

A Appendices

A.1 More Comparisons Between TLS and MTLs Systems

Besides MARSTCHAT2018 method, we also compare between TLS and MTLs systems based on the other two TLS algorithms introduced in Section 6.2, to show their adaptability to mixture datasets. The results are shown in Table 7 and Table 8.

A.2 Output Examples

For intuitive understanding of the systems output, we show several example outputs. Table 9 shows the output of TLS algorithm (GHOLIPOUR2020) working on dataset D_{11} , which is a mixture of *egypt*, *h1n1* and *iraq*. The first 5 dates and summaries are for topic *h1n1* while the following 4 dates and summaries are for topic *egypt*. In contrast, MTLs yields more meaningful results, as shown in Table 10. It distinguishes different topics, and generates a relatively coherent timeline for each topic. The timeline tags are generated by *Tagging* step described in Section 4.2.

A.3 Full Timeline Case Study

We examine the cases of full timelines generated by our 2SAPS on different datasets. Figure 2, Figure 3 and Figure 4 show the generated timelines when $L = 1, 2, 3$, respectively. We marked different topics with colors.

Model	Metric	L=1	L=2	L=3	L=4	L=5
TLS (CHIEU2004)	align+m:1(R1)	0.015	0.043	0.027	0.028	0.018
	align+m:1(R2)	0.003	0.012	0.008	0.010	0.007
MTLS(k-means-CHIEU2004)	align+m:1(R1)	0.017	0.051	0.070	0.081	0.101
	align+m:1(R2)	0.000	0.013	0.020	0.023	0.029
MTLS(LDA-CHIEU2004)	align+m:1(R1)	0.019	0.037	0.047	0.077	0.078
	align+m:2(R2)	0.002	0.010	0.013	0.022	0.019

Table 7: Performance comparison between TLS and MTLS systems.

Model	Metric	L=1	L=2	L=3	L=4	L=5
TLS (GHOLIPOUR2020)	align+m:1(R1)	0.093	0.115	0.096	0.099	0.121
	align+m:1(R2)	0.024	0.032	0.025	0.021	0.031
MTLS (k-means-GHOLIPOUR2020)	align+m:1(R1)	0.089	0.142	0.123	0.127	0.152
	align+m:1(R2)	0.023	0.039	0.035	0.029	0.040
MTLS (LDA-GHOLIPOUR2020)	align+m:1(R1)	0.084	0.156	0.123	0.133	0.131
	align+m:2(R2)	0.020	0.049	0.043	0.037	0.035

Table 8: Performance comparison between TLS and MTLS systems.

2010-01-12	The 7.0-magnitude quake , Haiti 's worst in two centuries, struck south of the capital...
2010-01-13	The United Nations says that its headquarters in Haiti has been seriously damaged...
2010-01-14	BBC reporter on the ground in Port-au-Prince The US is mounting one of the biggest...
2010-01-15	2142 US Secretary of State Hillary Clinton says at a news conference that she will go to Haiti ...
2010-01-16	The ICRC and Save the Children , both of which have worked in Haiti for many years , have been distributing...
2010-01-17	We 've had incidents of violence that impede our ability to support the government of Haiti and...
2010-01-18	Earthquake misery in Haiti hospital Medical help is slowly getting to some of the survivors of...
2010-01-19	The request for international assistance for Haiti will have been speeded up by the presence of UN troops...
2010-01-20	Haitian officials say the death toll from the quake was likely to be between 100,000 and 200,000...
2010-01-21	They say that while images of the misery in Haiti can spread rapidly around the world , aid supplies...
...	

Figure 2: Case study on $L = 1$.

2010-01-12	The 7.0-magnitude quake , Haiti 's worst in two centuries , struck on Tuesday...
2010-01-13	Haiti has moved to the center of the world 's thoughts , and the world 's compassion...
2010-01-14	The minute-long quake was felt all over the island and reached 7.0 on the scale measuring...
2010-01-15	Twitter spreads news from Haiti Jane O'Brien reports on how new technology such as Skype...
2010-01-16	Charities given Haiti funds boost An international effort is under way to help...
2010-01-18	Earthquake misery in Haiti hospital Medical help is slowly getting to some of the survivors...
2010-01-20	Haitian officials say the death toll from the quake was likely to be between 100,000 and 200,000...
2010-01-21	To speed up the process , aid flights are also coming into and out of the neighbouring...
2010-01-22	Clooney on raising money for Haiti Other acts taking part in the telethon include U2 's Bono...
2010-01-23	A Haitian man has been pulled alive from the rubble of a ruined hotel after 11 days...
...	

(a) Generated timeline 1.

2009-04-25	Testing has shown that the human swine influenza H1N1 can be treated with the antivirals oseltamivir...
2009-04-26	Swine flu : fears of pandemic rise as Mexico death toll reaches 80 Suspected cases reported in US...
2009-04-27	the UN 's health agency , expert said the swine flu virus could be capable of mutating into...
2009-04-28	The World Health Organization has confirmed that at least some of the human cases are...
2009-04-29	The latest swine flu is a variation of H1N1 , which causes seasonal outbreaks of flu in humans...
2009-04-30	The WHO is now referring to the bug as influenza A -LRB- H1N1 -RRB- , not swine flu
2009-05-01	Inside the lab where experts are working on a swine flu vaccine British scientists have begun work...
2009-05-04	Another nine UK cases of swine flu have been confirmed taking the total to 27 , according to...
2009-05-05	Health officials are carrying out medical checks on people with flu symptoms arriving via air and...
2009-05-07	The United Nations said killing the pigs would be a mistake , but even after the World Health Organization...
...	

(b) Generated timeline 2.

Figure 3: Case study on $L = 2$.

2008-09-17	Aided by a far more transparent financial system that has made it more difficult for U.S. banks to hide...
2008-09-28	The measures to take toxic debts off the hands of financial and insurance firms are intended...
2008-10-01	While Wall Street has only recently felt the bite of foreclosures and delinquencies , communities across...
2008-10-11	Treasury Secretary Henry Paulson , center , listens as President Bush , not pictured , makes a statement...
2008-10-12	Leaders had agreed , he added , to `` take decisive action to support systemically important financial institutions...
2008-10-26	While the world 's attention has been focused on rescuing investment banks and stock markets from collapse...
2008-11-24	The expansion in Fed lending has come in the form of numerous new programs to inject cash into the financial ...
2008-12-24	Retailers have blamed the global financial crisis for a litany of ills over the past year...
2009-03-03	On Capitol Hill , meanwhile , Federal Reserve Chairman Ben S. Bernanke said the government...
2009-06-15	Relying on the Federal Reserve 's lending authority to avert the disorderly failure of nonbank financial firms...
...	

(a) Generated timeline 1.

2011-02-21	Libya 's justice minister , Mustafa Abdul Jalil , has resigned to protest the `` bloody situation...
2011-02-22	Libyan state TV described the crowds on the streets who were watching Gadhafi 's speech as his supporters...
2011-02-25	For most Arabs , al Qaeda appears more irrelevant than ever But spiraling violence in Libya may...
2011-02-26	The Libyan people deserve a government that is responsive to their aspirations and that protects...
2011-02-28	Industry reports suggested Libya 's oil output had been halved as expatriate workers pulled out...
2011-03-01	No one expects any direct foreign military intervention in Libya for now , although there has been talk of...
2011-03-02	Libya 's deputy ambassador to the United Nations , one of the first Libyan diplomats to denounce...
2011-03-03	Libya is not a signatory of the ICC treaty , `` but we are willing to deal with the ICC and take action against...
2011-03-05	Almost 200,000 people , a majority of them foreign workers , have fled Libya -- nearly 100,000 to Tunisia...
2011-03-07	- The Libyan army is attempting to drive out loose formations of rebels opposed to Muammar Gaddafi that...
...	

(b) Generated timeline 2.

2009-06-25	Michael Jackson died in June 2009 aged 50 Executors of Michael Jackson 's estate have asked the Discovery Channel to...
2009-06-28	Michael Jackson 's family are said to be seeking a second autopsy because they still have questions about...
2009-06-29	Stars performed Jackson 5 hits at the start of the show Stars have been celebrating the life of Michael Jackson in Los Angeles...
2009-07-28	Police raid Jackson doctor 's home Drug police are searching the Las Vegas home of Michael Jackson 's doctor...
2009-08-25	But , on the morning of the singer 's death , Dr Murray is reported to have relented and given Jackson a lower dosage...
2010-06-25	Fans around the world marked one year since the singer 's death Pop star Michael Jackson 's father has filed a wrongful death...
2011-01-11	The detective said Dr Murray admitted giving Jackson it after a night administering lesser drugs to help him sleep...
2011-09-27	La Toya Jackson arrives at the opening day of Dr Conrad Murray 's trial into the death of her pop star brother Michael Jackson ...
2011-10-08	The Michael Forever concert will take place at Cardiff 's Millennium Stadium on 8 October...
2011-11-08	A jury has found Michael Jackson 's personal doctor Conrad Murray guilty of the singer 's involuntary manslaughter after...
...	

(c) Generated timeline 3.

Figure 4: Case study on $L = 3$.

Date	Summary
2009-04-27	What is swine flu ? Reuters -RRB- - Fears of a global flu pandemic grew as new suspected cases of a dangerous new strain of swine flu appeared around the world .
2009-04-28	WASHINGTON -LRB- Reuters -RRB- - U.S. health officials confirmed a total of 91 human cases of H1N1 swine flu across the country on Tuesday . Swine flu : How serious a threat ?
2009-04-29	A -LRB- H1N1 -RRB- , not swine flu . Reuters -RRB- - Staying inside to avoid the flu ?
2009-04-30	A -LRB- H1N1 -RRB- , not swine flu . WASHINGTON -LRB- Reuters -RRB- - U.S. officials said on Thursday the national total of confirmed H1N1 swine flu cases had risen to 109 , but that the country had still only recorded one fatality in the outbreak .
2009-05-01	Swine Flu :-RRB- - Hong Kong confirmed Asia 's first case of the new H1N1 flu virus in a Mexican traveler on Friday , prompting authorities to seal off the hotel where the 25-year old man had been staying .
2011-01-25	Thousands of people who filled the streets of Cairo on Tuesday hope their demonstrations against corruption and failing economic policies will cause upheaval in the government , like the similar protests in Tunisia that inspired them . Demonstrators protest in central Cairo , Egypt , on Tuesday , calling for reforms and the ouster of President Hosni Mubarak .
2011-01-27	Thursday in Cairo , 5:16 p.m. ET Wednesday -RRB- People protesting against Egyptian President Hosni Mubarak appear to have pushed pro-Mubarak crowds away from Cairo 's Egyptian Museum , though the two sides still are clashing , with Molotov cocktails being thrown , CNN 's Anderson Cooper and Ivan Watson report . From Ben Wedeman , CNN Senior International Correspondent ElBaradei : Egypt is not stable Egypt is a much more dominant influence on the Arab world than Tunisia Protester in Egypt have been able to make much more effective use of the internet Egypt has seen lower rates of unemployment in recent years Middle classes have played a major role in protests in Egypt and Tunisia Cairo , Egypt -LRB- CNN -RRB- – Egypt has been rocked by protests in recent days , only weeks after similar disturbances sparked revolution in Tunisia and forced then-president Zine El Abidine Ben Ali to flee the country .
2011-01-28	Thousands of people took to the streets of Cairo on Friday to call for an end to Egyptian President Hosni Mubarak 's authoritarian 30-year rule . CNN -RRB- - President Barack Obama spoke to Egyptian president Hosni Mubarak by telephone and urged restraint Friday night .
2011-01-29	Egyptian military tanks surrounded Cairo 's Tahrir Square , where hundreds of protesters had gathered on Saturday . Egyptian President Hosni Mubarak says he has asked the government to resign so he can appoint a new government Saturday .

Table 9: Timeline generated by TLS framework for dataset \mathcal{D}_{11} (mixture of three topics). Due to space limit, we show first nine dates and summaries.

Timeline1's TAG: egypt; mubarak; people	
Date	Summary
2011-01-25	Thousands of protesters spilled into the streets of Egypt on Tuesday , an unprecedented display of anti-government rage inspired in part by the tumult in the nearby North African nation of Tunisia. A somber Egyptian President Hosni Mubarak recognized demonstrators ' concerns while asserting his government 's duty to protect the African nation 's security in a nationally televised speech early Saturday , which he punctuated by announcing that he had asked his government to resign .
2011-01-26	Twitter says its site is being blocked in Egypt Egyptians took to the streets in what could be a sequel to the recent revolution in Tunisia witter , Facebook and YouTube were widely used in Tunisia 's uprising and in Iran last year -LRB-. Egypt cracks down on protesters Protesters fill the streets of Cairo ElBaradei :
2011-01-28	With parts of his capital ablaze , Mubarak said he was asking his government to resign and would soon announce a new one , pledging to address the concerns of thousand of Egyptians protesting in Cairo 's streets . Amre Moussa , the Arab League 's secretary-general and a veteran Egyptian diplomat , joined protesters in Cairo 's Tahrir Square on Friday , state-run Nile TV reported .
Timeline2's TAG: flu; swine; h1n1	
Date	Summary
2009-03-02	There is no indication the two other types of season flu now circulating , H3N2 and influenza-B , resist the effects of Tamiflu and the CDC recommends using a cocktail of flu drugs in patients now . GlaxoSmithKline , which makes the rival flu drug Relenza , said there was no indication influenza viruses were resistant to its drug .
2009-04-25	The World Health Organisation has warned countries to be on alert for any unusual flu outbreaks after a swine flu virus was implicated in possibly dozens of human deaths in Mexico . Swine flu : How seriousa threat ?
2009-04-27	the UN 's health agency , expert said the swine flu virus could be capable of mutating into a more dangerous strain but that more information was needed before raising the WHO 's pandemic alert phase . The H1N1 virus is the same strain that causes seasonal flu outbreaks in humans but the newly detected version contains genetic material from versions of flu which usually affect pigs and birds .
Timeline3's TAG: iraq; war; invasion	
Date	Summary
2003-03-07	Full text : Iraq legal advice The full text of the advice about the legality of war with Iraq given by the attorney general , Lord Goldsmith , to the prime minister , Tony Blair , on March 7 2003. "Mr Amin , whose ministry monitors conditions in Iraq 's US-run penal facilities , said the transfer will begin after the formation of the new Iraqi government , which is due to happen in the next few weeks .
2005-01-27	For what makes Arab regimes fear an Iraqi democracy makes them fear civil war more. and while quite possible with elections , that would be even more so without them .
2005-03-31	Prof Ziegler based some of his analysis on a US study in October 2004 which estimated that up to 100,000 extra Iraqis , mostly women and children , had died since the invasion than would have been expected to before the war . It is clear , in this context , that there are three main elements to American unilateralism : Iraq and the Middle East ; the Atlantic alliance ; and the US 's attitude towards international treaties and law .

Table 10: Timelines generated by our MTLs framework for dataset \mathcal{D}_{11} . We show first three dates and summaries of each timeline.