Laura Kovács



▲□▶ ▲□▶ ▲□▶ ▲□▶ ▲□ ● のへぐ

| STRATEGICS STRATEGICS  | there are a state and the state of the state | - Sutter   |   | Charman -                               |  | R  |   
   | Mental Street  | 1110.  | 200000   | WD-seturi shi shi va   | Non-                                    |   
  | Tradat Barnet  | Contraction of the second  | Distance.  | States and a state of the state   |  | STATUSTICS   
   | State approximation of   | 1005   |  | CONTRACT OF  |   
  |  | Managarang   | STATE OF STREET  | NUL  | 2                          |   
  |
|--|--|--|---|---|--
--	---	--	--	--
--	--	--	--	
--	--	--	--	
--	--	--	--	
--	----------------------------	--		
Statistica Statistica	Witte	BATHS BASAN		
   | Contraction of the local  | 128  | (With comm   |  | Contraction of the second  
   | ARRITATION OF THE OWNER                 | GLUDB UTABLICOL  | 205 anton  |  | W. P.Determent   |   
  | No.  | CORE IN COMPANY  |  |  | Contraction of the   
   |  |  |  | Like   | | |
  | Service A.   | Competence 2               | SARANANA<br>Maria Babana<br>Maria Babana   |
| 107.31   | Street an Spirite.   | 1 Marthanson   | title .   | entry it.                               |  |  
   |   | Carrow   | 21127-000  | *visitifiitilitaanin   | ACCOUNTS OF  
   | She.                                    | Cline-tr   | William Street   | And a second sec   |  | E  |  
   | And Address  | Collector Collector  | Patron States  | Ville  |   
  | -  |  |  | - Conservation -   |  
   |                            | E  |
| Collins  | Dura Dura  |  | Mary Construction   | 10043003063332<br>100009847284          |  | Discontantia.  
   |   | H Hot:   | Station of the   | Mole in  | Contraction of the second  
   |   |  | 1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.   | St 2-sup maple   | - Change - C | Character and  | Contraction of the second  
   | William"   |  |  | Contraction of the local of the | Tra Steingel,  | Star 1  
  | Contraction of the local data  | illin-   | States.  |  | and and a second           | No.   
  |
| T Base   | Same   | Charles and the second  | internation in the  |   |  | -  | Widthe man.  
  | 1.1896   | Concentration  | VARMAN   |  | ulan.                                   | No.  
   | inter Carola   | A MARKEN AND AND AND AND AND AND AND AND AND AN  | 1950   | Non-transformer al   | 143014 ;  
  | Anter State State of  |  | and and and a  | BHEIR R.   | RELEASE  | ROAD IN  
   | Pir.   | 4,3 <b>1</b> 1,  |  | 1.   | Statistics                 | PERMIT (CONSERVE)  
   |
| No.  |  | L. Contentar   | in it   | annon a                                 | Arrive seaver -  |  
   | Party of the second   | and a second   | S  | Title against  | de seren de la companya de la compan | Ser                                     | Principationer:   
  | Yorgania   | States and a state   | 140 di 100-  | Channe B   |  
   | Na.  |  |  | Denty,<br>III I denty Coloradore   |   
  | Distant of the second  |  | k  | nai bin fi   | WITE .   
   |                            | and a second   |
| Barrow Barrow  | Not a real formation of the second se | Zugati<br>Zugenze uzvanovana   | Anna anna anna anna anna anna anna anna   | ipaninala.                              | 211<br>Ant- 211  |  | Television -   
  | Titletita  | Company  |  | Careford and   | Course of March                         | Selen -  
   | TEN B BUILT  | Victor Constructions,  |  | Transfer and the second of the   | Second Carl   
  | Alternative and an an  | 15   | ting.  | 63   | Enterstates.   
   |  | intranana.   |  |  | All Andrews   
  |                            | REACH-   | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| State State  | NERPHYRC: COLLEWISCH   | Constanting  | Besardan St   | anta anta anta anta anta anta anta anta | 21   | BURNING  | A CONTRACTOR OF THE OWNER OWNER OF THE OWNER OWNE | Tor patients   | Development.   | With .   | 240 Sentencer  | in.                                     | No-  | Name   | P. Processing  | Section of the sectio | Vitiena S  |  | And a state of the |  |  | Sea.   | Resident and a second s |  | COM  | HISING   | Million and  |  |                            |  |
| Contraction Provide  | AND ADDRESS OF ADDRESS | Eline.   | - Des Alla Provide State  |   | Aller Bill   | 1600- (  | in the second   | Stammer .  | Teliphonen.  | MARTIN   | SIDE   | COLUMN                                  | Ea Arbenter  | 2. Standard  | States   | Barren .   | Non-   | AVS .  | Street and  | Mirater b  | Print at   | And Departments  | And a state of the |  |  |  |  | B Mine Low To see 1  | ***                        | All the call don't Gran  |
| Transferrer Constant   | Silking and  | Cilling.   |   | 100 Sec. 10                             | All North And  | AL DATE AND A  
   |   | Sectore  | Transfer and the second |  |  | 1010L                                   | No.  
   | Part And   | MANNON-  | Billion Actions  | Carte  | a manufa  
  | MgBass op  | Electronic art   | Martine a  | A A A A A A A A A A A A A A A A A A A  | 2.12. tog  
   | Station .  | Martinet and the second  | Charles and a state of the local of the  |  | 2000 Charles and  
  | Approxime them are used of | Service of the servic |
| ALL  | Silve.   | TUNEA.C.   | Times I   | this sector                             |  | *4444  
   | Mail and  | milton   | the state  | ALC: THE REAL PROPERTY AND A DECIMAL PROPERTY | Janders General  | Title Automa                            | ALT DATE   
   | ENDN:  | California.  | Water and  | Water Street   | Witholdson State State  
  | States and a second  | AND SHOULD THE R   | nostra   | and  |  
   | CONTRACTOR OF THE OWNER  | Second Second  |  | atterna  | 2000000000000   
  | ANTRA LUDGE COLOR          |  |
| Contraction Contraction  | Titleson   | And  | Gamera. 3   | 1997. H                                 |  |  
   |   |  | Mener  | Sector Sector  | Winds.terr   
   | Batter                                  | Concernance and  | Pretter Prantos  | The second second  | The Report   | Washington and  
  | 2kg  | 100.00   | -  | inter.   | THE CONTRACT OF  
   | -  | All character and  | ARCTIC TOTAL   |  | max.  
  | 2  | historia annar             |  | | | |
| With Street  | Acconom  | The second second  |   |   |  |  
   | Martin .  | Annaldan   | Part Value   | William Street   |  
   | Contraction of the                      | Sun"   | PRAN Parent  | Zarren   | Water and  | TRANSPORTATION  
  | United States  | St   |  | 2  | Susana   
   | Sectoralization  | Participante and a second  | Bring Oak States   | And a state of the | Part and and and and   | Notes  
   | 2.40020.m 2                | 2015.<br>2015.   |
|  | Anna Patente   | SICE SICE  | 200 Automation  | INCOMENTAL INCOMENT                     | BIRNE -  | Bassing own  
   | Section 1   |  | houses   | III DANKS  | 1 Berstein   
   | IDECKOR.                                | HILF COME TON  | Harange United States  | HIRE PLANS   | Thusase  |   
  |  | INC.   | Î Bastan I   | 100000   | intrast<br>illituseconaria   
   | Streets and an and a   | Witte revealer and   | III POHISES  | ilibertari,  |   
  |  |                            | ANT CALLER ANT   |
| TO SUBJETY   |  | Reiderstawerser  | William Stranger  |   |  | NE CARRON  
   | <b>Marine</b>   | Hitterateratera  | The second   |  | 10402  
   | Ballar, et values and                   | IIIKS 261  | Million and some   | Millipageaux   | - Para   | file assessed   
  | ( MARCONT  |  |  | (Bilter)   | COLORISTICS COLORISTICS  
   | HIGH LINE  | and the second s |  | III III AAAAAAAAAAAAAAAAAAAAAAAAAAAAAA   | Crontian.  | E G22  
   |                            | marattan-  |
| States States  |  | All reasons  |   |   | figuration in  | BROTHER  
   |   |  |  | HUR 24-12  |  
   | A CONTRACTOR                            |  | III SP 20 TON  | INDEXTON   |  |   
  |  | <b>1</b> 2   | an Chi   | Biggs.   | Auforent warmen at   
   | tiller susses  | ing somer  | diritan.   | TAMENTAL   | 105   
  |  | Sum.                       | March Nichtster.   |
| Contraction of the second  | RIEA   | Statements of some   |   |   | interest 2   | HIND-DATEANS   
   | Withers searchers   | HER CALLAR   |  | Hard States  |  
   | HIR SHOW                                | <b>HRORER</b>  | market and a second  | TREESE   | 1 Parts  |   
  |  |  |  | Street and   | Him wordstern  
   |  | The first  | PERSONAL ONLY  | W. there   | IIIA.   
  | Note-  | Allows                     | Stratute.  |
| finite Signa   | Manual Continues   | Ander  |   | HERE DEDUCTO                            | ilimnesource II<br>R   | NOCCESSION IN  
   | Martin Constants  | methodic strategy and  | HIGH TO A DEC  | HE COLOR   |  
   | 1005000 1102100 100                     |  | Series worth once  | THERE EXAMPLE  | 10000259   | e manesaana i   
  | I forstate out   |  | Tilfaseurcese)   |  | announces and  
   | 目認知的設定   |  | A COMPANY AND A COMPANY  | Collements   | Contentings   
  |  | Constant and               | Coportation of the   |
| tong and the second second second  | C  | TOTAL CALL   | - Hilling a sector of   |   |  |  
   |   |  | I CONTRACTOR   | in the second  | IN STREET  
   |   | 10 A.V.  | MINE AVGAGES   | in the second  |  | illine second   
  |  |  |  | Hill Contraction   |  
   | Light and the  | Ballion areas  |  | Katta a  | a says no du  
  |  | attratement I              | Tis:   |
|  | Winner Machiner  | ALCHEON BORN   |   |   | These services of  | IN STREET  
   | THE REAL PROPERTY.  | <b>HE</b> YES  | in Cara  | I BOOM   | |
   |   | anne server and  | Million and and a state  | HIBS BALLAC  |  |   
  | and the second second  | ALC: NO.   | A CONTRACTOR OF STREET   | STREET ALLER   |  
   | And the second s | Selferante   | A CONTRACT   | (24  | A COLUMN   | 100.   
   | terre area                 | dialy-   |
| Sauth and Andrew Street  | distanting distant   | ADDATE TO THE REAL PROPERTY OF   | In the second second  |   | NESSONS I  | Contraction of the   
   | I REAL  | 100000000000000000000000000000000000000  |  | illines.   | INCOME   
   | <b>B</b> RATES                          | alitikkytenenesses<br>alitikkytenenesses   | 1000 2 10 10 10 10 10 10 10 10 10 10 10 10 10  | <b>Messon</b>  | l Rente  |   
  |  |  |  | ALC: NO.   | Billion to the state   
   | And the second second  | Statements and an a  | and a state of the | AND  | All the second s | Response   | tine II                    | III.   
   |
|  | Auforgenergenergenergenergenergenergenergen  | TRAKANSTER   |   |   | Second 1   | in the second  
   | and a second second   |  |  | in the second second   | anancontaine<br>Militeraturation   
   | INTER                                   | And a second second  | illing the second  |  | <b>B</b> ASSAG   |   
  |  |  | Com.   | Kita   | articles   
   | Chemican .   |  | Maritin,   | No alintustristes Stra Stra-   | A BAC   
  | Contraction of the second seco | 12m                        | auto -<br>uzin-L   |
| States and States and States and States  | Contraction of Contraction   | Threater-  | INCODA PROPERTY AND   |   | BUCCOLLEGIC SCI  | Contractor   
   |   | 11.000   | Tollaper concerns  | Tameratakoonan<br>William  | Solar activities   
   | 14 A 14 A 14                            | 1  | <b>HROSE</b>   | Million Sold   |  |   
  | HERASAMETER<br>WEREAUSTRATION  |  | Interesting and Interesting  | 6 25.2   | Sec. 25  
   |  | HBASE  | fidefinte.   | CONTRACTOR   | Carl Colorador  
  | The state  |                            | 1-12-170-14-1  |
| The Case   | All and a second | 12850 and  | THE REAL PROPERTY OF  |   |  | Silling  | Rest in   | in the second se | No. Contraction  | Balling, Solar and Solar   |  | A STATE                                 |  | Million and a  |  |  |  | infinence and  | Carlos a   | MA SPORT   |  |  |  | CTO.   | Sector State   | . ·  | Contraction of the local division of the loc | A Statement  | Same in                    | The property lives and the second  |
| Entrange Barrage   | The States   | ing the second   | Sector Contract   | And | Monau and  | -  
   | Bar State   |  | likespesse   | ALL  |  
   | <b>B</b> RANK                           |  | In the second  | CRA:S  | ALL AND ALL AND  | - Hitchotchu  
  | And the state of the second se |  |  |  | RUX.on   |   
  | 1000 V   | (Patienter 1   | 1944<br>1955   | Constantine and  | State and and  
   | -                          | New York and a second  | | | | |
| Transformer Street Street Street   | an manual of   |  | human anna  | Aldramentarian (Al                      | Chrenner hild  |  
   |   | hiter of second  | Jama mourous   | Barrier de mettor de   |  
   |   | Hidevelotor  |  |  | ing the set  |   
  | · 開闢構成的ないのです。  |  |  | 10.00  |  
   | Contraction of the second  |  | tilles .   | 125/0  | The States  
  |  | Boc"                       | A BARRIER BARRY  |
| Parente Phone  | New stanson Birth and  | in and   | Sastration  | ACCESSION AND ADDRESS OF                | Miter II   | CITIZEN CONTRACTOR   
   | Cardin and a second   | 111865451455   | initiale. to restartest  |  | S HISPARANS  
   | Marche Creix State                      | INTERNATION  | BRIME COLOR  | INTER COLORIDA   | Harris Contractor  | States and a state of the state   | Tables  
  | THE PROPERTY AND   | THERE AND A  | Contraction of the second s  |  | E DE LA TRAN   
   | CARD.  | And  |  | TEL  | Colorest Street   
  | Warm-                      | Contraction of the local division of the loc |
| in the second second   | Market and a second sec | 118.   |   |   | artanta dia  |  | Sector .   
  | and the second second  | Card and   | Distante.  | there are a  | Everenceus                              | Storne   
   | BORT BUCK  | a manter and   | TRADUCTION AND   | - Andrews - Andrews - B  | Kon States  
  | Barner   | Tarl strategy and  | 24.  | C.R.   | ACCOUNTS ON THE OWNER  
   |  | and an and a second second   | The state of the second  | heldoutewy -   | Reletion  
  | Martin at Martin           | Stag.  |
| Man grant total  | - mater  | With Street  | Statues .   |   |  | Contraction of the   
   | Water   | State State  | Sector and   | all allow  | STATES.  
   | CONTRACTOR OFFICE                       | Mindes May 2 (27)  | ACCOUNTS OF  |  | State State  | AND CONTRACTOR  
  | Active.  | ,  | *#D  | the state of the second  | Wills assessed and   
   |  | Margare !  | in the second second   | title the second second  | AND THE OWNER OF THE OWNER OWNER OF THE OWNER OWNER OF THE OWNER OWNE   
  | State of the state | Carlotter - C              | in the second  |
| inter and  | hit.   | Bridertelunger marrie  | -   |   | 85. S  |  
   | 6(8)11(Rails  | State-   | Silenter to the second second  | Address to the   | Anna Anna  
   | ALL COM                                 | 2014   | Michael and Annual -   | I scenace and  | Billy contractions and   | NAME TO DO TO DO  
  | I Water  | Children Junet   | PRODUCTION OF  | Contraction of the second  |  
   | ARTING AND THE   | Non-   |  | ato-   | Station of  
  | NA.  | is.in.                     |  | | | |
| Maria and Andrewson  | Stature Stature  | Paratana .   | Farigitation  | All and a second second                 | Hin,   |  
   | 10104   | TU, APTIN  | ond marries  | Ed.Ska   |  
   | WW.LOUTLAN<br>WW.LOUTLAN                | Elibritan,   | A STATISTICS   | Selectory Selectory  | 112  | Anarumana antian (  
  | Constrainty of the   | Stansonout.  | States. (1   | CARDING STORE  |  
   |  | Transcores   | Victoria<br>Starogi,<br>Victoria   | ike.   | LURN  
  | Hi Balanda Antonio   | tranker .                  | Collins and a second   |
| Water and the second second  | tonen Tasigar  | THE DEWSON   | Tableton and the second second  |   |  | E.   
   | Martin Contractor   | 24 4 54  | STAT.  | Concentration of the second  | MILLON A   
   | 120                                     | H 39459102   | -  | in the second  | - Contraction of the second  |   
  | Char.  |  | 職に   |  | 888 ·····  
   | 1012   |  | No.  | gire   |   
  | and a state  |                            | Contraction of the second  |
| States and   | Telephone Sectores   | THE OWNER WAR  | Arriver and a second  |   | Antono parte a   | Beschmitteren  
   |   | William  | The second   | W20.   | 100/0-   
   | Contractor a                            | it with a contraction of the   | Sauce-   | Contraction of the second  | - MENETA   | -   
  | Balana   | and the second s | Book   | Contraction of the second s  | Signa  | -   
  |  |  |  |  | | |
   |                            | HOw  |
| THE AND AND A COMPANY  | working -  | 1113* 30-9<br>112* 30-9  | William - S   | An 121                                  | ilin- W  |  
   |   | Street   | Carried of the second s | - Chrometer  | State of the local sectors and   |   | Particular Contractor  
   | II BERNE   | BOTUL-   |  |  | Contraction of the second   
  |  |  |  | 1000 Participation   | 1800   
   |  |  |  |  | | | | | | | | | | | | | | | | | | | | | | | | | | | |
  |                            | all and the second   |
| Print Party  | Balanting  | Ber test   | Termony the second  |   | in the second se | and the second s | The Sector  | Walsach  | States of Long Street, | (Managers  | Sector Contraction   | 1180.<br>11 192028 no.                  | Helioficialmau   |  | Battan   |  | - Research - F   |  | -  |  |  | 2.4  | -  |  |  |  |  |  |                            |  |
| 100  | E  | 2000   | -   |   | 18   | 2.101  
   | The protostation  | The second se  | Sida_  | and the second second  | Therear  
   | A CONSCIPTION                           | in all the second  |  | Rotting-   |  | Monte-  
  | Caller,  | Seren.   | Children of  | ADDIDATE AND ADDIDATE  | and the second   
   | Mion-  | Party of London December 1   | Dat"   | dar  | A Decision  
  | Sand Street Stre | These search and           | 1992   |
|  | Nalara -   | Contraction of the second  |   |   |  |  
   |   | introduction of the  | As Reproceedings   | CTAL OF STREET   | The second   
   | Alama .                                 | Constanting of the second  | A STATEMENT  | Contration of the  | Chiermanan m.  | THERE   
  |  |  |  | avitati-   | II fabelow   
   | And and a second | ALC: NO  | Manual .   | NAOTO Junto  | Winterst.  | SUMPLE OF  
   | Winbertrytony _            | Aller .  |
|  | - 184  | -  |   | -                                       |  | 152  
   | -   | Inalas   | II DOG STREAM OF   | And and a second | State one  | All Provide states                      | Comparison of the second  
  | ii bāk   | Martin and Annual and Annual A   | States and a state of  | Neurosen d   |  | All Phase   
  | Station I  | internet subscription  | Wight nations  | contectores,   | Wine.  
   | toria.   | Realized States  | watzin   | Secondary .  | A Contraction              | 19459A   
   |
|  |  |  | Tillerer A  | 1                                       | 2014.<br>2014.   | -  
   |   | Janife   | The second   | Mall and   | -  
   | Tet:                                    | ISPE   | STREE-   | William at   | Nation Press   | Contraction of  
  | Contraction Contract   | while destroy  | Manual Contraction of the second   | Contract 1   | Nige :   
   | interest of  | And a second sec | WALLAND AND AND AND AND AND AND AND AND AND  | 1998-14  |  | South same   
   |                            | 102R   |
| Lange Lange  |  | Billion Street   |   | The G                                   | CR. 3  |  
   |   | A STA  | 10 da  | The surger and surgers   | 322  
   | THE COLOR                               | HHELENAR"  | - Alexandra  | Contraction of the second  | Milline.   | Arrest P  
  | Transition.  | THE OWNER OF THE OWNER OWNER OF THE OWNER OW   |  | Ser.   | Longer Britering   | -   
  | Ellination   | Sector Sector  | IN WORKS   | Citize and   | With Statester   
   | Citikanana.                | Wallandaria.   |
| againe anos  | - Billing  | CARLS  | Antorious and Street  |   | 1000-  | 15.a.  
   | - Selencov  |  | in many strengt  | Marazzi  | Santone.   
   | And | 1200°  | March 199  | COLORISCI.   | Partie landerin  | and the second s   | WEIght   
   | State.   | Q.A.   | TONDON -   | Andreas.   | 22.27 Land  
  | Sector Protocol  | Station of the second  | 10.0   | No.  | 1987   
   | 034                        | Stan.  |
| Harrister and the second   | Content and a second   | H 105  | The second se | 10 - SU                                 |  |  
   | ditte.  | ALM PA   | A DESCRIPTION OF THE OWNER OWNER OF THE OWNER OWNER OF THE OWNER OWNE OWNER OWNE  | Trans.   | Skehillers   | Barrister and                           | Distance and an  
   | Contraction of the local division of the loc | Selection  | -  | then a   | Sector States  | With the set   
   | AR-  |  | tient.   | internet.  
   | Contrainings   |  | Scare -  | Barriston to another   |   
  | Ketar                      | and Son Douterry   |
| Consecution States   | 100  | Transfer and the second | Sister Worup. 20  | <u>h</u>                                | Tex .  | 100  | tents<br>Nuus-sees   
  |  | Prise  | Consecutive and a second   | Sector Sector Sector   | RUCC                                    | -  
   |  | WENG-  | and the second s | And the second second  |  | San .  
   | The second second second   | And the second second  | and a start  | and an   | MORD:   
  | Sectors.   | Waters-  | 14 may   | Colorado -   | Roy .                      | Gullas/thm.   
  |
| Sectors West   | Alleren  | 2123 in Thilly-belly   | Ellinero.   |   |  |  
   |   | *  | Without  |  | Real Property lies   
   | The second                              | Station -  | Sector of the se |  | Contraction of the second  | ACREATED ST.   | Musida 1   
   | Stama  | TOURCE.  | and a state of the | Section.   | \$4.0%   | YEAR AND   
   | Beg  | 1000   | No.  | Alfa States  |                            | A.   
   |
| There are  | Withow   |  | menter 1  | line 20                                 | MARCE IN   | -  
   |   | Production -   | A LE D.  | EAD SHIT   | Walkingen-   
   | Superior.                               | Constanting Street   | ENELATING AND A  | Silver and state   |  | Konan .   
  | and the second   | Automa.  | And the second s |  | Minte  | |
  | Dan ets.   | -  | CARL NOT COMPANY   | Tangon .   |  
   |                            | Las  |
|  | EL.  | 20.  | Billion States  |   | Manto Ma   |  
   |   | 2 decrementary   | Tribulation  | 10000000000000000000000000000000000000   | Excelore.  
   | ALL A                                   | ACCEL BURNING  | ANT ACCOUNTS   | Ene.   | Salarana and and and and and and and and and   | They are  
  |  |  | antia  |  | dt Manetersantines.  
   | NDR-18-Henry   | in the second se | ALC: NOT   | Manager and Andrews  | Tanger   |  
   | Linds .                    |  |
| Martin Street  | 81 <b>8</b>  | Line of the  | - West  |   | Williams III   | 15°  
   | a manual dama a   | DEPTER   | Bunga Bank   | Straffia   | States   
   | Server                                  | ditation   | Contraction of the second  | Mann   | areas  |   
  | There are a second s  | internet and a second  | i Martin   | COMPACTOR."  | Billor-   
  | Contractor   | MR.  | -  | ations.  | Citotica.  
   |  | Management.                | 2000   |
| and the second   |  | No. of Concession, Name  | a little iber   | ante ITu                                | tatorna an   | a.   
   | 1005  | II BOOK.   | States -   | SIT  |  
   | 1000 Mar.                               | 12 Car   | 7948 (B  | 1.   | Transition   | Trouberton  
  | 2.493  | Part internet a two  |  | 15000  | 110 and 1  
   | 1111000000000  | ALC: NOT A   |  | ALIAN .  | North   
  |  | *ALTONIAL*                 | Citie centitati  |
| Withher Hills.   | Contraction of the   |  | - 100.0000000- 20   | 20 ara 204                              | 1.20°. ma.   | - Vite-  
   | Datas. 1  |  |  | With the best of the   | 500 A  
   | -                                       | Parsand comments   | THE STREET AND   | 10200000000000   | Busenese a   | Truck and   
  |  | Constances .   | Contractor in  | =0.  | A BANK   
   |  | -  | Crash Marine   |  | Lass generates  
  | 19751.1.mm 3   | N830                       | 10.000 h   |
|  | The second   | The second   | - 18490385- 3   |   | 13.00k. 13.  | greatenter   
   | Darran,<br>Kalan<br>Lainen diragan  | ii baay  | Contraction of the   | 242.00   | Maiberrat The  
   | TO B                                    | 110020020  | 10 004610  | attuin term  | 122 012 AV   | International States  
  | Contraction of the local day   | State of the second sec | Same Provide under   | 5.3 ····   | BUT BARA   | ADMIN  
   | Marries .  | No. of Contraction of |  | 1000 C   | Mere.  |                            | Parties and a state of the   
   |
| Surgering  |  |  |   | Marian<br>Marian<br>Marian              | internet int |  |   
   |  | Althought  | 24250.<br>8.00 0000.00 000.  | Conference of  | William Street                          | Markey A  
  | NO STORES  | Ministerin<br>Ministerin<br>Ministerin<br>Ministerin<br>Ministerin   |  | Contractor Services  | These  
   | 10000000000000000000000000000000000000   | Same and   |  | And  |   
  | Annan Annan Anna Anna Anna Anna Anna An  | BCD.   | MOUTUP<br>HETAN<br>HETANICA  | 1999, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 2009, 200  | endets pression.   
   |                            | 120.00L  | | | | |
| televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite<br>televisite |  |  |   |   |  |  
   |   |  |  |  |  
   | Mannan and Andrewson                    |  |  | Ministeries<br>Ministeries<br>Ministeries<br>Ministeries<br>Ministeries<br>Ministeries<br>Ministeries<br>Ministeries<br>Ministeries  | Constanting  |   
  |  | 2000   |  |  | All Barry  
   |  |  | And  | North States   |   
  |  |                            | Contraction of the second  |
| Nave Annual States   |  |  |   |   |  | gran Bannan<br>gran Bannan<br>gran Bannan<br>gran Bannan<br>Watar wara<br>Fur  
   |   |  |  |  | | |
   | Allantin and a                          | Manager States   |  | UT-MENALAN<br>ALANA DALAMA<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-MENALAN<br>UT-M |  | And Andreas and An   |  
   |  |  |  | HIT EDWA   | All and a second |  
   |  |  |  | NUT  |                            |  
   |
															Article of the second s	Eliza (1997)     E	The parents							Variante de la companya de la compan	And Annual Annua			And and a second		
											Ministration		A Construction of the second s		Artistanti Hold States Hold S		And Andreas An								South States of					
   |   |  |  |  |  
   |   | A second  |  |  |  | And Andrewski and<br>Andrewski and Andrewski a |  |  
   |  |  |  |  |   
  |  |  |  |  |                            |   
  |
   |   |  |  |  |  
   |   |  |  |  |  | Marine Ma   |   
  |  |  |  |  |  
   |  |  |  |  |   
  |                            |  |
|  |  |  |   |   |  |  
   |   |  |  | And a second sec |  |   |   
  |  |  |  | Million and American Street St   |  |   
  |  |  |  |  |  
   |  |  |  |  |                            |  
   |
   |   |  |  |  |  
   |   |  |  |  |  |   
  |  |  |  |  |  
   |  |  |  |  |   
  |  |                            |  |
|  |  |  |   |   |  |  
   |   |  |  |  |  
   |   |  |  |  |  |   
  |  |  |  |  |  
   |  |  |  |  |   
  |  |                            |  |
|  |  |  |   |   |  |  
   |   |  |  |  |  
   |   |  |  |  |  |   
  |  |  |  |  |  
   |  |  |  |  |   
  |  |                            |  |
|  |  |  |   |   |  |  
   |   |  |  |  |  
   |   |  |  |  |  |   
  |  |  |  |  |  
   |  |  |  |  |   
  |  |                            |  |

### (ex. ~250kLoC, Vampire prover)

| STLOP THE  | E. Shara   |  | interesting in the second  | Re <sup>2</sup>  
   | Bart   | And Personal   | T IR   | 2178700F   | Meranda and   
   | 11111  |   | NO BALTING AND - BALTIN   | No.  
   |  |  | AND  | 10 / Sulvin  | States and  
  |  | WINDLOW THE REAL   | Belle approximation  | 5-1005   | Station and states   
   | No.  | -  |  | St. Monastrong   
   | STAR STAR   | anturnes   | Nelastation and  |  |
--	--	--	--
--	---	--	---
---	--	--	--
--	--	--	--
--	--	--	--
--	--	--	--
---	--	--	--
801914	Support Strates	No.	BERE
   | a de la competition de la comp | Start and a  | Contrest-  | Out allows   | 1998  | 100000.0000   
  |   | The second second   | Nitorit Westerney  | Global Statistics of  
  |  |  | Branktore .  | Wold .   | Martin and   
   | CORRECTION OF STREET,  | Sandara and  | Sectors Sectors  |  |   
  |  | N.S.   | C.S.   | Andread and a second se  | No.  
   | Secondaria and   | energy and a second sec |
| 1012 304   | States and an and  | Separate<br>Separate<br>Separate   | Contraction of the local division of the loc | All An   | Manhapping  
  | County County  | Mart   |  |   |   
  | - Control Control   | With the second   | Ste-   | Chine Street  
  | Total  | Verlagen of the second  |  | FE.  | Dan and  | COLUMN TRANSPORT   
   | Nolan.   | Therease .   | V. STA   |  | 1                               
  | States and a state   | STLOUTERS.   | Mine services   | No.  
   | No.  | £.   |
|  | Contraction of the local division of the loc | Diale and a second   | 127  | 10 Miles   | HARDWINSERFER.  
  | Less.  | Martun Barris  |  | II IBQ:   |   
  | Mole Con  | Differi2.   | And a state of the | Statistical and a second   | 111116   
   | St 3 auto mater  | NUTRINGS   |  | Window Westman   | William   
  |  | ET.  | An or Andread and Andre  | Vou bres pa  | Ser.   
   | Angelanders<br>Without and a second second   | Sillin-  | With them   | Novi.  | And a state of the | A State   
  |
| Ľ  | Ball Downstrange   | All and a state of the state of | Charles /  | jagmannuma.;   | and the second s |   
  | The second second  | Start  |   | Contraction  | William Street  
   | 255   | 1000-  |  | Sam Sauce   
  | Villevilles.com  | 185m   | Sector Sector  | Reality  | And a state of the |   
  | Contraction of the second  | Internet   | A Subaran  | ARCHEN TO A  | No.                            
   | #.5%   | 11101232-   | The  | Martin Theory   
  | Steady (Constant)  |
| MCF  | States of the second second  | n mannen and   | A Providence of the second sec | The second   | COMPOSITION OF  
  | Solone Save  | Contract of the second second  | Parts and  | in the second se  | ×  | Tillingense<br>Tillingense   
  | de general  | Stranger   | Malastor and an  | Yorgania   
   | Contraction of the second  | 10.134   | All prove  | Personale -  | Man   
  | in the second se | 100 mm   | The statistic territe  | Victorial and a second second  | Engrand -  | 10  
  | IR<br>Sib  | 112105-00   | MIT.   |  
   | Coperti.   |
| Sector .   | BASSIET PRINT  | Constanting of the second  | Aurent anter anter   | A Destandy at  
   | and the second s | States and a   | 2  | Land on the balling-   | Ningel and  | 20.00   
  | 1000 pt   | Michigane-  | Supers   | Selent.   
  | Telvil de vere   | Antonia Contractions   | 2.000-00-00-00-00-00-00-00-00-00-00-00-00  | Tothers eren   | And the second   
   |  | 110  |  | Golanna .  | Selectority.  
  | ting.  | La - Adiana  |  |   
   | All Market and All All All All All All All All All Al  |  | Webdok-  |
| Carl Haure   | ANARA NALAPATAT  | AND ADVISION AND ADDIE   | Cartornia and  | Manager and  
   | Sugar,   | State of the second second   | Anna and a state of the state o | SALES CONTRACTOR OF SALES  | The patients  | Disupposes.  
   | Weight.   | Toplan  | Service  | W  
   | Carter -   | P. Manager   |  | Net inter  | 1001 T  
  | And a state of the | 1996   | in the second  | Sea.   | Resident unter-  | 127.00  
  | A WALL   | GRISING.   | internet  | 10101  
   | in the second se |  |
| C G Martine  | The states   | CALCULA CONCERNING   | Elines.  | State -  
   |  | State Street and a street  | BIII BOT   | weet-  | Manan .   
   | Le aporto.   | MARTIN  | SIDE  | States -   
   | Tale of  | 1 St Char  | Sector Se | Bar  | Personal and   | ANS<br>Miles  
  | - Logene   | in the second  | Biness.  | Contraction and Annual   | States and   
   | 1157   | 5-0-1-   | HIN CONTRACTOR   |  
  | B differen herrin samer  | All and a second | Patrice and the second stores  |
| Martin L   | Terrary.   | Constant.  | Contraction of the second  | 2005   
   | Contract Services  | TOP NOTION   | Mart   |  | Stellown  
   | toppen   | 1000 ····   |   | 10200  
   |  | Press Acc  | MANNON-  | Manual Construction  | CDPR-   
  | T ALARA LA   | Wg Beat top  | Digital and  | Contraction of the   | Sales and the second   
   | 7-147 Now  | Antes<br>Brack Stranger  | MANNEL AND   | Concept of the last of   
   | Carps.  | STANDARD ST  | Myowen metalliter  | Ser.   |
| ALC: NO  | Harris   | titles   | Min.   | VALUE:   
   | DELENSION  | Contraction of the local division of the loc | Promanen   | Martine B  | mitton  | CALL  
  | All comments  | -   | Line surrows   | Magazine.   
  | 100N:<br>106/1   | CLORON .   | Walkerstein and  | Water Street   | ***********  
   | 170072.002   | TRUCKSON COLUMN  | E offer  | Marries  |   
  | Crided   | Manager Land   | Service of Lotate  | WEDDINGA  
   | 20000000000  | AND THE REAL   | 1993 Pr.   |
| (1000)   | Exchanges and  | Digantas   | Same and a state   | General.   
   | Nes  | investa<br>Veterformen   | And and the second   | The second se  | No.   
   | And a second second  | Service Street  | WINDS. St.  | Bane   | Concession of the                         
  | Wan Pratos   | With Million and Street  | The Report   | "Annorsteinung"   
  | 19thm  | in the second  | State and a state  | And and a state of the state of | THE CONTRACTOR   | -  
   | All a full and a set   | 10010SIMTER'   | A DE LE CALLER   | IIIR.  
  |  | 2011 Contraction   | 1000   |
| 10. m  | Same and   | William  |  | Sur.   
   | And the second sec   | Salary   | Sector Sector  | Martin Concern   | Chantagenter.   | Part Manuel   
  | With the second   | -   | WIRODAUSTR   | Martin  
  | In Sark Press  | Married Woman  | WIRESPICTION INCOMENTS   | TEMPINENSING ST  | WICH COL   
   | -  | and the second s |  | Seetings   | Sectoritera.  
  | Prostantes   | Berten Bratt Interes In.   | Peterstand application   | Passager  | 2¥2555  
  | WARDER   |  |
| 10.000 and 10.000  | mpanffal.m.m.  |  | CAPE-  | 20Brandara   
   | STREET, STREET | INCOME.  | in the second second   |  |   | interest  
  | III CARGO   | 16um  | I BERGE  | in the second second  
  | HERBERGERSON   | HIRE CONTRACTOR  | Thistern   |  | - Statis   
   |  | and the second second  | I govern   | illen and and  | ALTERNA DECARSON  
  | Willing records to be  | In Patricks  | in the second  |   
   | NGP-   | 1000   | and the place of the   |
| 12-51400-TV  | 5500   | ALCONCE.   | Reseasement  | The second   
   | fillence vo  |  | 102/02/5   | TRACT  | ditterance of   
   |  |   | 10  | Belgrennense<br>Bergennensen   
   |  | Without a service of   | Million and a second   | Tores.   | <b>IIIP</b> ANERO   
  | I BUSSES   |  |  | 1 Bilerous   | HIMMONY COM  
   | HORAENOA   | inter an anna an a  |  | HINE PERSON   
  | Dentilan  | 1020-  | Tar Thirty   | mination-  | |
| An and a state   | All of the second secon |  | 18 m   |  |  
   | Hillippensionerse  | Theorem  |  | IN CORE   |  
   | HER PARTY   |   | In the second  |  
   | HIS COTON  | All and a second   |  | Contraction of   | i fascantes   
  |  | distant.   |  | adding the second of   | hillife summer   
   |  | <b>M</b> 11137   | CALCULATION OF THE OWNER   | A MAR  
  |  | Sectores.  | andrect.withmer.   |
| Career and  | Missie<br>Balley<br>Bally  | RIEA   | With an and a second   |  | N. CO.   
   | ()INSERTION  | HERBO-DATALANN<br>HERBO-DATALANN   | i illinessense   | III AND A   |  
   | Internet in sec   |   | I Reader   |  
   | IN THE OWNER   | TROUT OF STATES  | 1 Kinger   | i pose %   | and the second  
  |  |  | A Chart Carns  | THE REAL PROPERTY OF   | I Di Longe   
   |  | PER-INDERIGATION   | MA Tabur   | T I I I I I I I I I I I I I I I I I I I  
  | 16810-   | Milway   | Constants.   |
| in more  | DOMAGNET   | White to the second second   | And the second s |  | HER REPORT  
  | This means of the  | NEW CONTRACTOR   | hinesesters  | methodiz-strategiste  | INCOMPANY   
  | HER ALCONT  |   | method and an art  |   
  | HERMOGRAPHICS  | THE STREET   |  | THE PARTY OF   | I DERIVER  
   |  | THE REPORTS OF   |  | 1017   | 11201022  
  | HINGS STORE  | Staffing Internation   | Contractor and the second  | Willars   
   | LINE.  | Same and the second second   | ilos   |
| Soft Contractor  | 59-14<br>(72)24  | Shifternan,  | DOLUGE CALL  | Manager and a  
   | HING BALLAND   | Manager Street and   | SUNDO COLLARS  |  | 1000  
   | i i i i i i i i i i i i i i i i i i i  | III III IIII  | in Research   |  
   |  | MINE AND SOLD  | State of the second  |  | ilinteres:  
  | I Reality  |  |  | And the second second  |  
   | Distant and  | Burthan area Bash  | Succession in the  | NAME OF TAXABLE PARTY  
   | N NHO ALO   | 1997   | -  | The second   | |
| 420100   | COLUMN T   | ALL CONTRACTOR   | ALC CONTRACTOR   |  
   | 1.0  | Tanta and a second | Interester   |  |   |   
  | <b>HEAR</b>   |   |  | iles.   
  | differences  | BIRDS BATCHAST   |  |  | interesting.   
   | 12 12 19 19 19 19 19 19 19 19 19 19 19 19 19   | In the second second   | All and the second second second   | and a state of the state   | Same and  
  | Million Co   | 1  | 102A   | And and a second second   
   | 1108.<br>(*****  | Planting and   | alair-   |
| ADDANCS.   | Stratter.  | California anno  | Statutes   | III CARA   
   | A SEC  | THE ACTIVITY OF A  |  |  | HERE'S CALL   
   |  | <b>MARKE</b>  |   |  
   | alitikkonsessore<br>Talleksessessore   | 10822000   | <b>Messee</b>  | E. Contra  |   
  | 14172.1  |  |  | ALC: LA  | Editor at the same   
   | Strates  | And the second sec   | - Andrews  | PRODUCTION OF THE OWNER  | AUTO AND AND A  
   | B  | Stort Supramount   | Deres .  |
| fore or fer  | And Statements   | Martic States  | THREE ADARAMETERS  | <b>Hib</b> secore  
   |  | <b>BRANK</b>   | THE REAL PROPERTY OF   | Marran   |   
   |  |   | Interview in the  |  
   | Billio naveran   | illighten am   |  |  | a second second   
  |  | i i i i i i i i i i i i i i i i i i i  | i tem  | Williamon  | articles.  
   | AGANC  | California   | Menna.   | State and a second second  
   | ATTA.   | Contraction of the second  | Conto  | Serie  |
| State of State of State  | N. Gutter  | And assessed   | The states   | REAL PROPERTY AND INCOME.  
   |  | AD OTHER DATE  | ACCOUNT OF THE OWNER  |  |  
  | Tifferen en ante   | The states  | INSTRUCTOR  | and a second   | i i i i i i i i i i i i i i i i i i
i  | BROOM  | THE STREET   | THE RESTANCES  | 12   
   | and the second s |  | I DECORDE  | 1. de  |  |  | 開閉時設計   
  | Treasure.  | 1041-144-14-14-14-14-14-14-14-14-14-14-14-   | Gall Contraction of the   | Bes.   
   |  | 11-12-199-14-1   |
| 2.1.   | And the second second  | 100 in the second  | 1285 Warner  | THE PROPERTY   
   | Mahanan  | Sector Street St | Station-   |  | <b>I</b> MARCO  | Beerst  
  | districtions  |   | 4 h  | III BOARD   
  | HIMAN STREET   |  | Ca.St  | 100 C  | filling works  
   |  | a sheet  | 1 Marcasso   |  | 11254853  
  | STR.   | Stanterer .  | 2072.  | C. Marthan  
   | a Zilinananan  | Vienne   | And the plant of the same is not   |
| This areas   | Billiog-dat  | MARCH AND  | ing man a  | Senten :   
   | Contraction of the second  | Salado and a second  | Carlo  | 100 and 1  |   | interaction of the second   
  | IN STREET   | A DEPARTMENT  | <b>B</b> FERR  |   
                          | BRANSON BRANS  |  |  | TIMETERS   | Million to the second  
   | a state of the sta |  |  |  |  | 100/   
   | (ind   |  |   | NUMPERAL STREET   
  | and a  | Construction of the same   |
| Same and a second  | Wat Notes  |  | - Langer   | huter  
   | Sector Sector  | Statute and a second   | The second   |  | HIM CONST   
   | <b>MANNER</b>  | THE COURSE  | - HERRICH   |  
   | likesses   | 10.000   |  | in the second  | Read  
  | THE REAL POINT   |  | Tilling and the  | d de la companya de la   |  
   | 1000202033   | 1118.  | COMP.  | 1125/3-  
   | STAN TRANSFORMER  | Antonia.   |  | ATTACK BAR   |
| Tanan.   | There are a second   | there are a second   |  | Storeston.   
   | Manager  |  | HIGHLENSTOWN   | Water and  | MICH SCOLOG   
   | A million to the section   | million di convint  | And approximately and a second second   | Manufacture and  
   | A HERBY ALT IN THE REAL  | HEIMER RELEASE   | STREET, STREET | Handwoods Status   | Older and and a  | Aberratat.   
   | The second second  | Total  | in and the second second   | There we have  | HEIGHT & HARDON   
  | 6551   | Statuter and   | Alter States   | 8.5.P.  
   | Validation of Offices<br>Conference of Street  | 1 Million  | 9 1. <b>-</b>  |
| 54   | Report Frank State   | NHAPPINE   | 118:   | internet in the second    | All and a state of the state of | datantante.  
   | 02   | NO.S.  | ALC: NO.  | Canager  | Viterality,  
  | the sta   | Proto Barriero   | - Storney  | BURNISH STR  
   | Contraction of the second  | 110220-0000  | Condent Constants  | Barrahara  | Downer  
  | 1000   | 1922A  | Terration of the second  | A DECEMBER OF DECEMBER   |  
   | And the state of t | mit water  | STIME?  | States Courses   | Maria and and an   | Wag and   
  |
| Think group heles  | -  | The state of the s | Print:   | Statuster.   | Ser- and  
  | atiga.   | Service Courses  | No Distant   | State State   | Same and  
  | BAD Aber  | States  | Contraction of the   | MMC.  
  | Parter in  | Allen and a  | Allenter.  | Martinesener.  | Bartin.  
   |  | water and the second   | 10000000000000000000000000000000000000   | Will's an array of the   | Contraction of the local division of the loc | Margar-                              
   | And States of States of States   | Mare -   | Souther   | Without   
  | Sector Sector  | Wanger of  |
| States,  | Section  | -  | Supervise and  | -  
   | and the second   | An Western   |  | Concern.   | 30.1 ·····  
   | ANACOMO  | Augustania and Augustania   | Care .  | William  
   | A STATE  | William  | The second second  | CONTRACTOR AND   | The other states and  
  | 11 West  | Cighten Asteria  | Contraction of the second  | WERE AND   | Cartal Andrews   
   | S COMPANY  | and the second   | 2000   | 10   
   | ENERGY  | States of States of States   | 10,50Res   | and the second   |
| Pitter,  | With the state of  | arread .   | harmon and a state of the state | Manapasa   | Wall Stopperson  | nStdian,  
  | Tel.   | Contraction of the second  | THE REPORT OF   | and margh  | Boll-Spint  
   | Sec.  | Transition of the second   | Ellina.  | A Matyre  
  | Bellingeren.   | States -   | Delastration.  | State of the second second   | the second second  
   | Minter.  | High.  | Manager and American   | I Den  | EM.   
  | Store.   | III Ker  | -ERSC.  | Elifetter  
   | Titelite and   | Web Barris   |
| Sheetineed line -  | 105 Off scheme   | Tasian   | Mellogansen.   | Barry Che  
   | Stat.  | 10000 million  |  | . Mer.   | A su al se  
   | WINT   |   | Market Stra   |  
   | 11 30455000 1000 1000  | -  |  | -  | -   
  | States -   | and a second   | 186 C  |  | -9865  
   |  | Alter .  | No.  |  
   | 200   | 1000 m   |  | A Statement  |
| All Charles  | Transferration   | THOLES-  | algorith.  | 10. 10. 10. 10. 10. 10. 10. 10. 10. 10.  
   | 1  |  | State  | -  | WWW.  | en referant anna<br>an agust<br>en referant anna an tharann ann an<br>an Taglina<br>an Taglina<br>an Taglina  
  | W70,  | W25/pr  | Glanger Land   | Manager and   
  | 1000,***   | Con users  | Services   |  | 2  
   | and the second s |  |  | and and  |  |  
   |  |  |   |   
  |  | Manager 1  |
| TOTAL AND A  | 1106-  | Sector .   | 1127.229<br>987.925  | MR201  
   | Mar C  |  | Name   | With the second  | SPER-   
   | Geneticy in a stress   | Theoremany.   | and the second se   | No.  |   
  |  | B.STUR-  |  |   
  | - Contraction  |  |  |  | Southern Street  
   | BRA  |  |  |  |   
   |  | - Contraction  | in an  |
| BOOLD  | Sienze   | Engen Transvers  | BOCKESS.   | Ball Print   | Sales and the second second   
  | -  | 1000 ······  | and the logations  | 1000-   | Section of the sectio | States  
   |   | 1198028 nin  | Housenau   |   
  | The second   |  | And  |  | Land Land  
   | 1-   |  | - Contraction  | -  | 100 C   
  |  |  |   |  
   | -  |  |
| 280  | -  | 10   |  | -  
   |  | ings.  |  | -  | Such circles  
   | SSIGN_   | Noncer .  | CHERTON .   | Sil despares   
   | 150  | A STATE  | States and the second second   | An annual  | With the second second  
  |  | Streve.  | And Barriston Barriston  | Charles Party - Constant   | And The second second  
   | STATION.   | Martin Constant Strategy   | shall.   | Clant Anna   
   | Lancerer<br>Lancerer  | and the second   | Wataveging   | Stores   |
|  | -Eliphenes-  | Sector Sector  | Service and a  |  
   |  | Sold Street  | Store and I - Part of  | Areas  | inere and   
   | -is Representation   | Station St.   | The second  | AND DE LOS DE  | Para Tit  
  | a many   | Laferman   | Santa and a second second  | THERE   
  | LILE:  |  | augebren .   |  | HINDOW-  
   | And and a second se   | and a second sec | History.   | WANDERSTREET.  | Manager  
  | NO. STORES   | Witherstow   | Station_   |
|  | This can   |  |  | -  
   | Service.   | States and   | ALCON  | Seat-  | Instant.  
   | II SSSIter.  | 2075an  | State out   | 100  
   | and the second s |  | States and   | State of Sta | Secon  | daharan<br>Maharan<br>Maharan  | Allen.  
  | And the second   | Interconductoria   | Wisper-  | energies   | S.C.   
   | Tell.  | and a state of the | Wattries  | NORACE   | Addition and   
   | 1994.992   |
|  | -  | Beatran  | -  | all and a second   
   | 1  | 100  | Louis.   | il<br>in mo-   | Interior.   
   | States.  | State -   |   | ter  
   | STATE  | STREE-   | Billine .  | Nation Please  | Contraction of the second   
  | PROVINGING STATE   | white the  | . Manuanana  | and  | Not .  
   | The second second  | WCO.   | Russian -  | 100000   
   | 2.111.111.1   | Street Sector  | Martine  | 100000   |
|  | 120100-00000000  |  | -Stant   |  
   | BELCO.   | Sact.  |  |  | and the second  
   | 1000   | Version and a second  |   | Weinfight -  
   | With the sea   | airmetet   | Haddadaada   | N. Martiner  | Antonia.  
  | Electron.  | Caller of a  | 100  |  | Longer Britsteren Brit   
   | States and  | Man and a second   | Sectore  | History.   | |
  | States and a state of the state | Million .  | Stranger 2.  |
| Antician and Antician a | CONTE-   | All California   | 1  | ALCONTRACTOR.  |  
   | ALLE STATES  | Jakes-   | Wood Balling Book  |   | an area antipipali   
   | Marazzi   | ALL STAT  | Sectore and the sector   | Aller .  
   | No. Contraction  | CLARK C  | Contrelandorg  |  | WELS  
  | 100  |  | NONDON-  |  | Briddl-  
   | No.  | States and a state of the  | Elf la mar   | ALC: NO POINT OF THE POINT OF T  | 1992  
  | 2034   | anor.  |
|  | - ANDIANA PARA   | -  | State.   | Della Press  
   | E.S.   | STATISTICS.  | Mr.  | 1 Lie  | ALC: NO.  
   | of the second second   | Nongilaria.   | Mahildon  | and the second second  
   | TRAMOGRAMMONT.   | Contraction of the second  | The second second  | HEA-   | in a  
  | Sect.  | William Press  | Same a state processor   | No.  | NIGHT.   
   | BRING STREET   | Service Service  | ALCONTRACT   | Same   
   | 200 Manuary   | all and  | Notes  | Carlos Contervo  |
| Contraction of the   | Sener-   | *  | 1950 Mil.  | 1 15 detruction 127  
   | Salar  | Second States  | Teast  | Thus the second  | Contraction of the local division of the loc  | Provide States  
  |   | Section Section   | HIDOVO/Am  |   
  | States and   | WENGE  | 10   | ACRONAL  | State State  
   | and the second   | 1980C  | All and a second   | Water  | an in the second  
  | States.  | Sector Sector  | With the second  | 03  
   | 24245-   | Roy  | DV.  |
| All carton.  | - Wasifers   |  | and the and the second star  | Fillbarg.  
   | in the second se | ANY.   | Volume.  | And a state of the | 20000   | Mineral Contractor   |  
  | Million .   | Dien   | SCHOOL ST.   |  
   |  | Saltores Black   | Vill Standard  | Balanda -  | HAR-  
  | En alter   | and the second second  | William.   | Sector Street and  | Aller and a second   
   | iner-  | 100 mm   | LIS   | WHEN PERSONNEL  
  | Telesta.   | Beam and   |
| 2000 and 1000  |  | the the dead   | - Marting  | HIRRORIZ-  
   | time .   | SINGULAR   |  | and the second second  | Aller and   
   | September -  | CARDIN  | This item   | Contract Alter   
   | Character.   | 200.20   | SPEN.a.  |  | Loreman .   
  | Alt Alter and Alter a  | interez.   | THE REAL PROPERTY AND  | area.  | Minne<br>Receiver  
   | 33330-10-10-10-1   | fiamen.  | No.  | A  
   | Transer.  | fitter.  | aser.  | VLD2   |
| Alley Martines   |  | Time.  | 10.<br>18.   | 1100000000000  
   | And a state of the | the second second  | -Ban, mar mag-   | JULITING SPIR  | And the same  | WINDOW COMP   
  | NOVER STREET  | Second.   | 200200   | -   
  | an ad man  | Pine   | titleun,   | They.  | and the second s | Armente.  
  | More -   | in the second  | An official states   | NOR AND A  | all and a second | Magner<br>Naven<br>Jacobs                     
  | Billion .  | Strain-   | North Control  | auraa.,  
   | tid plane,   |
| Mille:   | 10.000   | BER  | The Local and Lo | Succession and the second  | AND THE REAL PROPERTY AND   
  | Statistical and  | The set of the lot of the  | in other states of the states  | COTTON.   | Presson Presson  | ACCOMING.  
  | StatePoor   | Citter.  | littatione   | Statute -  
   | State  |  | Annen en.  | and an interest of the second  | Director Corr   
  | in army  | Second States  | BREAT -  | NACTOR AND THE REAL  | MR.  
   | States-  | L'ERGUA.   | L'arenous   | State of the local division of the local div | Contractor -   
   | 1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.   |
| angeter  |  | Contraction of the second  | -  | - Internation  
   | and a state of the | NEWSON,  | ADDING.  | Sata<br>Data   | in mour.<br>In hiltor   | Manual Content  
  | SOL   | Contraction of the local division of the loc  | CODA.  | Differ .   | 1998   
   |  | Carlo Carlo  | TRANSPORT  | Jumpters   | Internet and  
  | TENL.  |  | The spectrum   | annan mennetera er   | Sales                                
   | Berringer and  | TALINE.  | A REAL PROPERTY AND A REAL  | NOP.   | A PARTING AND A PARTICULAR   
   | Section of the   |
|  | April 1  | Culture on   | Burkey   | Sector   
   | RECEIVER.  | Automotive concer  | Bernan   | Server and  | (I Mat  |  
   | 212.001   | Material Till   | William Street,  | Torritora  
   | N BHHH:<br>B BHHH:   |  | ite miker men  |  | Protection.   
  |  | Sand Production  |  | MALINGARDAN  | Minet and  
   | Ser.a.   | And the state of t | flatour.   | and and and   | San  
   | 7022   | La Contraction   |
| -terrastice  | tormere  | Contra and   | anne.  | 2000   
   |  | SADA SADA  | Statistics to service and the service of the servic | and and a state  | NAMES RATES   | Canal and a  
   | Lister List   | en perfect  | in the second second   | - Hand unter   
   | 100 Million Colored  | Stuff far. a   | Barry Brother Bills  | Table States   |   
  | 20   | Total Provent  | Subline<br>Suprime   | 1. States  | Harden and   
   | -  | EDGD.  | Souther Street   | 2/55   
  | Autorite Artistana   | WESS.  | Eller.   |
| TERESCIENCES   | Marine .   | -  | interior and interior  | States and a state of the states of the stat   |   
  | Standard   | and the second second  |  | Managan   | The statistic and the state   
  | -   | Aug the second of the   | ** waterextants  | Chillemanan.  
  |  | . Hillion  | Manager and the second   | 1-100000   |  
   | Sugar and Sugar Street, Street | Coate ton  | Service Services   | And the second   | WORKS  | Station-                 
   | Augo and Aug | Station -  | Route   | And the second second  | STANK STAN   
   | ALL COLOR  |
| TERMUN,  | deren  | Non Pray   | - the design of the  | Man e  
   |  | HI PIGN.   | 1992   | and the second second  | TRAIL BOARD   
   | -  | TREAR   | and a state of the  |  | SUCCESSION  
  | WPC.   | STORY STORY  | Performentation  | ELEMENT,   | State State  
   | Contraction of the second  | Particulation  | Weinsteinen.   | Sector Sector  | Sen   
  |  | 9796 cm  | A  | Second Second   
   | SHE COM  | Tar and the second second  |  |
| The parts  |  | jann   | Sent-  | There are a second and a   
   | NEDISON KI,  | 6-1000 C   | Annale Manager   |  | Subres .  
   | Contraction of the second seco | Service and and   | Therestervises.   | Appropriate  | Personal and a second second  
  | MARKET BASINGST  | States and   | All and a second second  | Martin Street,   | and the second   
   | Waltergraphics   | - Menning  |  |  | UNREE .   
  | Sarray and   | Sector Sector  | Det Settores and   | nguraxe rann.   
   | None of the other  | Statement .  | 1770 Ale   |
| Source and an owner of the   | THE MARK COMPANY OF THE PARTY  | Sh Marilana.   |  | CREEKERS.  
   | Par manage   | Anter and a second   | and the second s | Ranner   | Summer .  | Barriston   
  | States  | AT LASTIN   | Different Finan  | 100 m   
  | Anti-  | STATUSE TOOS   |  | ADDITION OF THE  | Same -   
   | 1000   | 10   | The second second  | The second second  | NUCCEUS-  
  | arte a   | Martin Street Street   | Antis Commence   | HECHEMPS  
   | W.S.C.   | TROM.  | Carton and Carton  |
| Section of the sectio | Alexander and a second   | A rather   | Contract of  | Succession and   | proventille,   
   | MILLING WARTING  | Manufacture  | Contractor and   | No.   | Street and   
   | Reason  | Gipoman.  | Constant of the  | Sector Sector  
   | Magazare .   | No Contractor  | State of the second  | Wither   | Distantion of the second  
  | ALCONTRACTOR   | Mantana  | Pices.   | ACAMPACTURE -  | Augustation  
   | WARD DOLLAR AND A  | Marrie Marrie  | Contraction of the second  | TEN.   
  | Print  | Numeron States   | 500 ga   |
| hitality   | Burgerson  | William States   | Property and the state   | Are and a second   
   | (mill)   |  | Terte and the second second  | (F1210) (S000) 12-001 24   | bar and a state of the state of  | A CONTRACTOR OF A CONTRACTOR O | Charles and an and an and an and an   
   | El Mar  | ALIA VEVENIE CON   |  | ESTADBOORT  
  | Provide and an and a  | William .  | Junio  | all all and a second   | participation (1997)  
  | 1000   | Same and   | Contraction of the second second   |  | SPELDING AND AND   
   | NOON.  | Battaneta.   | Sale and the second second  | Same and a state of the state o | frankling and the second second   
  | UT(D)  |
| Including and  |  | ALC:   | CLIPSING CHORAD  |  
   | 10.000<br>10.000<br>10.000   | Survey and   | Restance.  | Con one of the   | Billion the   
   | II III IIIAA.  | in hilling  | Terration to the second   | Burthershinettette   
   | WALLAS MANAGER   | Strangent.   | TTOTOP IN A Miller !!  |  | S.d. ik wages   
  | White and  | No. All Statements   | Survey and   | REAL BRANCH  | Minar  
   | Party of the second second   | Separate   | ANTIS."  | hourses and the  
   |   | Selection and  | all bank said  |  |
|  |  | Anto-  | And a second sec |  |   
  | Postante and pro-  | Ransport.  |  | Baladone<br>Baladone<br>Contrator<br>Contrator<br>Contrator<br>Contrator<br>Contrator<br>Contrator  | H HILL  
  | in hits   | inter a   | Rent and a state of the second | WETEN Marganeser   |  
   | **************************************   |  | Balansen.  | Station of the   | Call Marries  
  | Moyers.  | Barbanda generation<br>Transformation  | Winner   | Harden and Andrew Andre | - 14144.   | And and a second           
   | Barar-s  | Weither mart.   | Alter and  | AND   
  |  |
|  |  | All constants  | Contraction of the second seco |  |   
  |  | Reservery  | And a server | And a second sec  |  | for instance<br>in the second sec | 2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/00/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/06/<br>2014/0 | Research   
   | And Andreas and Andrea   |  | A POST OF THE POST OF  |  | Balance<br>Balance<br>Martin  
  | NATIONAL STREET  | Contraction of the second  |  | And and a second | Wenet:   
                           |  |  |  | Barran antisanta antis   | Williams,   
   |  | And Constanting  | Tores  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|  |  |  | Construction   | Key manager promotion<br>and the second |  |  | And Antonio antonio antonio antonio antonio antonio antonio antonio antonio an | Annale Service | And a second sec  | A difference   | in most of the second s    |   | Barrowski and and a second sec |  | Bernester<br>Protection of the second<br>Protection of the second<br>Protection of the second<br>Protection of the second<br>Protection of the second of the | and a second sec |  | Martine<br>Martine<br>Martine<br>Martine<br>Martine<br>Martine<br>Martine<br>Martine   | Billion and Billio | Totological and the second sec |  | An of the second | Wreet.   |  |  |  | Baran  | Negeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegeneration<br>Wegen |  | Barren and States  |  |
|  |  |  |  |  
   |  |  |  | Control (Control (Contro) (Control (Contro) (Con | BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAGADYAN<br>BAG |   
  | An antice and a second     |   |  | March Markey and State   |   
  |  |  | Manager<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>M |  | And Andrewson an |   
  | Record any device of the second secon | Wonest<br>Anne<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second<br>Second |  |  |   
                            | Name of the second seco | And a second sec  |  |  |  |
|  |  |  |  |  
   |  |  |  |  |   
   |  |   |   |  
   |  |  | And State and Annual An |  |  | And   
  | The second secon |  |  | Array  |  |   
  |  | Anno 1997 of the sector of the |   |  |   
  | Nonese Contractions  |

a=0, b=0, c=0;	
while (a <n) do<="" td=""><td></td></n)>	
<pre>if A[a]&gt;0 then B[b]=A[a]+h(b); b=b+1; else C[c]=A[a]; c=c+1;</pre>	
a=a+1;	













First-Order Theorem Proving

# **Our work**

Loop Analysis

### Computer Algebra

### First-Order Theorem Proving

# **Our work**

funded by:





European Research Council
Supporting top researchers
from anywhere in the world



VIENNA SCIENCE AND TECHNOLOGY FUND

Loop Analysis

▲□▶▲圖▶▲≣▶▲≣▶ ≣ のへで

Loop

Requirements

◆□▶ ◆□▶ ◆臣▶ ◆臣▶ ─臣 ─のへで

**First-Order Language** 



**Requirements** 

▲□▶ ▲□▶ ▲□▶ ▲□▶ = 三 のへで

**Extended** First-Order Language

Loop

Extend language with extra symbols:

loop cnt, array update predicates

Loop Properties

**Requirements** 

▲□▶ ▲□▶ ▲□▶ ▲□▶ □ のQで

**Extended** First-Order Language



Extend language with extra symbols:

loop cnt, array update predicates

Loop Properties

Derive consequences



▲□▶▲□▶▲□▶▲□▶ □ のQ@



◆□▶ ◆□▶ ◆臣▶ ◆臣▶ 三臣 - のへで

joint work with Pamina Georgiou and Bernhard Gleiss



```
\begin{array}{l} a := 0; \, b := 0; \, c := 0; \\ \underline{while} \; (a \le k) \; \underline{do} \\ \underline{if} \; A[a] \ge 0 \\ \underline{then} \; B[b] := A[a]; b := b + 1; \\ \underline{else} \; C[c] := A[a]; c := c + 1; \\ a := a + 1; \\ \underline{end} \; do \end{array}
```



◆□▶ ◆□▶ ◆□▶ ◆□▶ ● ● ● ●

```
a := 0; b := 0; c := 0;
while (a \le k) do
if A[a] \ge 0
then B[b] := A[a]; b := b + 1;
else C[c] := A[a]; c := c + 1;
a := a + 1;
end do
```



```
a := 0; b := 0; c := 0;
<u>while</u> (a \le k) <u>do</u>

<u>if</u> A[a] \ge 0

<u>then</u> B[b] := A[a]; b := b + 1;

<u>else</u> C[c] := A[a]; c := c + 1;

a := a + 1;

<u>end do</u>
```



```
\begin{array}{l} a := 0; \, b := 0; \, c := 0; \\ \underline{\text{while}} \ (a \leq k) \ \underline{\text{do}} \\ \underline{\text{if}} \ A[a] \geq 0 \\ \underline{\text{then}} \ B[b] := A[a]; b := b + 1; \\ \underline{\text{else}} \ C[c] := A[a]; c := c + 1; \\ a := a + 1; \\ \underline{\text{end do}} \end{array}
```



```
\begin{array}{l} a := 0; \, b := 0; \, c := 0; \\ \underline{\text{while}} \ (a \leq k) \ \underline{\text{do}} \\ \underline{\text{if}} \ A[a] \geq 0 \\ \underline{\text{then}} \ B[b] := A[a]; b := b + 1; \\ \underline{\text{else}} \ C[c] := A[a]; c := c + 1; \\ a := a + 1; \\ \underline{\text{end do}} \end{array}
```



```
\begin{array}{l} a := 0; \, b := 0; \, c := 0; \\ \underline{\text{while}} \ (a \leq k) \ \underline{\text{do}} \\ \underline{\text{if}} \ A[a] \geq 0 \\ \underline{\text{then}} \ B[b] := A[a]; b := b + 1; \\ \underline{\text{else}} \ C[c] := A[a]; c := c + 1; \\ a := a + 1; \\ \underline{\text{end do}} \end{array}
```



◆□▶ ◆□▶ ◆□▶ ◆□▶ ● ● ● ●



#### Invariants with $\forall \exists$

Each of  $B[0], \ldots, B[b-1]$  is non-negative and equal to one of  $A[0], \ldots, A[a-1]$ .

 $(\forall p)(0 \le p < b \Rightarrow B[p] \ge 0 \land (\exists i)(0 \le i < a \land A[i] = B[p]))$ 

a := 0; b := 0; c := 0;	<b>A</b> :	1	3	-1	-5	8	0	-2
<u>while</u> $(a \le k) \operatorname{do}$		a = 1	7					
$\underline{if} A[a] \ge 0$ then $B[b] := A[a]:b := b + 1:$	<b>B</b> :	1	3	8	0	*	*	*
<u>else</u> $C[c] := A[a]; c := c + 1;$		b = c	4					
a := a + 1;	<b>C</b> :	-1	-5	-2	*	*	*	*
end do		c = 3	3					

Invariants with  $\forall \exists$ 

Each of  $B[0], \ldots, B[b-1]$  is non-negative and equal to one of  $A[0], \ldots, A[a-1]$ .

 $(\forall p)(0 \le p < b \Rightarrow B[p] \ge 0 \land (\exists i)(0 \le i < a \land A[i] = B[p]))$ 

< □ > < 同 > < 三 > < 三 > < 三 > < ○ < ○ </p>

a := 0; b := 0; c := 0;	<b>A</b> :	1	3	-1	-5	8	0	-2
<u>while</u> $(a \le k)$ <u>do</u>		$a = \overline{a}$	7					
$\frac{\text{if }A[a] \ge 0}{\text{then }B[b]} := A[a] \cdot b \cdot = b + 1$	<b>B</b> :	1	3	8	0	*	*	*
<u>else</u> $C[c] := A[a]; c := c + 1;$		b = 4	4					
a := a + 1;	<b>C</b> :	-1	-5	-2	*	*	*	*
end do		c = 3	3					

#### Invariants with $\forall \exists$

► Each of B[0],...,B[b-1] is non-negative and equal to one of A[0],...,A[a-1].

• Each of  $C[0], \ldots, C[c-1]$  is negative and equal to one of  $A[0], \ldots, A[a-1]$ .

#### Invariants with $\forall$

► For every p ≥ b, the value of B[p] is equal to its initial value.

For every  $p \ge c$ , the value of C[p] is equal to its initial value.

```
\begin{array}{l} a:=0; b:=0; c:=0;\\ \underbrace{\text{while}}_{ife}(a\leq k) \underbrace{\text{do}}_{iff}[a]\geq 0\\ \underbrace{\text{them}}_{ife}B[b]:=A[a]; b:=b+1;\\ \underbrace{\text{else}}_{a:=a+1}C[c]:=A[a]; c:=c+1;\\ a:=a+1; \end{array}
```

- 1. Extend the language Trace Logic:
  - ► variables as functions of *n*:  $v^{(i)}, i :: F$  with  $0 \le i < n$
  - predicates as loop properties: iter, upd<sub>V</sub>(i, p), upd<sub>V</sub>(i, p, x)

- \* ロ \* \* 個 \* \* 画 \* \* 画 \* \* 画 \* \* の < @

```
\begin{array}{l} a:=0; b:=0; c:=0;\\ \underset{if}{\text{while}}(a\leq k) \underbrace{\text{do}}\\ \underset{if}{\text{if}} A[a] \geq 0\\ \underset{if=se}{\text{hen}} B[b]:=A[a]; b:=b+1;\\ \underset{a:=a+1;}{\underline{\text{else}}} C[c]:=A[a]; c:=c+1;\\ \underset{end}{\text{end}} \underline{0} \end{array}
```

- 1. Extend the language Trace Logic:
  - ► variables as functions of *n*:  $v^{(i)}, i :: F$  with  $0 \le i < n$
  - predicates as loop properties: iter, upd<sub>V</sub>(i, p), upd<sub>V</sub>(i, p, x)
  - upd<sub>V</sub>(i, p): at iteration i, V is updated at position p;
  - upd<sub>V</sub>(i, p, x) : at iteration i, V is updated at position p by value x.

 $\begin{aligned} (\forall i)(i \in \textit{iter} \Leftrightarrow 0 \leq i \land i < n) \\ upd_B(i,p) \Leftrightarrow i \in \textit{iter} \land p = b^{(i)} \land A[a^{(i)}] \geq 0 \\ upd_B(i,p,x) \Leftrightarrow upd_B(i,p) \land x = A[a^{(i)}] \end{aligned}$ 

```
\begin{array}{l} a:=0; b:=0; c:=0;\\ \underset{if}{\text{while}}(a\leq k) \underbrace{\text{do}}\\ \underset{if}{\text{if}} A[a] \geq 0\\ \underset{if=se}{\text{hen}} B[b]:=A[a]; b:=b+1;\\ \underset{a:=a+1;}{\underline{\text{else}}} C[c]:=A[a]; c:=c+1;\\ \underset{end}{\text{end}} \underline{0} \end{array}
```

- 1. Extend the language Trace Logic:
  - variables as functions of *n*: v<sup>(i)</sup>, *i* :: *F* with 0 ≤ *i* < *n* 
     predicates as loop properties: *iter*, *upd*<sub>V</sub>(*i*, *p*), *upd*<sub>V</sub>(*i*, *p*, *x*)
- 2. Collect loop properties

 $\begin{array}{l} (\forall i)(i \in \textit{iter} \Leftrightarrow 0 \leq i \land i < n) \\ \textit{upd}_{B}(i,p) \Leftrightarrow i \in \textit{iter} \land p = b^{(i)} \land A[a^{(i)}] \geq 0 \\ \textit{upd}_{B}(i,p,x) \Leftrightarrow \textit{upd}_{B}(i,p) \land x = A[a^{(i)}] \end{array}$ 

(\*日) \*個) \*目) \*目) ヨークへで

 $\begin{array}{l} a:=0; b:=0; c:=0;\\ \underset{if}{\text{while}} (a\leq k) \underbrace{do}_{i}\\ \underset{if}{\text{if}} A[a] \geq 0\\ \underset{else}{\text{then }} B[b]:=A[a]; b:=b+1;\\ \underset{a:=a+1;}{\underline{else }} C[c]:=A[a]; c:=c+1;\\ \underset{end \ do }{\text{end }} b \end{array}$ 

- 1. Extend the language Trace Logic:
  - variables as functions of *n*: v<sup>(i)</sup>, *i* :: *F* with 0 ≤ *i* < *n* 
     predicates as loop properties: *iter*, *upd*<sub>V</sub>(*i*, *p*), *upd*<sub>V</sub>(*i*, *p*, *x*)
- 2. Collect loop properties
- Polynomial scalar properties
- Monotonicity properties of scalars
- Update predicates of arrays
- Translation of guarded assignments

 $\begin{aligned} (\forall i)(i \in iter \Leftrightarrow 0 \leq i \land i < n) \\ upd_{B}(i,p) \Leftrightarrow i \in iter \land p = b^{(i)} \land A[a^{(i)}] \geq 0 \\ upd_{B}(i,p,x) \Leftrightarrow upd_{B}(i,p) \land x = A[a^{(i)}] \end{aligned}$ 

a = b + c, a > 0, b > 0, c > 0

 $\begin{array}{l} a:=0; b:=0; c:=0;\\ \underset{if}{\textbf{while}} (a\leq k) \, \underline{\textbf{do}}\\ \underset{if}{\textbf{if}} A[a] \geq 0\\ \underset{a:=a}{\textbf{then}} B[b]:=A[a]; b:=b+1;\\ \underset{a:=a+1;}{\underline{\textbf{else}}} C[c]:=A[a]; c:=c+1;\\ \\ \underset{end \ \textbf{do}}{\textbf{end do}} \end{array}$ 

- 1. Extend the language Trace Logic:
  - variables as functions of *n*: v<sup>(i)</sup>, *i* :: *F* with 0 ≤ *i* < *n* 
     predicates as loop properties: *iter*, *upd*<sub>V</sub>(*i*, *p*), *upd*<sub>V</sub>(*i*, *p*, *x*)
- 2. Collect loop properties
- Polynomial scalar properties
- Monotonicity properties of scalars
- Update predicates of arrays
- Translation of guarded assignments

 $\begin{aligned} (\forall i)(i \in \textit{iter} \Leftrightarrow 0 \leq i \land i < n) \\ \textit{upd}_{B}(i, p) \Leftrightarrow i \in \textit{iter} \land p = b^{(i)} \land A[a^{(i)}] \geq 0 \\ \textit{upd}_{B}(i, p, x) \Leftrightarrow \textit{upd}_{B}(i, p) \land x = A[a^{(i)}] \end{aligned}$ 

a = b + c, a > 0, b > 0, c > 0 $(\forall i \in iter)(a^{(i+1)} > a^{(i)})$  $(\forall i \in iter)(b^{(i+1)} = b^{(i)} \vee b^{(i+1)} = b^{(i)} + 1)$  $(\forall i \in iter)(a^{(i)} = a^{(0)} + i)$  $(\forall p)(b^{(0)} \leq p \leq b^{(n)} \Rightarrow (\exists i \in iter)(b^{(i)} = p \land$  $A[a^{(\prime)}] > 0)$ 

▲□▶▲圖▶▲≣▶▲≣▶ ▲国 ● ●

 $\begin{array}{l} a:=0; b:=0; c:=0;\\ \underset{if}{\textbf{while}} (a\leq k) \, \underline{\textbf{do}}\\ \underset{if}{\textbf{if}} A[a] \geq 0\\ \underset{a:=a}{\textbf{then}} B[b]:=A[a]; b:=b+1;\\ \underset{a:=a+1;}{\underline{\textbf{else}}} C[c]:=A[a]; c:=c+1;\\ \\ \underset{end \ \textbf{do}}{\textbf{end do}} \end{array}$ 

- 1. Extend the language Trace Logic:
  - variables as functions of *n*: v<sup>(i)</sup>, *i* :: *F* with 0 ≤ *i* < *n* 
     predicates as loop properties: *iter*, *upd*<sub>V</sub>(*i*, *p*), *upd*<sub>V</sub>(*i*, *p*, *x*)
- 2. Collect loop properties
- Polynomial scalar properties
- Monotonicity properties of scalars
- Update predicates of arrays
- Translation of guarded assignments

 $\begin{aligned} (\forall i)(i \in \textit{iter} \Leftrightarrow 0 \leq i \land i < n) \\ \textit{upd}_{B}(i, p) \Leftrightarrow i \in \textit{iter} \land p = b^{(i)} \land A[a^{(i)}] \geq 0 \\ \textit{upd}_{B}(i, p, x) \Leftrightarrow \textit{upd}_{B}(i, p) \land x = A[a^{(i)}] \end{aligned}$ 

a = b + c, a > 0, b > 0, c > 0 $(\forall i \in iter)(a^{(i+1)} > a^{(i)})$  $(\forall i \in iter)(b^{(i+1)} = b^{(i)} \vee b^{(i+1)} = b^{(i)} + 1)$  $(\forall i \in iter)(a^{(i)} = a^{(0)} + i)$  $(\forall p)(b^{(0)}$  $A[a^{(\prime)}] > 0)$  $(\forall i) \neg upd_B(i, p) \Rightarrow B^{(n)}[p] = B^{(0)}[p]$  $upd_B(i, p, x) \land (\forall j > i) \neg upd_B(j, p) \Rightarrow B^{(n)}[p] = x$ 

▲□▶▲圖▶▲圖▶▲圖▶ 圖 のQ@

 $\begin{array}{l} a:=0; b:=0; c:=0;\\ \underset{if}{\textbf{while}} (a\leq k) \, \underline{\textbf{do}}\\ \underset{if}{\textbf{if}} A[a] \geq 0\\ \underset{a:=a}{\textbf{then}} B[b]:=A[a]; b:=b+1;\\ \underset{a:=a+1;}{\underline{\textbf{else}}} C[c]:=A[a]; c:=c+1;\\ \\ \underset{end \ \textbf{do}}{\textbf{end do}} \end{array}$ 

- 1. Extend the language Trace Logic:
  - variables as functions of *n*: v<sup>(i)</sup>, *i* :: *F* with 0 ≤ *i* < *n* 
     predicates as loop properties: *iter*, *upd*<sub>V</sub>(*i*, *p*), *upd*<sub>V</sub>(*i*, *p*, *x*)
- 2. Collect loop properties
- Polynomial scalar properties
- Monotonicity properties of scalars
- Update predicates of arrays
- Translation of guarded assignments

 $\begin{aligned} (\forall i)(i \in \textit{iter} \Leftrightarrow 0 \leq i \land i < n) \\ \textit{upd}_{B}(i, p) \Leftrightarrow i \in \textit{iter} \land p = b^{(i)} \land A[a^{(i)}] \geq 0 \\ \textit{upd}_{B}(i, p, x) \Leftrightarrow \textit{upd}_{B}(i, p) \land x = A[a^{(i)}] \end{aligned}$ 

a = b + c, a > 0, b > 0, c > 0 $(\forall i \in iter)(a^{(i+1)} > a^{(i)})$  $(\forall i \in iter)(b^{(i+1)} = b^{(i)} \vee b^{(i+1)} = b^{(i)} + 1)$  $(\forall i \in iter)(a^{(i)} = a^{(0)} + i)$  $(\forall p)(b^{(0)} \leq p \leq b^{(n)} \Rightarrow (\exists i \in iter)(b^{(i)} = p \land$  $A[a^{(\prime)}] > 0)$  $(\forall i) \neg upd_B(i, p) \Rightarrow B^{(n)}[p] = B^{(0)}[p]$  $upd_B(i, p, x) \land (\forall j > i) \neg upd_B(j, p) \Rightarrow B^{(n)}[p] = x$  $(\forall i \in iter)(A[a^{(i)}] > 0 \Rightarrow B^{(i+1)}[b^{(i)}] = A[a^{(i)}] \land$  $b^{(i+1)} = b^{(i)} + 1 \wedge$  $c^{(i+1)} = c^{(i)}$ 

▲日▼▲圖▼▲画▼▲画▼ 画 めんの

 $\begin{array}{l} a:=0; b:=0; c:=0;\\ \underset{if}{\text{while}} (a\leq k) \underbrace{do}_{i}\\ \underset{if}{\text{if}} A[a] \geq 0\\ \underset{else}{\text{then }} B[b]:=A[a]; b:=b+1;\\ \underset{a:=a+1;}{\underline{else }} C[c]:=A[a]; c:=c+1;\\ \underset{end \ do }{\text{end }} b \end{array}$ 

- 1. Extend the language Trace Logic:
  - variables as functions of *n*: v<sup>(i)</sup>, *i* :: *F* with 0 ≤ *i* < *n* 
     predicates as loop properties: *iter*, *upd*<sub>V</sub>(*i*, *p*), *upd*<sub>V</sub>(*i*, *p*, *x*)
- 2. Collect loop properties TraceLemmas:  $(\forall i \in iter)(a^{(i)} = a^{(0)} + i)$
- Polynomial scalar properties
- Monotonicity properties of scalars
- Update predicates of arrays
- Translation of guarded assignments

 $\begin{aligned} (\forall i)(i \in \textit{iter} \Leftrightarrow 0 \leq i \land i < n) \\ \textit{upd}_{B}(i, p) \Leftrightarrow i \in \textit{iter} \land p = b^{(i)} \land A[a^{(i)}] \geq 0 \\ \textit{upd}_{B}(i, p, x) \Leftrightarrow \textit{upd}_{B}(i, p) \land x = A[a^{(i)}] \end{aligned}$ 

a = b + c, a > 0, b > 0, c > 0 $(\forall i \in iter)(a^{(i+1)} > a^{(i)})$  $(\forall i \in iter)(b^{(i+1)} = b^{(i)} \vee b^{(i+1)} = b^{(i)} + 1)$  $(\forall p)(\mathbf{b}^{(0)}$  $A[a^{(i)}] > 0))$  $(\forall i) \neg upd_B(i, p) \Rightarrow B^{(n)}[p] = B^{(0)}[p]$  $upd_{B}(i, p, x) \land (\forall j > i) \neg upd_{B}(j, p) \Rightarrow B^{(n)}[p] = x$  $(\forall i \in iter)(A[a^{(i)}] \geq 0 \Rightarrow B^{(i+1)}[b^{(i)}] = A[a^{(i)}] \land$  $b^{(i+1)} = b^{(i)} + 1 \wedge$  $c^{(i+1)} = c^{(i)}$ 

```
(\forall i)(i \in iter \Leftrightarrow 0 < i \land i < n)
  upd_{B}(i, p) \Leftrightarrow i \in iter \land p = b^{(i)} \land A[a^{(i)}] > 0
 upd_{B}(i, p, x) \Leftrightarrow upd_{B}(i, p) \land x = A[a^{(i)}]
 a = b + c, a > 0, b > 0, c > 0
 (\forall i \in iter)(a^{(i+1)} > a^{(i)})
 (\forall i \in iter)(b^{(i+1)} = b^{(i)} \vee b^{(i+1)} = b^{(i)} + 1)
 (\forall i \in iter)(a^{(i)} = a^{(0)} + i)
 (\forall i, k \in iter)(k > i \Rightarrow b^{(k)} > b^{(j)})
 (\forall i, k \in iter)(k \ge i \Rightarrow \mathbf{b}^{(i)} + k \ge \mathbf{b}^{(k)} + i)
 (\forall p)(\mathbf{b}^{(0)} 
                                                        A[a^{(i)}] > 0))
 (\forall i) \neg upd_{B}(i, p) \Rightarrow B^{(n)}[p] = B^{(0)}[p]
upd_{B}(i, p, x) \land (\forall j > i) \neg upd_{B}(j, p) \Rightarrow B^{(n)}[p] = x
(\forall i \in iter)(A[a^{(i)}] > 0 \Rightarrow B^{(i+1)}[b^{(i)}] = A[a^{(i)}] \land
                                         b^{(i+1)} = b^{(i)} + 1 \wedge
                                         c^{(i+1)} = c^{(i)}
```



◆□▶ ◆□▶ ◆□▶ ◆□▶ ● ● ● ●

1. Challenge: Deriving useful loop properties

2. Challenge: Reasoning with first-order theories

▲□▶ ▲□▶ ▲ 三▶ ▲ 三▶ - 三 - のへぐ

- 1. Challenge: Deriving useful loop properties
- ▶ For every loop variable  $v \rightarrow \text{TARGET SYMBOLS } v_0$  and v

 $v^{(0)} = v_0$  and  $v^{(n)} = v$ 

- USABLE symbols:
  - target or interpreted symbols
  - skolem functions introduced while clausification
- USEFUL clauses:
  - contains only usable symbols
- Reduction ordering >: useless symbols > usable symbols
- Property-directed inferences using loop post-conditions/assertions

(日) (日) (日) (日) (日) (日) (日)

- 1. Challenge: Deriving useful loop properties
- For every loop variable  $v \rightarrow \text{TARGET SYMBOLS } v_0$  and v
- USABLE symbols:
  - target or interpreted symbols
  - skolem functions introduced while clausification
- USEFUL clauses:
  - contains only usable symbols
- Reduction ordering >: useless symbols > usable symbols
- Property-directed inferences using loop post-conditions/assertions

・ロト ・ 同 ・ ・ ヨ ・ ・ ヨ ・ うへつ

- 1. Challenge: Deriving useful loop properties
- For every loop variable  $v \rightarrow \text{TARGET SYMBOLS } v_0$  and v
- USABLE symbols:
  - target or interpreted symbols
  - skolem functions introduced while clausification
- USEFUL clauses:
  - contains only usable symbols
- ► Reduction ordering ≻: useless symbols ≻ usable symbols
- Property-directed inferences using loop post-conditions/assertions

・ロト ・ 同 ・ ・ ヨ ・ ・ ヨ ・ うへつ

- 1. Challenge: Deriving useful loop properties
- For every loop variable  $v \rightarrow \text{TARGET SYMBOLS } v_0$  and v
- USABLE symbols:
  - target or interpreted symbols
  - skolem functions introduced while clausification
- USEFUL clauses:

x + y = y + x is not useful

・ロト ・ 同 ・ ・ ヨ ・ ・ ヨ ・ うへつ

- contains only usable symbols
- contains at least a target symbol or a skolem function;
- Reduction ordering >: useless symbols > usable symbols
- Property-directed inferences using loop post-conditions/assertions

- 1. Challenge: Deriving useful loop properties
- For every loop variable  $v \rightarrow \text{TARGET SYMBOLS } v_0$  and v
- USABLE symbols:
  - target or interpreted symbols
  - skolem functions introduced while clausification
- USEFUL clauses:
  - contains only usable symbols
  - contains at least a target symbol or a skolem function;
- Reduction ordering >: useless symbols > usable symbols
- Property-directed inferences using loop post-conditions/assertions

(ロ) (同) (三) (三) (三) (○) (○)

- 1. Challenge: Deriving useful loop properties
- For every loop variable  $v \rightarrow \text{TARGET SYMBOLS } v_0$  and v
- USABLE symbols:
  - target or interpreted symbols
  - skolem functions introduced while clausification
- USEFUL clauses:
  - contains only usable symbols
  - contains at least a target symbol or a skolem function;
- Reduction ordering >: useless symbols > usable symbols
- Property-directed inferences using loop post-conditions/assertions

1. Challenge: Deriving useful loop properties

- 2. Challenge: Reasoning with first-order theories
  - Term algebras: subterm predicates for finite axiomatisations

- Arrays: polymorphic theory with extensionality
- Integers/Reals: incomplete but sound set of axioms
- Natural numbers: Integer vs term algebra encoding

1. Challenge: Deriving useful loop properties

- 2. Challenge: Reasoning with first-order theories
  - Term algebras: subterm predicates for finite axiomatisations

◆□▶ ◆□▶ ▲□▶ ▲□▶ ■ ののの

- Arrays: polymorphic theory with extensionality
- Integers/Reals: incomplete but sound set of axioms
- Natural numbers: Integer vs term algebra encoding

1. Challenge: Deriving useful loop properties

- 2. Challenge: Reasoning with first-order theories
  - Term algebras: subterm predicates for finite axiomatisations
  - Arrays: polymorphic theory with extensionality
  - Integers/Reals: incomplete but sound set of axioms

 $x \ge y \iff x > y \lor x = y$  $x \ge y \land y \ge z \Rightarrow x \ge z$ x + 1 > x

Natural numbers: Integer vs term algebra encoding

◆□ → ◆□ → ◆三 → ◆三 → ● ◆ ● ◆ ●

1. Challenge: Deriving useful loop properties

- 2. Challenge: Reasoning with first-order theories
  - Term algebras: subterm predicates for finite axiomatisations

◆□▶ ◆□▶ ▲□▶ ▲□▶ □ のQ@

- Arrays: polymorphic theory with extensionality
- Integers/Reals: incomplete but sound set of axioms
- Natural numbers: Integer vs term algebra encoding

1. Challenge: Deriving useful loop properties

- 2. Challenge: Reasoning with first-order theories
  - Term algebras: subterm predicates for finite axiomatisations
  - Arrays: polymorphic theory with extensionality
  - Integers/Reals: incomplete but sound set of axioms
  - Natural numbers: Integer vs term algebra encoding

### BRIDGING THE GAP BETWEEN

SMT AND FIRST-ORDER THEOREM PROVING







### Tra

		A+T	A+1	$\mathbf{F} + \mathbf{T}$	F+1	A+T	A+1	$\mathbf{P} + \mathbf{I}$	F+1	A+T	A+1	$\mathbf{F} + \mathbf{I}$	$ \mathbf{F}+\mathbf{I} $
and Logic for Auto	absolute-prop1	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	t	t	t	t	t	t	t	t
ace Lodic for Auto	absolute-prop2	V 1	$\checkmark$	t	$\checkmark$	t	t	t	t	t	t	t	t
	atleast-one-iteration	<ul> <li>✓</li> </ul>	t	1	t	t	t	t	t	<ul> <li>Image: A start of the start of</li></ul>	$\checkmark$	$\checkmark$	~
	both-or-none	<b>↓</b> ✓	$\checkmark$	~	✓	t	t	t	t	t	t	t	t
	check-equal-set-flag	t	t	t	t	t	t	t	t	t	t	t	t
	copy	V .	~	1	V	t	t	t	t	t	t	t	t
	copy-nonzero-prop1	t	t	t	t	t	t	t	t	t	t	t	t
	copy-nonzero-prop2	t	t	t	t	t	t	t	t	t	t	t	t
	copy-odd	V.	×	×	V	t	t	t	t	t	t	t	t
Pormal Methods	copy-partial	V .	×.	~	×	t	t	t	t	t	t	t	t
	copy-positive	t	t	t	t	t	t	t	t	t	t	t	t
	copy-two-indices	t	×.	t		L L	L L	t	t	t	t	t	t
Trace Logic for In	find1-prop1	×,	t t	× /	t t	t t	t t	t t	t t	, v	× ·	¥	¥
flace Logic for m	find1 prop2	× 1	t	× /	t		L +	t +	t +	t +	т т	t +	t +
	find2 prop1	l v	×,	× /	×		+		+		L.	6	6
Pamina Gaorgiou B	find2-prop2	ľ,	×.	· ·	ľ.	, t	+	¥	+	* +	· ·	*	* +
rannia Georgiou, D	find2-prop3	Nº C	×.	× ·	· ·	+	+	+	+	+		+	+
10	find-max	l +	* +	• +	¥ I	+	+	+	+	+	+	+	+
	find-max-up-to-prop1		+	+	+	+	+	+	+	+	+	+	+
	find-max-up-to-prop?		1	1	1	t	t	t	t	t	t	t	t
Abstract—We propose trace logic, an instance of many-s	find-max-from-second	t	t	t	t	t	t	t	t	t	t	t	t
first-order logic, to automate the partial correctness verific	find-min	t	t	t	t	t	t	t	t	t	t	t	t
of programs containing loops. Trace logic generalizes sema	find-min-up-to		1	1		t	t	t	t	t	t	t	t
of program locations and a strength of program locations by enco	find-sentinel	1	1	1		t	t	t	t	t	1	t	t
III MARKAN AND AND AND AND AND AND AND AND AND A	wo-max-prop1	l t	t	t	t	t	t	t	t	t	t	t	t
	x-prop2	t	t	t	t	t	t	t	t	t	t	t	1
		t	t	t	t	t	t	t	t	t	t	t	t
Dravad 24 unique proble	-prop1	V 1	$\checkmark$	1	1	t	t	t	t	t	t	t	t
Proved 24 unique propie	ms -prop2	1	$\checkmark$	t	<ul><li>✓</li></ul>	t	t	t	t	t	t	t	t
	ength	✓	$\checkmark$	1	1	t	t	t	t	<ul> <li>✓</li> </ul>	$\checkmark$	~	1
		V 1	$\checkmark$	1	<ul><li>✓</li></ul>	t	t	t	t	t	t	t	t
	onditionally-prop1	t	t	t	t	t	t	t	t	t	t	t	t
	init-conditionally-prop2	l t	t	t	t	t	t	t	t	t	t	t	t
I. INTRODUCTION	init-even	t	V.	t	<ul> <li>✓</li> <li>✓</li> </ul>	t	t	t	t	t	~	t	t
One of the main challenges in automating solution	init-non-constant	V.	V.	×	V	t	t	t	t	t	t	t	t
comes with handling inductive reasoning over p	init-partial	V .	×.	×	×	t	t	t	t	t	~	t	t
taining loops. Until recently, automated reasoning	t-previous-plus-one	t	t	t	t	t	t	t	t	t	t	t	1
verification was the primary domain of satisfiability b	-prop1	V.	×	×.	×	L L	L L	t	t	t	t	t	t
theory (SMT) solvers [1] [2] vielding powerful advancen	prop2	l ·	× /	× ·	×	L L	L L	t	L L	t	L L	t	t
alcory (birr) solvers [1], [2], yielding powerful advancen	terleave-prop1		¥.	L L	¥,	L +	L +	L .		L +	۰ ۲	t.	L +
	erieave-prop2	1 t	t +	ι τ +	t 1	+	+ +	+ L	+ +	1 t	ь +	ι +	+
	par	1 t	+	+	+	+	+	+	+	+	+	+	+
	partit	l t	t	t	t	t	t	t	t	t	t	t	t
	push-bac	l t	1	t	1	t	t	t	t	t	1	t	1
	push-back-	t	1	t		t	t	t	t	t	t	t	t
	reverse	1	1	1		t	t	t	t	t	t	t	t
	set-to-one		t	1	t	t	t	t	t	1	1	1	1
	str-cpy	1	$\checkmark$	1	V	t	t	t	t	t	t	t	t
	str-len	~	1	1	1	t	t	t	t	t	t	t	t
	swap-prop1	t	t	t	t	t	t	t	t	t	t	t	t
	swap-prop2		t	t	t	t	t	t	t	t	t	t	t
	vector-addition		1	1	1	t	t	t	t	t	t	t	t
	vector-subtraction		$\checkmark$	1	$\checkmark$	t	t	t	t	t	t	t	t
	Total		3	5			1				1.	3	

VAMPIRE

24

CVC4

0

Z3

2

Benchmark

Unique

### **Trace Logic for Auto**

#### Benchmark

absolute-prop1 absolute-prop2 atleast-one-ite both-or-none check-equal-set-n copy copy-nonzero-prop1

### Proved 63 problems with improved Trace Logic encodings

 $\mathbf{Z3}$ 

F+T|F+I

Benchmark	RAPID <sup>-</sup>	<b>RAPID</b> *	Benchmark	RAPID <sup>-</sup>	$\texttt{Rapid}^*$	Bencl		$\texttt{Rapid}^-$	$\texttt{Rapid}^*$
atleast_one_iteration_0	$\checkmark$	$\checkmark$	find_max_local_2	-	-	init_pre	ult_0	-	$\checkmark$
atleast_one_iteration_1	$\checkmark$	$\checkmark$	find_max_up_to_0	-	-	init_prev	lt_1	-	$\checkmark$
both_or_none	-	$\checkmark$	find_max_up_to_1	-	-	max_prop_		-	$\checkmark$
check_equal_set_flag_0	$\checkmark$	$\checkmark$	find_max_up_to_2	-	-	max_prop_		-	$\checkmark$
check_equal_set_flag_1	-	$\checkmark$	find_min_0	-	$\checkmark$	merge_interl		-	-
collect_indices_eq_val_0	-	$\checkmark$	find_min_1	-	-	merge_interle.		-	-
collect_indices_eq_val_1	- 1	$\checkmark$	find_min_2	-	$\checkmark$	merge_interlea		-	-
collect_indices_eq_val_2	-	$\checkmark$	find_min_local_0	-	-	min_prop_0		-	$\checkmark$
collect_indices_eq_val_3	-	-	find_min_local_1	-	-	min_prop_1		-	$\checkmark$
сору	-	$\checkmark$	find_min_local_2	-	-	partition_0		-	$\checkmark$
copy_absolute_0	-	$\checkmark$	find_min_up_to_0	-	-	partition_1		-	$\checkmark$
copy_absolute_1	-	$\checkmark$	find_min_up_to_1	-	-	partition_2		-	$\checkmark$
copy_nonzero_0	-	$\checkmark$	find_min_up_to_2	-	-	partition_3		-	$\checkmark$
copy_nonzero_1	-	$\checkmark$	find_sentinel	$\checkmark$	$\checkmark$	partition_4		-	-
copy_partial	-	$\checkmark$	in_place_max	-	$\checkmark$	partition_5		-	$\checkmark$
copy_positive_0	-	$\checkmark$	inc_by_one_0	-	$\checkmark$	partition_6		-	-
copy_positive_1	-	$\checkmark$	inc_by_one_1	-	$\checkmark$	partition-harder_0		-	$\checkmark$
copy_two_indices	-	$\checkmark$	inc_by_one_harder_0	-	$\checkmark$	partition-harder_1			$\checkmark$
find1_0	-	$\checkmark$	inc_by_one_harder_1	-	$\checkmark$	partition-harder_2			-
find1_1	-	$\checkmark$	indexn_is_arraylength_0	$\checkmark$	$\checkmark$	partition-harder_3			-
find1_2	$\checkmark$	$\checkmark$	indexn_is_arraylength_1	-	$\checkmark$	partition-harder_4			-
find1_3	$\checkmark$	$\checkmark$	init	-	$\checkmark$	push_back			$\checkmark$
find1_4	-	$\checkmark$	init_conditionally_0	-	$\checkmark$	reverse			$\checkmark$
find2_0	-	$\checkmark$	init_conditionally_1	-	$\checkmark$	set_to_one			$\checkmark$
find2_1	$\checkmark$	$\checkmark$	init_non_constant_0	-	$\checkmark$	str_cpy_0			$\checkmark$
find2_2	$\checkmark$	$\checkmark$	init_non_constant_1	-	$\checkmark$	str_cpy_1		-	$\checkmark$
find2_3	$\checkmark$	$\checkmark$	init_non_constant_2	-	$\checkmark$	str_cpy_2		$\checkmark$	$\checkmark$
find2_4	$\checkmark$	$\checkmark$	init_non_constant_3	-	$\checkmark$	str_cpy_3		$\checkmark$	$\checkmark$
find_max_0	-	$\checkmark$	init_non_constant_easy_0	-	$\checkmark$	str_len		$\checkmark$	$\checkmark$
find_max_1	-	-	init_non_constant_easy_1	-	$\checkmark$	swap_0		-	$\checkmark$
find_max_2	-	$\checkmark$	init_non_constant_easy_2	-	$\checkmark$	swap_1		-	$\checkmark$
find_max_from_second_0	-	-	init_non_constant_easy_3	-	$\checkmark$	vector_addition		÷	$\checkmark$
find_max_from_second_1	-	-	init_partial	-	$\checkmark$	vector_subtraction		-	$\checkmark$
find_max_local_0	-	-	init_previous_plus_one_0	_	$\checkmark$				
find_max_local_1	-	-	init_previous_plus_one_1	-	$\checkmark$	Total solved		15	78

further extensions in Trace Logic: <a href="mailto:variable(trace">variable(trace</a>, <a href="loop">loop</a> iteration)



further extensions in Trace Logic: variable(trace, loop iteration)



## Verifying Relational Properties using Trace Logic

Gilles Barthe<sup>\*†</sup>, Renate Eilers<sup>‡</sup>, Pamina Georgiou<sup>‡</sup>, Bernhard Gleiss<sup>‡</sup>, Laura Kovács<sup>‡§</sup>, Matteo Maffei<sup>‡</sup> \*Max Planck Institute for Security and Privacy, Germany

<sup>†</sup>IMDEA Software Institute, Spain <sup>‡</sup>TU Wien, Austria

<sup>§</sup>Chalmers University of Technology, Sweden

Abstract—We present a logical framework for the verification of relational properties in imperative programs. Our framework reduces verification of relational properties of imperative programs to a validity problem in trace logic, an expressive instance of first-order predicate logic. Trace logic draws its expressiveness from its syntax, which allows expressing properties over computation traces. Its axiomatization supports fine-grained reasoning about intermediate steps in program execution, notably loop iterations. We present an algorithm to encode the semantics of programs as well as their relational properties in trace logic, and then show how first-order theorem proving can be used to reason about the resulting trace logic formulas. Our work is implemented in the tool RAPID and evaluated with examples coming from the security field.

```
func main()
 1
 2
   {
 3
4
         const Int[] a;
         const Int alength;
 5
6
         Int i = 0;
 7
8
         Int hw = 0;
 9
         while (i < alength)</pre>
10
11
            hw = hw + a[i];
12
            i = i + 1;
13
14
```



Vampire

**Summary** 

• Software semantics in (extensions) of first-order logic

• First-order theories of data structures

Induction







### Challenges

• **Software semantics** in (extensions) of first-order logic *in extensions of trace logic with algebraic and probabilistic features* 

### • First-order theories of data structures

reasoning with quantifiers + int/real, naturals/term algebras, arrays, ...

### Induction

not a first-order property







# Verifying Relational Properties using Trace Logic

Gilles Barthe<sup>\*†</sup>, Renate Eilers<sup>‡</sup>, Pamina Georgiou<sup>‡</sup>, Bernhard Gleiss<sup>‡</sup>, Laura Kovács<sup>‡§</sup>, Matteo Maffei<sup>‡</sup>

\*Max Planck Institute for Security and Privacy, Germany

<sup>†</sup>IMDEA Software Institute, Spain

<sup>‡</sup>TU Wien, Austria

<sup>§</sup>Chalmers University of Technology, Sweden

Abstract—We present a logical framework for the verification of relational properties in imperative programs. Our framework reduces verification of relational properties of imperative programs to a validity problem in trace logic, an expressive instance of first-order predicate logic. Trace logic draws its expressiveness from its syntax, which allows expressing properties over computation traces. Its axiomatization supports fine-grained reasoning about intermediate steps in program execution, notably loop iterations. We present an algorithm to encode the semantics of programs as well as their relational properties in trace logic, and then show how first-order theorem proving can be used to reason about the resulting trace logic formulas. Our work is implemented in the tool RAPID and evaluated with examples coming from the security field.

```
func main()
 1
 2
 3
         const Int[] a;
 4
        const Int alength;
 5
 6
         Int i = 0;
 7
        Int hw = 0;
 8
 9
        while (i < alength)</pre>
10
            hw = hw + a[i];
11
12
            i = i + 1;
13
14
```





- Array **a**: bit-wise representation of a secret key
- Hamming weight hw: number of 1s in the key



- Array **a**: bit-wise representation of a secret key
- Hamming weight hw: number of 1s in the key

- Leaking hw?

(e.g. measure of side-channel leakage)



- Array **a**: bit-wise representation of a secret key
- Hamming weight hw: number of 1s in the key

- Leaking hw?

No matter what permutation of **a**, the **hw** is the same

## **Relational Verification**















### Relational Verification (non-interference, sensitivity)



**Summary** 

• Software semantics in (extensions) of first-order logic

• First-order theories of data structures

Induction







### Challenges

• **Software semantics** in (extensions) of first-order logic *in extensions of trace logic with algebraic and probabilistic features* 

### • First-order theories of data structures

reasoning with quantifiers + int/real, naturals/term algebras, arrays, ...

### Induction

not a first-order property





