH WJDMHFWRULHV E\ VSDWDO UHODLWRQV H J WRSRORJ\ RULHQDWRQ GLVMDQFH DQG WKLV DOORZV XV WR LGHQWL\ JURXS RI REMFWW RU EHKDYLRUDO VLPLDULWLV LQ JHQHUDO ,W VKRXOG EH QRWIG WKDW DW WKLV WNDJH RXU DQDO\VLV IREXVHV RQ WKH VSDWDO SURSHULWV RI DQ REMFWW H J ORFDLWRQ VKDSH DQG ZH DUH QRW DGGUHVVLQJ WKHPDULF LQIRUPDWRQ H J XVH RZQHUVKLS

: KLOH ZH IREXV RQ WKH DQDO\VLV RI YLGR GDWDVHW WKH IUDPHZRUN FDQ EH JHQHUDO]HG WR IXQFWLRQ RQ DQ\ W\SH RI VSDMLRWHPSRUDO GDWDVHW ,QHG D YLGR VHTXHQFH FRXOG EH VXEVWLWXWHG E\ D DOUJH FROOHFWLRQ RI \*,6 OD\HUV UHSUHVHQWLQJ GLIHUHQW LQVMDQFHV RI WKH VDPH DUHD RYHU PDQ\ \HDUV RU E\ D FROOHFWLRQ RI LPDJHU\ JDWKHUHG E\ D VDMHOLWH DV LW SDVVHV RYHU WKH VDPH UHJLRQ LQ LW OLIHNLPH RU HYHQ E\ WKH SRVLWRQDO LQIRUPDWRQ RI \*36 HQDEOHG DJHQW URDPLQJ LQ D ILHOG 6LPLDULW\ DQ REMFWW LQ D YLGR VHTXHQFH FRXOG EH VXEVWLWXWHG E\ DQ HYROYLQJ JHRVSDWDO HOWN\ H J D FURS ILHOG RU D EXLOGLQJ FRPSOH[

7KLV SDSHU LV RUJDQL]HG DV IROORZV ,Q VHFWRQ ZH SUHVHQM D JHQHUDO RYHUYLHZ RI RXU VXPPDUL]DWRQ IUDPHZRUN ,Q VHFWRQ ZH SUHVHQM RXU QRYHO DSSURDFK IRU VLQJOH REMFWW JHQHUDO]DWRQ ZKLOH LQ VHFWRQ ZH GLVFXVW LVVXHV UHODWIG WR WKH JURXSQJ RI PXOWLSOH REMFWW : H FROFOXGH ZLWK HDUO\ H[SHULPHQDO UHVXOW LQ VHFWRQ

## 2. Proposed Framework

2XU DSSURDFK SURFHGHV E\ DQDO\]LQJ WKH VSDMLRWHPSRUDO WJDMHFWRULHV RI PRYLQJ REMFWW 7KH SURSRVHG IUDPHZRUN LV VKRZQ LQ ILJXUH ,Q WKH YLGR GDWDVHW ZH DVVXPH D FODVLI]DWRQ RU FRDUVH WJDFNLQJ WKDW KDV LGHQWLILHG LQ HDFK IUDPH RU LQ VHOHFW IUDPH WKH DSSUR[LPDWH RXWLOH RI PRELOH REMFWW 7KLV LQIRUPDWRQ PD\ EH FRUUXSWHG E\ YDULRXV W\SHV HUURUV OLNH RFFOXVLRQV QRLVH DQG PLVFODVLIHG SL[HQV \$ VSDMLRWHPSRUDO WJDMHFWRULHV LV SURGXFHG E\ OLQNLQJ DQ WKLV LQIRUPDWRQ DQG LQFOXGHV LQKHUHQW\ DQ SHULQHQW LQIRUPDWRQ IRU WKH EHKDYLRU RI D PRYLQJ REMFWW RYHU WKH FRUUVSRQGLQJ WLPH LQWUYDO +RZHYHU VRPH RI WKLV LQIRUPDWRQ LV UHGXQGDQW DQG VKRXOG EH WUXQFDWHG IRU LPSURYHG DQDO\VLV VWRUDJH DQG FRPPXQLFDWRQ ZKLOH VRPH RI WKLV LQIRUPDWRQ LV VLJQLILFDQW DQG VKRXOG EH LGHQWLILHG DQG HPSKDV]HG ,Q RUGHU WR FDSWXUH WKH VLJQLILFDQW SRUMLRQ RI WKLV LPPHQVH GDWD IORZ ZH UHTXLUH WKH HILFLHQW DQG DFFXUDWH VSDMLRWHPSRUDO JHQHUDO]DWRQ RI WKHVH WJDMHFWRULHV

7JDMHFWRULHV FDQ EH SHUFHLYHG DV SDMKV LQ WKH VSDMLRWHPSRUDO 67 VSDFH 7KHUHUH ZH KDYL H[WHQGHG D PHWKRGORJ\ RULJLQDOO\ LQHQGHG WR SHUIRUP URDG H[WJDFWRQ IURP VDMHOLWH LPDJHU\ WR FDSWXUH DQG JHQHUDO]H VSDMLRWHPSRUDO WJDMHFWRULHV 2XU URDG H[WJDFWRQ DSSURDFK ZDV EDVHG RQ WKH XVH RI VHOI RUJDQL]LQJ PDSV 620 >. RKRQHQ @ WR H[WJDFW URDG FHOWUOLQHV >' RXFHWHH HW DO @ 7KH 620

WHFKQLTXH QRW RQO\ OLQNV SL[HOV LQWR URDG FHOVHUOLQHV EXW DOVR GLVWLEXMHV QRGHV DORQJ WKH URDG WR JHQHUDOL]H WKH H[WUDFWHG FHOVHUOLQH

&RPPRQ 620 VROXNLROV SUHVHQQV VRPH VKRUFWRPLQJ\ PRVW QRWDEOH RI ZKLFK DUH WKH KLJK YDULDELOLW\ RI WKH WHFKQLTXH LQ YDULRXV LWHUDNLROV DQG WKH LQDELOLW\ WR GHQVL\ WKH QXPEHU RI QRGHV LQ KLJKO\ FRPSOH[ DUHDV 7R RYHUFRPH WKLV SUREOHP ZH LQJURGXFH LQ WKLV SDSHU D\K\EULG DSSURDFK ZKHUH 620 LV IXUMKHU HQKDQFHG E\ D JHRPHWULF DQDO\VLV 7KLV DOORZV XV WR LGHQWL\ KLJK YDULDNLRO DUHDV H J PRPHQW RI UDSLQ W\XUQV RU DEUXSW DFFHOHUDNLRO GHFHOHUDNLRO LQ D YLGR DQG GHQVL\ VHOHFWLYHO\ WKH QXPEHU RI QRGHV RYHU WKHVH LQWHUYDOV 6LPLQDUO\ ZH FDQ DOVR LGHQWL\ DUHDV RI QRZ YDULDNLROV H J LQWHUYDOV RI VWHDG\ PRYHPHQW DQG VHOHFWLYHO\ WKLV WKH QXPEHU RI QRGHV RYHU WKHVH LQWHUYDOV 7KLV JHRPHWULFDUO\ HQKDQFHG 620 VROXNLRO DOORZV XV WR H[WUDFW JHQHUDOL]HG OLIHOLQHV IURP WKH GHQVH VSDWLRLWHPSRUDO WUDMHFWRULHV RI VLQJOH REMHFW OXOML REMHFW WUDMHFWRU\ DQDO\VLV LQJURGXFHV UHODNLRODO FROVLGHUDNLROV IRU WKH VHOHFWLRQ RI DGGLWLRQDO QRGHV ([DPSOHV RI LPSRUNDQW VSDWLRLWHPSRUDO REMHFW UHODNLROV LQFOXGH WRSRORJ\ SUR[LPLW\ DQG XVHU GHILQHG UHVWULFWLRQV \$Q DQDO\VLV RI WKHVH SURSHULHV FDQ SURYLGH XV ZLWK TXDOLWLYH PHWULFV WR GHILQH TXDOLWLYH FROFHSW OLNH  $\mu$ JURXS $\eta$   $\mu$ FROYR $\eta$  RU  $\mu$ H[SHFWHG EHKDYLRU $\eta$  ZKLFK DUH HVVHOMDO IRU VXPDPUL]LQJ VSDWLRLWHPSRUDO GDNDVHW 6XFK PXOML REMHFW LQIRUPDNLRO SURYLGHV XV ZLWK DGGLWLRQDO LOSXW ZKHQ LGHQWL\LQJ LPSRUNDQW LQVWDQFHV LQ RXU GDNDVHW DQG DOORZV XV WR PRYH WR KLJKHU OHYHOV RI DEVWDFNLRO

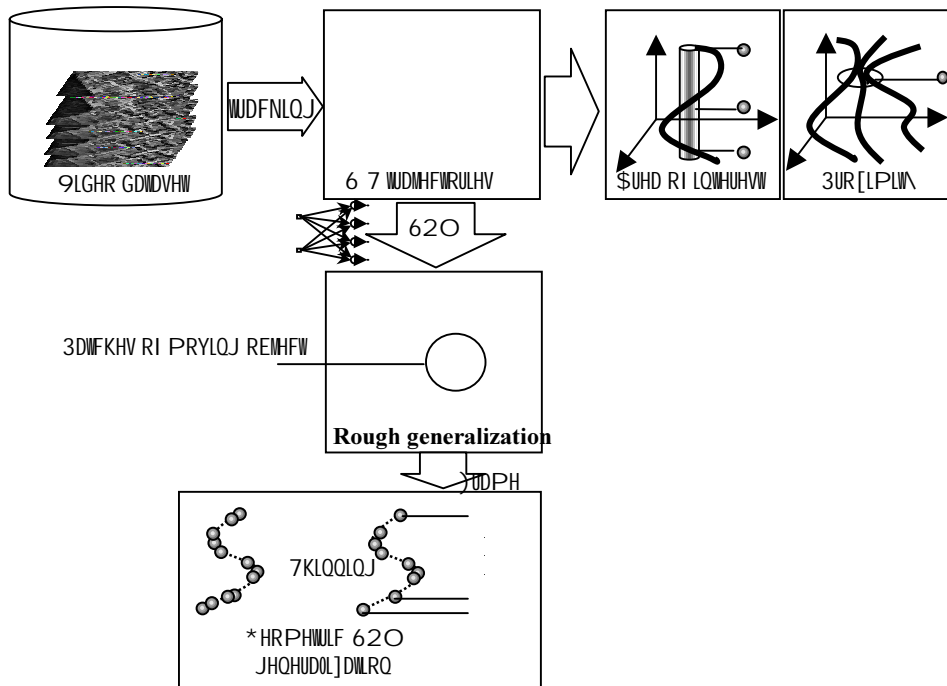


Figure 1: Outline of proposed framework

)RU YLGR VHJPHQDNLRO VIRUDJH DQG UHWLHYDO DSSOLFNLROV WKH PRVW LPSRUNDQW DVSHFW RI RXU K\EULG JHQHUDOL]DNLRO DSSURDFK LV WKDW LW DFFRPPRGDWHV VSDWLRLWHPSRUDO JRRPLQJ 7KLV JRRPLQJ LV EDVHG RQ D G\QDPLF FROVHQW GHILQHG VFDOH UDWKHU WKDQ D VWDEOH WHPSRUDO LQFUHPHQW EDVHG VFDOH ,Q RYHU ZRUGV ZH FDQ XVH PRUH IUDPHV FROVHU WR HDFK RYHU WR UHSUHVHQW DEUXSW PRILROV FRPSDUHG WR IHZHU IUDPHV WR UHSUHVHQW VPRRWK UHJXODU PRYHPHQW ,Q DGGLWLRQ WKH UHVXOWLQJ OLIHOLQHV FDQ EH VHUWH DV REMHFW PHWDGDND

ILOHV WIKDW IDFLQDQW UHWLHYLOJ TXHU\LOJ DQG VLPLODULW PDWFKLOJ 7KH\ GLVPDQNH WKH EHKDYLRU RI D PRYLOJ REMHFWLQ LW SULPDU\ DWWULEXWHV DQG WKXV HQDEOH EHKDYLRU EDVHG TXHULHV

### 3. Single Object Analysis

7KH VHOI RUJDQL]LOJ PDS 62O DOJRULWKP LV D QRQOLQHDU DQG QRQSDUDPHWULF UHJUHVVLRO VROXNLRO WR D FODVV RI YHFWRU TXDQML]DWLRO SUREOHPV ,W EHOQJV WR D GLVWLQFW FODVV RI DWWLILFDO QHXUDO QHWZRUNV \$11 FKDUDFWLUL]HG E\ XQVXSHUYLVHG DQG FRPSHWLILYH OHDUQLQJ ,W SURFHGV E\ GLVWULEXLOJ ORGHV WR GHVFULEH WKH VSDWDO GLVWULEXLOJ RI WKH LOSXW VSDFH : H XVH LW DV WKH EDVLV RI RXU VSDWLRIWPSRUDO JHQHUDOL]DWLRO

6WDOGDUG 62O DOJRULWKPV WHQG WR IXQFWLRO ZHOO ZKHQ OLQHDUL]LOJ URDG VHJPHQW LO DHULDO LPDJHU\ DV WKHVH VHJPHQW DUH UHDFRQDE\ VPRRWK OLQHV +RZHYHU VSDWLRIWPSRUDO WUDMHFWULHV WHQG WR LQFOXGH DEUXSW YDULDWLRQ H J DQ REMHFW PD\ FKDQJH LW YHORFLW DQG RULHQDWLRO YHU\ RIWQ LO D OLPLWHG DUHD 7KLW PDNHV WKH XVH RI VSDWDOGDUG 62O WHFKQTXHV LQDGHTXDWH IRU VSDWLRIWPSRUDO JHQHUDOL]DWLRO 7R RYHUFPH WKLW SUREOHP ZH KDYH GHYHORSHG D K\EULG JHRPHW\ HQKDQFHG WHFKQTXH &RPSDUG WR D VSDWDOGDUG 62O SURFHVV RXU K\EULG WUDMHFWRU\ DQD\VLV DSSURDFK RI IHUV WKH DGYDQD]HV RI

- LOYDULDQFH WR WKH VHOHFWLRO RI WKH LQLWDO QXPEHU RI ORGHV DQG WKH
- DELOLW WR VHOHFWLRO\ GHQVL\ RU WKLQ RXU ORGH GLVWULEXLOJ WR EHWLHU FDSWXUH WKH FRPSOH[LW RI FROWHQW RI WKH SURFHVVHG GDWDVHV

7KLW DOORZV XV WR XVH PXOWSOH UHVROXNLROV ZKHQ JHQHUDOL]LOJ D VLOJOH OLIHOLQ 7KLW LV HTXLYDOHQW WR VHOHFWLQJ YDULRXV VFDQ IDFWRUV EDVHG XSRO WKH FRPSOH[LW RI WKH LQIRUPDWLRO LQFOXGHG LO WKH GDWDVHV &RPSOH[LW LV GHILQH LQ RXU FROWHQW DV WKH YDULDWLRQ RI DQ REMHFWV VSDWLRIWPSRUDO ORFDWLRQ ,Q RUGHU WR GHWHFW DQG TXDQML\ WKLW YDULDWLRQ ZH XVH DV NH\ PHWULF IRU RXU DQD\VLV WKH GLPHQVLRQDO DOJOH IRUPHG EHWZHHQ WKLW VXEVTXHQW ORGHV LO WKH GLPHQVLRQDO VSDWLRIWPSRUDO VSDFH [ \ W (DFK SDLU RI SRLOW GHVFULEHV D μVNDW\ RI VSDWLRIWPSRUDO EHKDYLRU 7KH DOJOH EHWZHHQ WZR FROWHFWLILYH VNDWV LV LQGLFDILYH RI WKH ORFDO VSDWLRIWPSRUDO YDULDWLRQ +LJK GHYLDWLRQV RI WKHVH DOJOHV IURP ° LQGLFDWH H[WHPH YDULDWLRQV EHWZHHQ VXEVTXHQW VNDWV DQG UHTXLUH PRUH GHQVHO\ GLVWULEXHG JHQHUDOL]DWLRO ORGHV

2XU DOJRULWKP LGHQWLILHV ORFDWLRQV ZKHUH GHQVLILFDWLRQ LV QHHGHG DQG HYDOXDWHV WKH QXPEHU RI DGGNLRODO UHSUHVHQMLQJ ORGHV 7KHQ QHZ ORFDOL]HG 62O VROXNLROV DUH SHUIRUPHG DQG WKLQQLQJ WDNHV SODFH LO RUGHU WR UHPRYH ORGHV WDW GR QRW FROWLXWH WR JHQHUDOL]DWLRO ,Q WKLW PDQGHU WKH GHJUHH RI JHQHUDOL]DWLRO LV EDVHG RQ WKH YDOXH RI WKH GLPHQVLRQDO DOJOH DQG ORGH UHSRVLWRLOLQJ DQG GHQVLILFDWLRQ SURFHVV WDNHV SODFH XVLOJ WKLW VSDWLRIWPSRUDO DOJOH LQIRUPDWLRO \$ GHNDLOHG GHVFULSWLRO RI WKH DOJRULWKP PD\ EH IRXQG LQ >6WHIDQLGLV HW DO @ 7KH SURGXFW RI WKLW SURFHGXUH LV D JHQHUDOL]HG VSDWLRIWPSRUDO OLIHNLPH RI WKH LQLWDO GDWDVHV )XUMKHU VSDWLRIWPSRUDO ]RRPLQJ FDQ WDNH SODFH E\ VHOHFWLQJ OHVV RU PRUH ORGHV WR GHVFULEH WKH PRYHPHQW DWWULEXWHV 7KH YDULDEOH XSRO ZKLFK GHQVLILFDWLRQ LV GHWHUPLQHG FDQ EH XVHU GHILQH DQG TXDQML\ WKH YROXPH RI WKH VSDWLRIWPSRUDO ]RRPLQJ

\$Q HUURU HVLPDWLRO LV GHILQH E\ PHDVXULQJ WKH GLVNDQFH EHWZHHQ WKH DFWXDO DQG JHQHUDOL]HG OLQH XVLOJ ERWK 62O DQG K\EULG JHRPHW\ 62O JHQHUDOL]DWLRO SURGXFW ILJ

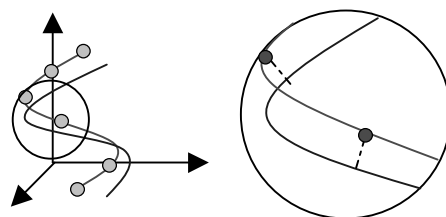


Figure 2. Lifeline distances in a 3-D ST space.

\$ PHDVXUH RI WKH VSDWLRIWHPSRUDO GLVNDQFH  $G_{ST}$  EHWZHHQ D WUDMFWRU\ L DOG WKH JHQHUDOL]HG QRGH SR0\ OLOH MLV SURYLGHG E\

$$d_{ST} = \sqrt{\frac{\sum d_n^2}{n}}$$

ZKHUH Q LV WKH QXPEHU RI 620 QRGHV DORQJ WUDMFWRU\ M DOG  $G^j$  LV WKH GLVNDQFH EHWZHHQ WKH WUDMFWRU\ DOG WKH JHQHUDOL]DMLRQ QRGHV LO WKH 67 VSDFH )LJ 8VLQJ ERWK JHQHUDOL]DMLRQ WHFKQTXHV LW LV REYLRXV DV GHPRQVUDWHG LO WKH H[SHULPHQWDO VHFMLRQ WKDW WKH SURSRVHG K\EULG WHFKQTXH LV VLJQLILFDQW\ FORVHU WR WKH RULJLQDO GDWDVHW WKDQ WKH 620 RQH

#### 4. Multiple Object Analysis

7KH FROVLGHUWLRQ RI PXOWLSOH REMHFW EULOJV IRUZDUG WKH QHHG WR DGGUHVW WZR LVVXHV )LUVW ZH KDYH WR VHOHFW VSHFLILF WLPH LOVNDQFHV IRU RXU YLGR VXPDPULHV XVLOJ LQGHSHQGQW QRGHV IURP PXOWLSOH WUDMFWRULHV 6HFRQG ZH KDYH WR FROVLGHU WKH LQWJRGXFMLRQ RI DGGULRQDO QRGHV ZKHQ WDLQJ LQWR DFFRXQW WKH UHODWLRQV RI WZR RU PRUH WUDMFWRULHV 2QH FDQ HDVLO\ XQGHUVWDQG WKDW WKH WHPSRUDO FRRUGLQDWHV RI QRGHV GHVFULELOJ WKH SDWK RI REMHFW DOG WKHVH GHVFULELOJ WKH SDWK RI DQRWKHU REMHFW M PD\ EH WRWDOO\ GLVWRLQW 7KH FRPSDUDWLYH DQDO\VLV RI WKHVH WZR OLIHOLQHV PD\ \LHG LOVNDQFHV RI LQWUHVV IRU H[DPSOH ZKHQ WKH\ DSSURDFK HDFK RWKHU 7KHUH IRUH ZH LQWJRGXFH QRGHV WHUPHG #SUR[LPLW\ QRGHV ZKHQ WKH GLVNDQFH EHWZHHQ WZR RU PRUH REMHFW GURSV EHORZ FHUWLOJ SUHGHIHQG WUHVVRQ ,Q DGGULRQ WKH XVHU PD\ GHILQH DUHDV RI LQWUHVV ZLWKLO ZKLFK ZH FDQ LOFUHDVH WKH PRQLWRULQJ UHVROXWLRQ

7RSRORJLF UHODWLRQV DQV GHILQH LPSRUDQW LQIRUPDMLRQ WKDW LV FDSWXUH WKURXJK DGGULRQDO QRGHV )RU D WHPSRUDO LOVNDQFH WKH HOHPHQW LOFOXGHG LO D UHODWLRQDO FRPSDULVRQ EHWZHHQ REMHFW DUH GLUHFWLRQ DOG GLVNDQFH : KHQ ZH UHWHU WR D WHPSRUDO LOFUHPHQW GLIHUHOHFW LO GLUHFWLRQ DOG GLVNDQFH DUH RI LQWUHVV ,Q DGGULRQ WKHVH DWULEXWV DQV UHWHU WR RQH REMHFW HYROYLOJ LO WLPH ,Q WKLW FDVH FDUGLQDO GLUHFWLRQ RU DEVROXW GLVNDQFH GR QRW FROWULEXW WR WKH VLJQLILFDQFH RI WKH FKQJH 7KHU GLIHUHOHFW SD\ WKH PRVW LPSRUDQW UROH ,Q RUGHU WR FDSWXUH WKH LOVNDQDQRXV UHODWLRQ EHWZHHQ WZR REMHFW ZH XVH RQH RI WKH NQRZQ WRSRORJ\ FDUGLQDOLW\ PRGHV >(JHQKR IHU )UDQ]RVD @ 7KHVH UHODWLRQV DUH TXDQNLHG WKURXJK WRSRORJLF PRGHV EXW WKH\ DUH EH\RQG WKH VFRSH RI WKLW SDSHU

,Q RUGHU WR LQWJUDWH DOG PHUJH DQ WKH VHOHFWHG QRGHV IURP PXOWLSOH WUDMFWRULHV ZH LQWJRGXFH FR UHJLVWUDWLRQ FKHFNV WR KDQGH RYHUFURZGHG QRGH DUHDV : KHQ JURXSLOJ PXOWLSOH WUDMFWRULHV QRGHV VHSODWWHG E\ OHVV WKDQ D PLQLXP LQWUYDO GW DUH PHUJHG DOG VXEVLWXWHG E\ D VLQJOH DYUDJH QRGH DYUDJLOJ SURFHV +RZYHU ZKHQ DGMDFHQW QRGHV DUH GHVFULELOJ ORQJ VHJPHQW WKH VXPDPULV LO ORFDQO\ DSSUR[LPDWHG E\ D EULHI QHGU YLGR VHJPHQW 2WKHUZLVH LW LOFOXGHV GLVNDQFH VSDUVH LOVNDQFHV &RPELQHG WKHVH VSDUVH LOVNDQFHV DOG EULHI YLGR VHJPHQW SURGXFH D QHZ UHSUHVHQDWLYH DOG FROFLVH YLGR VXPDPULV ZKHUH WHPSRUDO UHVROXWLRQ FKQJHV G\QDPLFDQW\ WR EHVW FDSWXUH YDULWLRQV RI VSDWLRIWHPSRUDO DWULEXWV

#### 5. Experiments

7KH DSSURDFK GHVFULEHG LO WKLW SDSHU KDV EHHQ LPSOHPHQWHG LO WKH O\$7/\$% HQYLURQPHQW : H FUHDWHG V\QWKHULF GDWDVHW RI PRYLOJ REMHFW WR XVH LO RXU H[SHULPHQW : H DQV JHQHUDWHG UDQGRP EHKDYLRUV RI VSDWLRIWHPSRUDO WUDMFWRULHV WR GHVFULEH REMHFW PRYLOJ ZLWK WDEOH RU YDULDEOH YHORFLW\ 7KH IRORZLOJ ILJXUHV VKRZ VRPH H[SHULPHQW SHUIRUPHG LO RUGHU WR H[KLELW WKH SUHVHQWHG WHFKQTXHV

,Q ILJXUH ZH SUHVHQW D URXJK JHQHUDOL]DWLRQ RI D VSDWLRWHPSRUDO WUDMHFWRU\ D WKH GHQVLILFDWLRQ RI WKH VSDWLRWHPSRUDO WUDMHFWRU\ ZLWK GLTIHUHQW JHQHUDOL]DWLRQ UHVROXWLRQ E F WKH SURGXFW RI WKLOQLQJ G DQG D GHWDLO RI WKH JHQHUDOL]DWLRQ H 7KH SRO\JRQLF OLQH LQ ILJXUH H GHPROVWUDWHV WKH VWDQGDUG 620 VROXWLRQ : H FDQ HDVLO\ VHH KRZ WKH QRGHV IURP RXU K\EULG DSSURDFK GHVFULEH WKH WUDMHFWRU\ P\XFK EHWWHU WKDQ WKH VWDQGDUG VROXWLRQ

Figure 3: a) SOM generalization, b,c) proposed generalization with different densification parameters, d) thinning product, e) generalization detail.

,Q ILJXUH WKH 620 JHQHUDOL]DWLRQ LV GHVFULEHG E\ †VNDU\ QRGHV ZKLOH WKH K\EULG JHQHUDOL]DWLRQ LV GHSLFWHG ZLWK WULDQJXODU QRGHV 7KH 506 HUURU DV GHILQH LQ VHFWRU LV SL[HOV IRU WKH 620 UHVXOW DQG RQO\ SL[HOV IRU WKH UHVXOW RI RXU K\EULG WHFKQLTXH

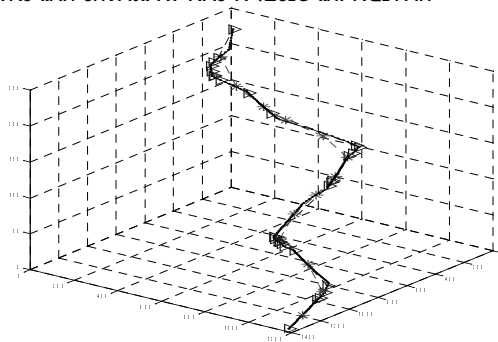
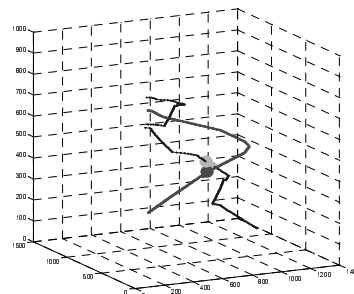
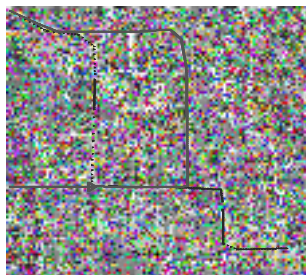


Figure 4: Precision comparison between SOM and hybrid techniques.

,Q ILJXUH ZH GHPROVWUDWH WKH VHOHFWRU RI SUR[LPLW\ QRGHV : H JHQHUDWHG WZR WUDMHFWRULHV WUDYHOLOJ WKURXJK URDG LQ WKH VFHQH VKRZQ LQ ILJXUH D 7KH SUR[LPLW\ QRGHV DUH LGHQWLILHG DQG VKRZQ DV FLUFQHV DORQJ WKH FRUHVSRQGLQJ WUDMHFWRULHV LQ ILJXUH E



)LQD00\ ZH VKRZ WKH FR UHJLVWDMLRQ RI WZR WUDMHFWRULHV LQ ILJXUH 7KH QRGHV IRU WKH VZR WUDMHFWRULHV DUH GHQRWHG E\ VWDUV DQG WULDQJOHV RQ WKH OHIW KDOG VLGH 7KH VNUXFVXUH RI WKH FRUJHVSROGLQJ VXPDPDU\ LV VKRZQ LQ ILJXUH ZLWK HORQJDWHG VHVPHQW LQGLFDMLQJ VKRUW YLGHRV DQG VPD00 VTXDUHV DQG FLUF0HV LQGLFDMLQJ VSDUVH LQVMDQFHV

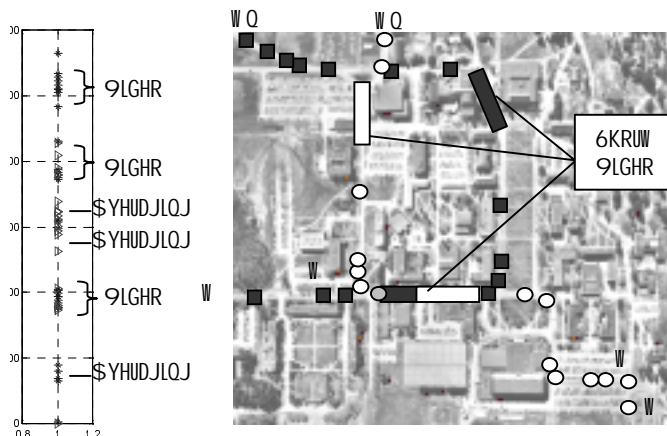


Figure 6: Registration and representation of product summary.

7KH DERYH ILJXUH DUH HDU0\ H[SHULPHQW0 UHVX0W DQG LQGLFDWH WKH SHUIRUPDQFH RI RXU SURSRVHG DSSURDFK ,W PDQJ DGYDQMDJH LV WKH SRMHQWDO IRU IX00 DXIRPDMLRQ DQG WKH DEL0W IRU REMHFWLYH \HW PHDQLQJIX0 DQD0\VLV RI VSDMLRWHPSRUDO GDMDVHW IR VXSURW WKHLU VWRULQJ EURZVLQJ DQG TXHU\LQJ 7KHVH DUH LVVXH WKDW ZH ZL00 EH DGGUHVVLQJ LQ WKH QHDU IXWXUH

**Acknowledgments**

7KLV ZRUN ZDV VXSURWHG E\ WKH 1 DMLRQD0 6FLHQFH )RXQGMLRQ WKURXJK ' LJLWDO \*RYHUQPHQW DZDUG QXPEHU ' \* ,

**References**

- > @ &KDQJ : \* 6KHLNKR0HV0DPL - : DQJ \$ =KDQJ ' DWD UHVRXUFH VHOHFWLRO LQ GLVMLEXMHG YLVXD0 LQIRUPDMLRQ V\VMHPV ,((( 7UDQVDFMLROV RQ . QRZ0HGJH DQG ' DWD (QJLQHULQJ
- > @ 6PLWK 0 7 . DQDGH 9LGH 6NLPPLQJ IRU 4XLFN %URZVLQJ EDVHG RQ \$XGLR DQG ,PDJH &KDUDFWHUL]DMLRQ 7HFK 5HSRUW &08 &6 &DUQHJLH 0H00RQ 8QLYHUVLW\
- > @ <HXQJ 0 %RRQ /RFN <HR 9LGH 9LVXD0L]DMLRQ IRU &RPSDFW 3UHVVH0WMLRQ DQG )DWH %URZVLQJ RI 3LFWRULD0 &R0WHQW ,((( 7UDQV RQ &697 SS
- > @ 9DVFROFH0RV 1 \$ /LSSPDQ \$ 6SDMLRWHPSRUDO 0RMLRQ 0RGH0 IRU 9LGH 6XPPDUL]DMLRQ &935¶ 6DQMD %DUEDUD
- > @ 0HGLRQL \* 5 1HYDMLD , &RKHQ (YHQW ' HWHFWLRO DQG \$QD0\VLV IURP 9LGH 6WUHDPPV ' \$53\$ ,PDJH 8QGHUVM0GLQJ μ SS

> @5RVD0HV 5 6 6F0DURI ' 7UDMHFWRU\ IRU 7UDFNLOJ OXWLSOH 2EMHFW DQG 7UDMHFWRU\ \*XLGHG  
5HFRJQLWRQ RI \$FWLRQV &935 μ

> @ 3IRVHU ' < 7KHRGRULGLV \*HQHUDLQJ 6HPDQMLFV %DVHG 7UDMHFWRULHV RI ORYLQJ 2EMHFW  
,QWUO : RUNVKRS RQ (PHUJLQJ 7HFKQRORJLHV IRU \*HR %DVHG \$SSOLFDMRQV %LUNKDHXVHU

> @ +RUQVE\ . O (JHQKRIHU 6KLIW LQ ' HMDLO WKURXJK 7HPSRUDO =RRPLQJ 3URFHGHGLOJV RI WKH  
WK ,QWUODMLRQDO : RUNVKRS RQ ' DWDVH ([SHUW 6\VMHPV \$SSOLFDMRQV

> @ . RKRQH 7 6H0I 2UJDQL]HG )RUPDMRQ RI 7RSRORJLFD0\ &RUUHFV )HDXUH ODSV %LRORJLFD0  
&\EHUQHMLFV SS

> @ ' RXFHWH 3 3 \$JRXULV \$ 6WHIDQLGLV O OXVDYL 6H0I 2UJDQL]HG &OXVWHULQJ IRU 5RDG  
([WDFMLRQ LQ &0DWLILHG ,PDJHU\ ,6356 -RXUQDO RI 3KRWRJUDPPHUU\ DQG 5HPRWH 6HQVLQJ SS

> @ 6WHIDQLGLV \$ 3 3DUWLQHYHORV 3 \$JRXULV 3 ' RXFHWH 6XPPDUL]LQJ 9LGHV ' DMDVHW LQ WKH  
6SDMLRWHPSRUDO ' RPDQ 3URFHGHGLOJV ' (; \$ ,((( 3UHV \*UHQZLFK SS

> @ 6WHIDQLGLV \$ 3 3DUWLQHYHORV 3 \$JRXULV \$XWRPDWHG 6SDMLRWHPSRUDO 6FDOLQ IRU 9LGHV  
\*HQHUDL]DMLRQ ,((( ,QWUODMLRQDO &RQIHUQFH RQ ,PDJH 3URFHVVLOJ ,&,3¶ LQ SUHV

> @ (JHQKRIHU O 5 )UDQ]RVD 3RLQW 6HW 7RSRORJLFD0 6SDMLD0 5HODMLRQV ,QW -RXUQDO RI  
\*HRJUDSKLFD0 ,QIRUPDMRQ 6\VMHPV