A Framework for Spatial-Temporal based Socio-Cyber-Physical System for Smart Environment

I. Introduction

A Cyber-Physical System (CPS) is a collaborative system where computational resources are intensively connected to the physical world (Monostori, 2018). According to research group leader Roberto Sabatini at RMIT university CPS has three fundamental attributes also known as three C's that is communication, control, and computing. In common practice, CPS combines embedded computing with sensor networks. According to Roberto, there are two types of CPS (i) autonomous CPS and (ii) closed-loop human-machine system (RMIT, 2021). An autonomous CPS is a system that is capable of decision-making independently. A closed-loop human-machine system is a CPS where a human operator can handle the components of a system. A complete concept map of CPS is shown in figure 1. Here we will discuss some key definitions of the terms that are important in contrast to this study.

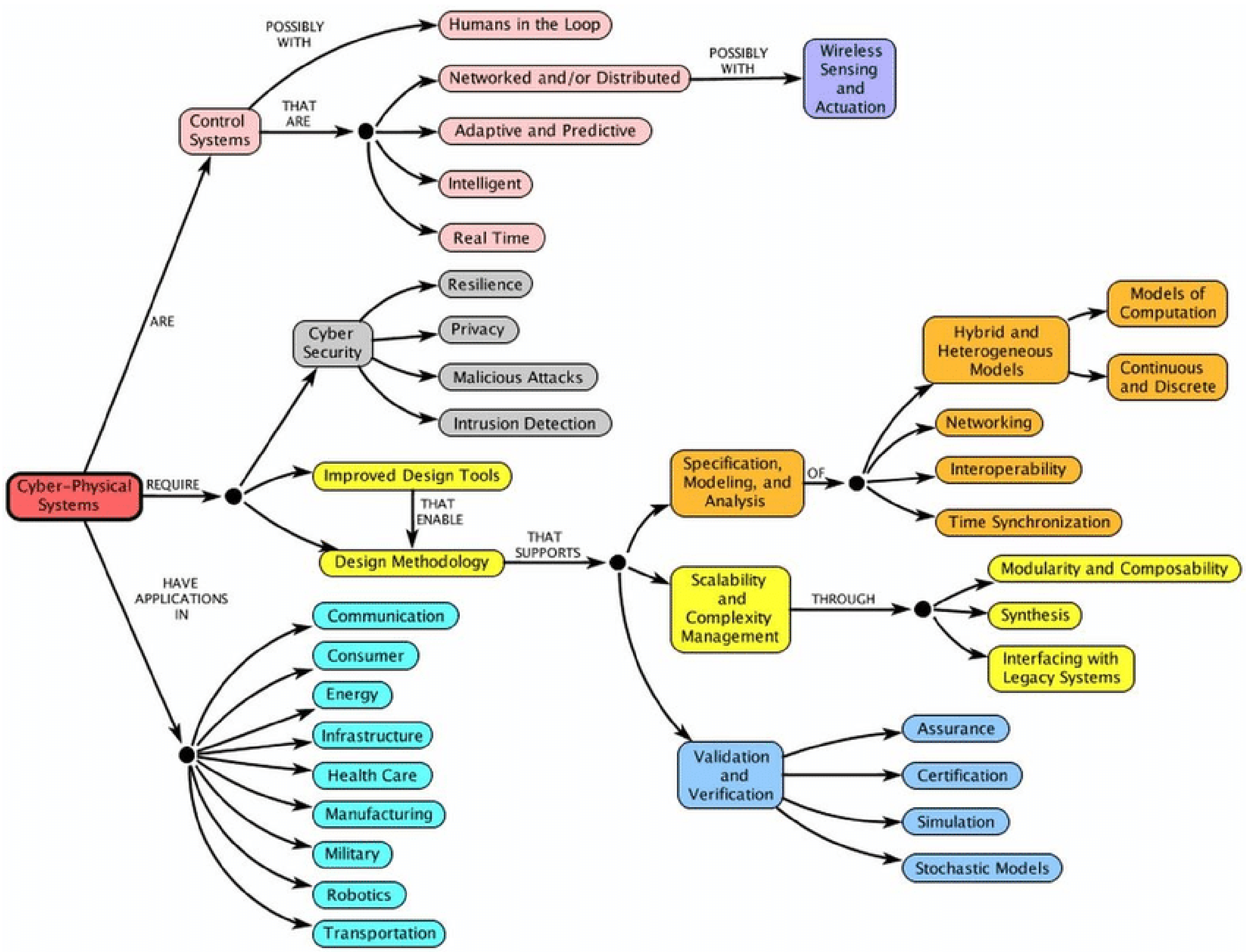

Figure 1: A concept map of CPS (CPS, 2021)

Like a socio CPS or social cyber-physical system is a system that integrates cyber, physical, and social space to work seamlessly (Puming Wang, Yang, Li, Chen, & Hu, 2019). Moreover, for dealing with temporal data authors have discussed different approaches (Tan, Vuran, & Goddard, 2009). Interestingly, there is a term for space and time-based CPS that is Spatio-temporal CPS. Which says a spatial-temporal or spatio-temporal CPS is a special system where we take time and space into consideration while making policies for CPS. In this study the ultimate target is to achieve smart environment. According to (Liguo, 2018) a smart environment is understandable controlled environment where users can leverage embedded sensors and computing. To achieve this goal this study will integrate multiple disciplines like Knowledge Graphs. According to (Ehrlinger & Wöß, 2016) Knowledge Graphs represents integrated source of semantics (relationships, strength, properties etc.). However, it is crucial to understand why should these areas integrated or how these areas will be integrated. To answer this aspect this study integrates Knowledge Graph as a source of representation for interconnected data that is between physical (surveillance, person, location) and cyber (sousveillance, social media profiling, Internet of Things, sensor(s)) part. Further to explore or find hidden patterns within Knowledge Graph this study will utilize social network analysis. Further, to show or represent outcomes of analysis an interface will be designed. Moreover, to add robustness in data collection surveillance, social media tracking and sousveillance will be used. Surveillance and sousveillance are French originated words meaning to monitor and do monitor respectively. Term sousveillance was coined by Steve Mann (Steve Mann, 2004).

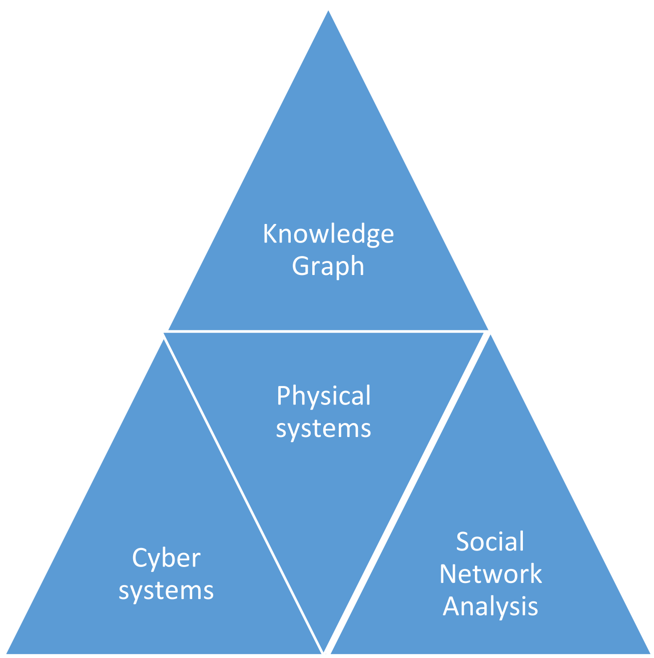

Figure 2: Inter-disciplinary Approach

For experimenting with the proposed idea a trial on digital advertisement domain will be conducted. This will help individuals to better analyze the impact of proposed framework. This report is divided into following sub-sections (I) Introduction, (II) Related work, (III) Methodology and (IV) Conclusion.

II. Related work

This section will discuss the area-wise works of literature. This section is divided into three sub-sections including (I) Current trends in CPS, (II) Current trends in surveillance and sousveillance and (III) Current trends in Knowledge Graphs.

A. Current trends in Cyber-Physical Systems

This section will discuss some recent pieces of literature in the domain of Cyber-physical systems. For discussion papers are only considered from renowned databases like IEEE, Elsevier, Springer. Furthermore, papers are reviewed from the years of 2018-2021. The objective of this study is to address the following questions:

O1) To survey CPS in spatial-temporal and social settings.

O2) To survey literatures from renowned sources from 2018-2021.

O3) To find literature gap between the associated areas of CPS.

A workflow for conducting systematic literature review is shown in figure 3. We have divided our workflow in two phases respectively.

Phase 1:

Identification of search queries and research questions. For identification first designed research questions. This step helped us to narrow down our focus for searching. Next, we identified search queries to extract related research papers from renowned databases. Here is the list of keywords or queries we used for literature extraction: (i) Cyber physical systems, (ii) Social cyber physical system, (iii) Sousveillance and surveillance (computer science domain), (iv) Spatial temporal CPS, (v) Temporal Knowledge Graph, (vi) Knowledge Graph embedding, (vii) cyber physical system + social network analysis + semantic web, (viii) cyber physical system + network analysis + semantic web, (ix) cyber physical system + social network analysis + Knowledge Graph, (x) Knowledge Graphs for profiling+ Knowledge Graphs for CPS. Further, we applied phase 2 to selected papers.

Phase 2:

In this phase we selected papers for review by applying following criteria: (i) Paper should be published in IEEE, Springer Elsevier journal/ conference, (ii) Paper should be published between 2018-2021, (iii) Paper discussed relevant idea to this study. In this systematic literature review we considered mostly survey papers on aforementioned criterion.

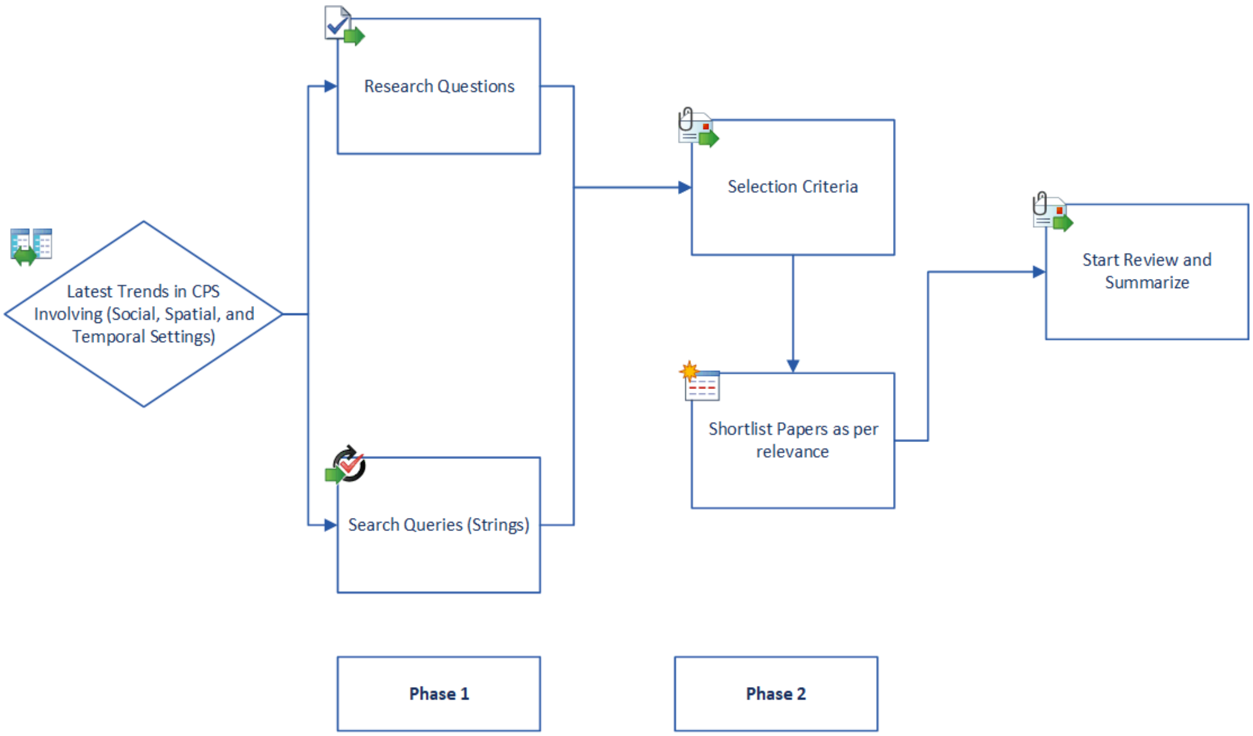

Figure 3: Systematic Literature Review Strategy for CPS

In (Li, Sun, & Zia, 2020) authors proposed a community detection algorithm based on social influence. To quantify influence authors used two approaches i. structure based social influence and (ii) behavior based social influence. Due to non-linearity in features, authors presented deep autoencoder based model backed with K-means algorithm for community detection. In (Hussain, Wang, Buckingham, & Zhang, 2020) literature an agent based semantic socio-collaborative based cyber-physical system has been presented. Presented system utilize ontological representation for social interaction between software agent and human agent. Authors also highlighted the challenges of socialization in cyber-physical settings. Paper includes detailed discussion over the cyber physical social system (CPSS)/ socio-cyber physical systems. (Z. Liu, Cai, Yu, Shen, & Jiang, 2021) Paper introduced a collective approach for modeling sequential event prediction. To aid their approach authors implemented an automatic event graph construction algorithm based on frequent episode mining. In (Amin & Choi, 2020) authors proposed a model for identification of potential hotspots in smart cities. The proposed model utilizes the network centrality measures inspired from social network analysis. To test the model authors used telecommunication environment in big data setting. (Su et al., 2018) Literature discussed the impact of malicious applications on android phones and proposed a community detection algorithm. Proposed method included large feature set for the behavior of application (malicious or not malicious). Method also include the implementation of E-N algorithm a graph construction algorithm inspired from KNN and epsilon graphs. Authors claimed that the proposed combined model rectify the issues of models if individually applied. Experiment shows the high rate achievement on clustering that is 94.3% and accuracy of 79.53%. (Xia, Xiao, Zhang, Cheng, & Pan, 2020) Introduces the reputation based trust mechanism in social cyber-physical system. Authors proposed the light-weight service for discovery of indirect trustworthiness across objects. For validation authors tested the proposed approach with four metrics including satisfaction rate, quality of recommended information, accuracy of trust assessment and convergence time. (Ríos, Aguilera, Nuñez-Gonzalez, & Graña, 2019) Paper proposed semantic aware methodology for identification of influencers in online social network. Proposed model use fuzzy concept analysis and famous topic modelling approach latent dirichlet analysis for filtering out bogus influencers. In literature (Franco, Aris, Canberk, & Uluagac, 2021) review the utilization of honeypots and honeynets for mitigation of cyberattacks in internet of things, industrial internet of things and CPS settings. Authors also discussed taxonomy for honeypots and honeynets. This lead them to analysis of future trends in particular domain. Authors in (Napoleone, Macchi, & Pozzetti, 2020) discussed a two-way survey of literatures on technological and operations management of CPS. Authors also emphasized on the characteristics of future smart industries aided by CPS. (Jimenez, Jahankhani, & Kendzierskyj, 2020) authors discussed the implication of CPS in healthcare sector. Specifically, authors discussed the impact of wireless body area network on healthcare. Last not least literature also discussed definitions for Medical-CPS in cloud and internet of things setting. In (Jimenez et al., 2020; Müller, Jazdi, Schmidt, & Weyrich, 2021) authors discussed the future challenges and there solutions with the help of CPS in production also known as CPPS (Cyber-Physical Production System). As a resolution towards challenges authors suggested the reconfiguration management scheme based on genetic and A* algorithm for CPPS. The proposed scheme can provide a basic solution to the reconfiguration in CPPS. Literature (T. Zhu, Xiong, Li, Zhou, & Yu, 2020) presented differential privacy model for CPS. In paper authors addressed the problem of data publishing in machine learning environment. Proposed model can predict results of newly entered queries of users. (Gürdür Broo, Boman, & Törngren, 2021) discussed the applications and future of CPS in education and research. Authors studied 12 major factors, categorized into two classes that is certainty and uncertainty. Literature also highlighted different scenarios and discussed how future will be impacted by certainty or uncertainty. In literature (D. Zhang, Wang, Feng, Shi, & Vasilakos, 2021) authors presented a review of recent contributions from the domain of security namely denial of service attack and deception attack in industrial CPS. Authors deeply analyzed articles and extracted conclusions on how different systems can be modelled to deal with security attacks in industrial CPS. Further article also put light on possible future directions for securing industrial CPS. In article (Y. Yang, Wang, Wen, & Xu, 2021) proposed an evaluation method for reliable and secure CPS. Proposed model implements instantaneous availability by leveraging markov process principle and Runge-Kutta method. For testing authors suppressed fluctuations and tested reliability of CPS and instantaneous availability under different parameters. Authors in (Yaacoub et al., 2020) highlighted the challenges in CPS workspace. These challenges include security vulnerabilities, threats and attacks. Authors also analyzed former security settings and identified key limitations. Finally, paper discussed the future directions and recommendations for CPS. (Walker-Roberts, Hammoudeh, Aldabbas, Aydin, & Dehghantanha, 2020) reviewed pieces of literatures from the domain of cybersecurity in cyber physical settings. For data gathering authors utilized VERIS database. Research reveal that majority of attackers were from the US and Russian region and majority of the victims were from western states. Authors in (Zacchia Lun, D'Innocenzo, Smarra, Malavolta, & Di Benedetto, 2019) provided survey of 138 pieces of literatures from security via automatic control in CPS. All the literatures were studied empirically and several important aspects were identified like algorithms, model, attack and its defense in cyber physical settings. Authors also presented a comparison of approaches and discussed various current and future research topics for research and industrial community. (Yilma, Panetto, & Naudet, 2019) proposed a collaborative model for Cyber Physical Social System (CPSS) in industry 4.0 setting. Further, authors also considered the factor of human in loop while modeling

CPSS. Authors also proposed their own notation for CPSS modeling. Last not least authors also highlighted some future directions for CPSS. Authors in (Ponce et al., 2021) introduced the aspect of integration of CPS with the social aspect of life. Authors emphasized on the need of turning CPS into CPSS. Authors claim that integration of CPSS with smart cities can solve the social and technical challenges. Literature (Anda, 2018) discussed the impact of social technical systems for achieving CPSS. Proposed approach integrates modeling of CPSS requirements for designing, simulation and implementation. For the assurance of throughput, author transformed goals and features into mathematical functions. For experimentation author simulated the designed mathematical models for CPSS using SysML. In (Yilma, Panetto, & Naudet, 2021) authors conducted a SLR on CPSS. The posed survey includes state of the art literatures from the domain of CPSS regarding definitions, principles and application areas. Authors also discussed the feasible directions for future ventures in CPSS. Besides conducting SLR for CPS we also conducted SLR for Knowledge Graphs, surveillance and sousveillance. The criterion for SLR on the mentioned areas is same as CPS. Here table 1 shows the surveyed papers from the domain of CPS.

Table 1: Survey on CPS

Paper	**Application Domain with CPS**	**Methodology**
(Z. Liu et al., 2021)	Graph completion for CPS event prediction	Event Mining
(Franco et al., 2021)	Honeypots and honeynets	Industrial IoT
(Jimenez et al., 2020; Müller et al., 2021)	CPPS	Genetic and A* algorithm
(Gürdür Broo et al., 2021)	Education and research	Binary classification
(D. Zhang et al., 2021)	Network security	Denial of service and deception attacks
(Y. Yang et al., 2021)	Network security	Runge-Kutta method
(Ponce et al., 2021)	Smart Cities	Social CPS
(Yilma et al., 2021)	Social CPS	Survey
(Li et al., 2020)	Social influence and community detection	Deep Learning
(Hussain et al., 2020)	Agent socialization	Ontology
(Amin & Choi, 2020)	Telecommunication and big data	social network analysis
(Xia et al., 2020)	Reputation based trust network	Machine Learning
(Napoleone et al., 2020)	CPS	Operations management
(Jimenez et al., 2020)	Healthcare	Wireless body sensors
(T. Zhu et al., 2020)	Privacy	Machine Learning

(Yaacoub et al., 2020)	Network security	Survey
(Walker-Roberts et al., 2020)	Cyber security	Survey
(Zacchia Lun et al., 2019)	Cyber security	Survey
(Yilma et al., 2019)	Security in CPS	Human in loop
(Ríos et al., 2019)	Influencer based social network	Machine Learning and Natural Language Processing
(Su et al., 2018)	Malicious mobile application	Machine Learning
(Anda, 2018)	Social CPS	SysML

B. Current trends in sousveillance and surveillance

Steve Mann in (S. Mann, 2016; Ohn-Bar, Tawari, Martin, & Trivedi, 2015) explained different types of veillance(s) including surveillance (viewing from top from a fix point), sousveillance (viewing from below through mobile locations pervasively or non-pervasively), autoveillance (extreme level of surveillance is autoveillance), kineveillance (sensing through moving frame-of-reference), dataveillance (continuous tracking user digital data and personal data through social media, online transactions etc.), coveillance (simply peer-to-peer surveillance), countersurveillance (measure or practices taken to counter surveillance), malveillance (dangerous type of surveillance), stativeillance (surveillance of static frame-of-reference), bienveillance (machine sensing our presence and respond accordingly), uberveillance (surveillance using embedded devices). In this work, we are focused to use surveillance and sosuveillance as additional source for data acquisition of physical entities (Munir, Jami, & Wasi, 2021). There are two classes of surveillance: Preconstructive surveillance and Reconstructive surveillance. Preconstructive surveillance is to do veillance of any individual or group of individuals in a closed room like CCTV (Closed Circuit Television). While Reconstructive Surveillance is doing veillance by different law and technological tools including fingerprinting, phone tapping, internet tracking etc. However, we can use several mechanisms for performing surveillance. For instance, telephones, physical cameras, social network analysis, biometric surveillance, aerial surveillance etc. Recent research trend shows that there are range of practical and industrial problems that can be solved by surveillance by incorporating computer vision like (Ajiboye, Birch, Chatwin, & Young, 2015; Chahyati, Fanany, & Arymurthy, 2017; Chory, Vela, & Avtgis, 2016; Mishra & Saroha, 2016; Saemi, See, & Tan, 2015; Sajjanar et al., 2016; Tsakanikas & Dagiuklas, 2018; Walia & Kapoor, 2016). Surveillance is more concerned with computer vision and its experts. In surveillance or computer vision systems we need to work with large collections of images and videos etc. This study shed light on latest research trends in surveillance. In (Ajiboye et al., 2015) authors provide insight on video surveillance. With the help of four million CCTV cameras deployed by BSIA (British Security Industry Association). Authors proposed a novel technique using hierarchical architecture named FVSA (Fused Video Surveillance Architecture). Proposed model is capable to provide a multi-layer hardware abstraction that can effectively use with the Internet of Things (IOT) based systems. (Chahyati et al., 2017) discusses the applications of gender detection using surveillance. Some regions across the globe have intensely cold climate and detection or surveillance on the basis of gender can help law enforcement departments to catch vulnerable people. The proposed approach includes RCNN (Region-based Convolutional Network) and transfer learning. Authors in (Chory et al., 2016) discussed the behavioral aspect of employees working under organizations doing surveillance. In literature authors surveyed full-time employees and tried to observe following attributes: (i) organizational trust, (ii) privacy, and (iii) commitment to organization. (Doucek, Pavlicek, & Luc, 2018) proposed a study on 'Surveillance of Things' which can be connected to IOT. For implementation Sigfox a wireless network for IoT based devices was used, with the assumption that the acquisitioned data for surveillance is incorrect. Moreover, authors also explored new venues for surveillance like surveillance of people inter-related or connected to surveillance of things. (Duncan, 2018) literature put lights on using surveillance and Big Data for digital citizenship or contemporary democracy. Proposed study also discussed critical analysis of five works. Authors also suggested "how ambivalent digital citizen mechanism should be constructed to target every citizen". In (Fescioglu-Unver, Choi, Sheen, & Kumara, 2015) proposed an object detection approach using RFID for surveillance. (Fularz, Kraft, Schmidt, & Niechciał, 2016) discussed a new open source database for (i) video, (ii)surveillance, (iii) tracking, (iv) recognition and (v) re-identification. Proposed database contains gigs of high resolution images. Authors suggested several applications of proposed database like computer vision based algorithmic evaluation, comparison with other databases for computer vision etc. The proposed work in (Kulchandani & Dangarwala, 2015) reviewed former and latest mechanisms for object detection in dynamic environment. Authors also discussed different challenging application areas of object detection like illumination variation, moving object appearance, abrupt motion, occlusion, complex background, shadow, and camera motion. (S. Liu & Young, 2018) literature discussed the applications of data gathered from social media for surveillance. Authors also discussed several aspects like (i) behavior analysis, (ii) medical insights or news etc. (Mishra & Saroha, 2016) authors briefly discussed the implications of video surveillance for objects. Specially in dynamic settings, authors also emphasized on the open challenges. Further, literature also discussed the suitable solutions for the identified open challenges. In (Ohn-Bar et al., 2015) authors highlighted the applications of surveillance in the domain of computer vision. Authors also discussed use cases for safety of drivers in self-assessment settings. Authors also evaluated the proposed approach with complex datasets. (Saemi et al., 2015) proposed a novel approach to integrate classical approaches for object detection. Authors also described that for dealing with surveillance based applications for real world applications we need gigs of data. So that detection of objects can be accomplished. Detection of objects from long series of videos is a unique task. In the proposed literature authors provided a framework for object detection in long series of videos. The proposed approach accompanies classification and Bag-of-word and classification. Experiments shows that proposed approach achieves the highest accuracy that is 92% on LOST (Longterm Observation of Scenes (with Tracks)) dataset. In (Sajjanar et al., 2016) authors proposed FPGA (Field Programmable Gate Arrays) the cost effective optimization techniques for object tracking and detection under dynamic settings. Proposed system uses low resolution camera with 30 frame-per-sec for real-time tracking. Further, authors also optimized the posed system for working under high speed and low memory requirements. Literature (Tsakanikas & Dagiuklas, 2018) shed light on the recent and future trends of surveillance systems. During discussion authors highlighted different approaches for tracking, recognition and detection of objects. Authors also emphasized on the usage of recent techniques like Deep Learning, cloud computing, mobile-edge-fog computing and Augmented Reality (AR). Authors in (Walia & Kapoor, 2016) proposed the multi-cue object detection technique in dynamic environment. Literature also compared the state-of-the-art approaches under partial or full occlusion, dynamic illumination settings, different visibility and weather conditions. Experiments show that proposed approach achieved state-of-the-art results on multimodal modularity for object tracking. (S. Yang, Yang, Li, & Zhu, 2017) introduced a crowd segmentation or classification approach for intelligent video surveillance. Authors considered four metrics for the proposed approach including (i) crowd density, (ii) crowd saliency, (iii) crowd segmentation and (iv) statistical analysis. Whilst there is growing research in the area of surveillance. Researchers community specially computing researcher have not discussed the application or implementation of sousveillance based systems. Surveillance as an active area in research and recently proposed pieces of literatures are evident of it like (Saemi et al., 2015; Walia & Kapoor, 2016). There are huge number of applications for using surveillance and sousveillance collectively. As best to our knowledge surveillance alone fails at several occasions like consider a scenario where police officer's behavior with citizens was non-ethical. It is the matter of concern that on several occasions it has been noticed that on either personal biasness or due to high table connections common citizens are treated badly. However, the point to raise here that even some of such cases were also surveilled. But due to political, high table connections no actions were conducted by officials like surveillance records deleted or put pressure on a common man to stay away. Such cases raise a several suspects against surveillance based systems. Being a part of computing research what else can be done to rectify the failures of surveillance system working alone. A straight forward answer is to integrate surveillance with other types of veillance. Obviously, integration of all types of veillances is not possible in this work as each type have its own use case. Here in this work we propose an integrated approach that is surveillance with sousveillance. Surveillance has proven its potential by providing robust solutions in different areas of computer sciences and social sciences. A taxonomy of different types of veillance is presented in figure 4.

Identified challenges with surveillance systems working as stand-alone system (Munir & Jami, 2019)

1. Surveillance is a type of veillance about or around a fix point.
2. What can be done if surveillance based system was on update while certain event happened.
3. What will happen if any high profile person uses his or her resources for removing surveillance data.
4. What if system server was down-linked when X terrorism incident occurred.

The aforementioned queries are just a sample to show how surveillance fails under some scenarios. Another aspect of concern here is sousveillance integrated with surveillance is a potential solution to highlighted queries. Today's world is full of technology and digitalization. Keeping these technologies with right frame of mind could nearly solve all problems.

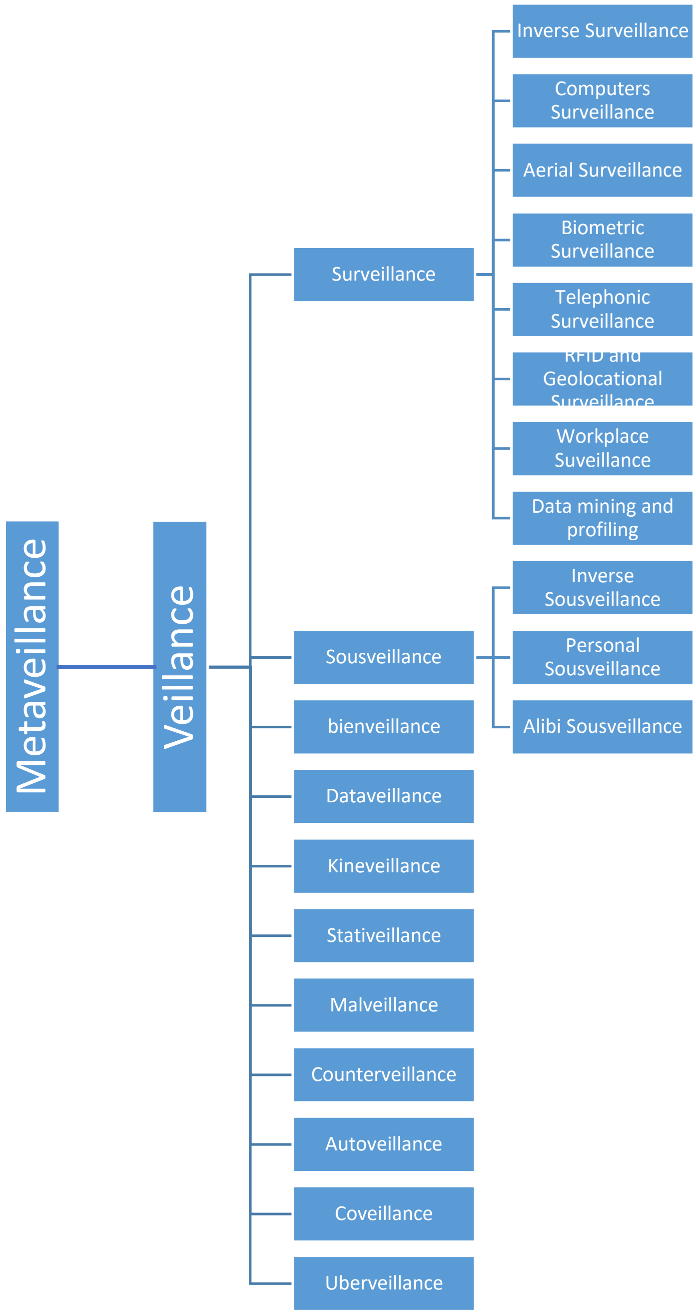

Figure 4: Taxonomy of surveillance through sousveillance (Munir & Jami, 2019)

C. Current trends in Knowledge Graphs

Term Knowledge Graphs was coined by Google in 2012 (Google, 2012) as a knowledge base for enhancement of results. Knowledge Graphs uses graphs and its inter-relationships or properties for extracting relevant results. In contrast to this study there can be several aspects where Knowledge Graphs can help like profiling of entity, community of interest, preferences, religious beliefs, likes and dislikes based on social profile, etc. The recent published works shows that Knowledge Graph are extensively used in domain modeling and semantic modeling. The pieces of literatures reviewed are (Alam, Gangemi, Presutti, & Reforgiato Recupero, 2018; Annervaz, Chowdhury, & Dukkipati, 2018; Arnaout & Elbassuoni, 2018; Aryan et al., 2021; Bean et al., 2018; J. Chen et al., 2018; Chen, Lu, Zheng, Chen, & Yang, 2018; Cheng, Zhang, Cai, Qiu, & Shi, 2018; Chun et al., 2018; Dou, Qin, Jin, & Li, 2018; Fathalla & Lange, 2018; Guo, Zhang, Ge, Hu, & Qu, 2018; He et al., 2018; Hong, Park, Chakraborty, Kang, & Kwon, 2018; Yan Jia, Qi, Shang, Jiang, & Li, 2018; Yantao Jia, Wang, Jin, & Cheng, 2018; Kampffmeyer et al., 2018; Kartsaklis, Pilevar, & Collier, 2018; Liang, Xu, Zhang, Lai, & Mu, 2018; Lin, Socher, & Xiong, 2018; Luan, He, Ostendorf, & Hajishirzi, 2018; Meilicke et al., 2018; Oldman & Tanase, 2018; Palumbo et al., 2018; Patel, Paraskevopoulos, & Renz, 2018; Pujara & Singh, 2018; Sawant, Chakrabarti, & Ramakrishnan, 2018; Silva, Freitas, & Handschuh, 2017; Somayeh Asadifar, 2018; Song & Park, 2018; C. Wang, Ma, Chen, & Chen, 2018; R. Wang et al., 2018; Z. Wang, Lv, Lan, & Zhang, 2018; Wu, Zhou, Lei, Qiu, & Li, 2018; J.-Z. Zhu, Jia, Xu, Qiao, & Cheng, 2018). This shows that recently Knowledge Graphs have been extensively studied for the integration of semantics among different domains like NLP, ML, DL. Authors in (Yan Jia et al., 2018) introduced a novel Knowledge Base (KB) for the domain of cybersecurity. Moreover, for effective utilization of KB quintuple rules were extracted. For enriching results ML based approach was introduced. Proposed approach works on path-ranking and conditional random field algorithm applied on ontologies. Literature (Oldman & Tanase, 2018) introduced a research platform named ResearchSpace. This platform helps researcher to collaborate with each other. Authors leveraged semantic web and its technologies to help researcher from different disciplines to collaborate, built trust and share knowledge with in digital environment. In (Pujara & Singh, 2018) authors conducted comparison of different approaches for the implementation of Knowledge Graphs. Compared approaches includes pre-explored approaches like probabilistic approach, latent space approach. Moreover, authors also highlighted expected future venues for Knowledge Graph implementation. Authors in (Chun et al., 2018) proposed a Knowledge Graph for the application area of energy. Formal approaches for Knowledge Graph implementations did not considered energy domain for semantic integration. Hence literature introduced a novel Knowledge Graph for the energy domain. (R. Wang et al., 2018) article discussed a large-scale Knowledge Graph. Authors claimed that proposed approach can help academicians to solve challenges in data mining. Specifications for the presented Knowledge Graph are as follow (i) It consist of 3.13 billion factual triples from academic domain. Experimentation shows that proposed Knowledge Graph can be utilize to test different data mining tasks. Literature work presented in (P. Chen et al., 2018) introduced a novel representation of Knowledge Graph for education domain. For data acquisition authors collected data from heterogeneous sources. Further, for the purpose of relation extraction and mapping authors implemented neural sequence labelling approach. As a proof of concept, implemented Knowledge Graph was tested on the course domain of mathematics. Experiments show that proposed approach achieved 70 % F1 score on relationship identification task. In (Dou et al., 2018) authors presented a Knowledge Graph cultural heritage in China. For data gathering authors referred to multiple sources. By the help of NLP techniques authors as a first step modeled ontology from collected data. As studies suggests (F. Noy & McGuinness, 2001) for ontology modeling domain knowledge is crucial. Hence in the proposed study author took help from domain experts and ontology engineers. Then transformed modeled ontology into a Knowledge Graph. Literature (Silva et al., 2017) presented an automated Knowledge Graph generation tool. For achieving the targeted problem authors made a classifier so that labels and semantic definitions modeled to generate Knowledge Graph. As a use case authors tested the proposed approach for text recognition task and achieved satisfactory results. (Fathalla & Lange, 2018) introduced a novel dataset named EVENTSKG. Proposed dataset encompasses semantical descriptors for different scientific events like (i) data acquisition, (ii) data preprocessing, (iii) data augmentation, (iv) data publication, (v) linked data enrichment, and (vi) linked data generation for computer science. According to study claims this was the first attempt towards Knowledge Graph implementation from metadata. Author in (Patel et al., 2018) proposed a novel Geo-to-Gra framework. Authors discussed that proposed framework is capable to compare different ML algorithms on specified metrics. For instance, (i) scalability, (ii) effectiveness and (iii) semantic similarity. Authors also implemented proposed framework for map-reduce in parallel distributed settings. (Cheng et al., 2018) proposed a novel approach for modeling traditional Chinese medicines using Knowledge Graphs. For completion of the desired work data mining and EMR (electronic medical records) were used with expert knowledge. Authors in (C. Wang et al., 2018) proposed an information extraction technique for documents of geoscience published in Chinese. Authors also introduce pipeline for extracting knowledge from raw text to generate Knowledge Graph for the domain of geoscience. (Kartsaklis et al., 2018) introduced an effective approach for transforming raw text into Knowledge Graph entities. For implementation of proposed approach authors utilized multi-sense LSTM (Long Short Term Memory) a neural network architecture for learning long sequences. Additionally, for the resolution of ambiguous issues in text data proposed model was enriched by word embedding technique. Finally, authors also compared findings with state-of-the-art models and achieved better results in entity classification task for Knowledge Graphs. Authors in (Luan et al., 2018) proposed a novel dataset and Knowledge Graph named SciERC. Proposed dataset includes examples of classification, recognition and co-referencing for scientific articles. Furthermore, literature introduced information extraction tool. Experiments show that the proposed tool outperformed previous approaches for information extraction. A novel approach was introduced for identification of entities in Knowledge Graph (Guo et al., 2018). Proposed approach utilize Deep Learning architecture named Multi-Layer Recurrent Neural Network (Multi-layer RNN). Results shows that the proposed approach outperformed previous state-of-the-art models in Knowledge Graph completion. In (Kampffmeyer et al., 2018) authors proposed a zero-shot neural learning approach name Attentive Dense Graph Propagation Module (ADGPM). Proposed approach can resolve dependency problems in graphs. Due to hierarchical structure graph consist of several levels of hierarchies. Proposed work also aided in establishment of referral connections between nodes of interest. For implementation of robust model authors also applied hyper-parameter tuning. Finally, authors claimed state-of-the-art results on zero-shot learning. (Palumbo et al., 2018) article proposed a recommendation mechanism for Knowledge Graph completion integrated with node2vec a graph embedding technique. For experimentation authors used two datasets namely MovieLens and DBpedia. Literature also claims the proposed approach achieved better results in contrast to formal approaches in graph completion task. Authors in (Z. Wang et al., 2018) proposed a semi- supervised approach for using graph convolutional networks to generate alignment scheme for cross-lingual Knowledge Graphs. For achieving proposed results authors utilized pre-trained model. Afterward this pre-trained model was integrated with cross-lingual graph model. Experiments show that authors achieved satisfactory results in contrast to the previously published approaches. (Yantao Jia et al., 2018) presented a Knowledge Graph embedding approach using loss minimization. Presented approach named (PaSKoGE) Path-specific Margin-based Loss Function. For Knowledge Graph utilize adaptive approach for minimizing loss. For the purpose of minimization PasKoGE evaluate correlation between expected paths across entities. Authors also compared proposed and achieved better result against state-of-the-art graph embedding approaches. In (Bean et al., 2018) author implemented a novel ML algorithm for Knowledge Graph generation. Proposed model achieved AUC (Area Under the

Curve) score of 92% in prediction of adverse reaction against drug. Experiments show that the proposed ML model can make better predictions in contrast to previously proposed approaches for classification task. To cater the problems of triple identification or classification in natural language text authors in (Annervaz et al., 2018) introduced a novel deep learning model integrated with Knowledge Graph. Proposed model utilizes attention mechanism to achieve better results in generic text classification tasks. Proposed model was also tested with multiple datasets to justify that deep learning models can work better with less labeled data, specially organized in Knowledge Graph. Author in (Lin et al., 2018) proposed a Q/A system for incomplete Knowledge Graphs. Proposed literature highlighted two major challenges in Knowledge Graph completion including falsified prediction and misinformed predictions. As a solution to the mentioned problems a reinforcement learning based approach was introduced. Initially, authors made an embedding policy for modeling falsified predictions. The proposed approach utilizes fuzzy logic for semantic triple embedding. Finally, for dealing with the other mentioned problem authors implemented reinforcement learning based agent. This agent can identify diverse possibilities to complete the missing links with in Knowledge Graph. Results shows that proposed approaches achieved better result on benchmark for embedding task in Knowledge Graph. (Meilicke et al., 2018) presented an ensemble learning based embedding approach for Knowledge Graphs. Proposed work also aided the formal approaches by integration of rule-based system. Experiments show that the proposed approach improved the problem of Knowledge Graphs completion. (Alam et al., 2018) in presented research introduced a semantic labeling model named TakeFive using Knowledge Graphs. Authors also discusses that proposed approach can model semantics at different levels like (i) dependency parsing, (ii) extraction of lexical frames and (iii) finding semantic roles. Authors also compared the proposed model with former semantic modeling approaches and achieved better F1 score. Which shows that the presented model can better deal with semantic modeling. In (Hong et al., 2018) authors discussed a novel approach PAGE for graph pattern embedding in Knowledge Graph. Proposed approach resolute challenges of uncertainty in Q/A system. For validation authors compared two well-known Knowledge Graphs namely, Freebase and NELL with PAGE. Results shows that PAGE generate 28% better results in question answering in comparison to formal Knowledge Graph approaches. (Somayeh Asadifar, 2018) literature introduced a novel Q/A approach. Proposed approach utilize Knowledge Graphs for representation of semantics. Result shows presented work enhanced performance for annotation in Information Extraction (IE) tasks. (He et al., 2018) introduced systematic study on semantic navigation in large scale Knowledge Graphs. Introduced algorithm uses Monte Carlo based tree search approach for dealing with semantics. Experiment shows that proposed approach proved to be more efficient in semantic navigation task. In proposed work (Wu et al., 2018) a keyword extraction approach using Knowledge Graphs was discussed. Proposed approach was implemented for extraction of question and answers from literature abstract. In (J. Chen et al., 2018) literature work authors introduced a path-semantic entity based probabilistic set expansion and entity ranking model for feature extraction in Knowledge Graphs. Authors also claimed that proposed model can be utilized to achieved better results in semantic search applications. Proposed model was also tested with different dataset for Knowledge Graph completion task. Result show that proposed approach outperformed state-of-the-art former approaches. (Arnaout & Elbassuoni, 2018) authors presented a searching framework for Knowledge Graphs backed with RDF (Resource Description Framework). Further, a statistical machine translation approach was integrated with query relaxation and marginal relevance to support RDF based searching over Knowledge Graph. In (Sawant et al., 2018) authors introduced a novel approach for query extraction and its interpretation named AQQUCN. The proposed technique was implemented using convolutional neural network and latent variables. Authors claims that proposed model can handle easy to complex structure questions. Experiments show that proposed model improves results by 16-18% when evaluated on mean average precision metric. (J.-Z. Zhu et al., 2018) article introduced TransCoRe (Translation-based Method via Modeling the Correlation of Relations) for graph embedding. Introduced model accompany low-dimension matrices to create co-relation matrix and learn relationships between entities. For experimentation authors tested the model using WordNet and Freebase. Results show that proposed model achieved satisfactory results in link prediction and triple classification tasks. In (Liang et al., 2018) authors introduced an indoor scene designing model by leveraging Knowledge Graph. For resolution of targeted problem authors implemented a factual representation based entity-relationship model. Moreover, for learning of relationship model over different aspects a supervised learning model was implemented over Knowledge Graph. Authors of (Song & Park, 2018) discussed translation based embedding approach for Knowledge Graphs. To support the learning process of Knowledge Graph embedding authors also introduced a regularization approach. Results show that proposed methodology outperformed former embedding techniques. Literature (Gottschalk & Demidova, 2018) introduced a temporal Knowledge Graph for events. The proposed work integrates the historical events data with timestamped Knowledge Graph. Dbpedia and YAGO were used for data acquisition of semi-structured sources. The presented Knowledge Graph consists 2.3M temporal relationships against 690 thousand events. (Garcia-Duran, Dumancic, & Niepert, 2018) literature presented LSTM (Long Short Term Memory) based temporal Knowledge Graph. Proposed Knowledge Graph only contains temporal relationships which were established at any stance of time. Authors also implemented link prediction model backed with LSTM and temporal information. Experiments show the satisfactory results of the proposed approach over 4 different datasets. Authors of (Aryan et al., 2021) discussed how explainability can help out CPS by integrating Knowledge Graphs. For experimentation authors utilized the proposed model in energy domain for smart grids. Authors discovered three different types of events coming from different sources and then on the top of these events they built ontological representation. This representation was further extended to build Knowledge Graphs.

Table 2: Literature Review on Knowledge Graph

Paper	**Methodology/ approach**	**Analysis Type**
(Yan Jia et al., 2018)	ML and Ontologies	Entity analysis
(Oldman & Tanase, 2018)	Ontologies (Previous Facts)	Entity analysis
(Pujara & Singh, 2018)	NLP	Semantic analysis
(Chun et al., 2018)	NLP	Semantic analysis
(R. Wang et al., 2018)	NLP	Semantic analysis
(P. Chen et al., 2018)	NLP	Semantic analysis
(Dou et al., 2018)	NLP and Ontology	Ontological analysis
(Silva et al., 2017)	NLP and ML	Semantic analysis

(Fathalla & Lange, 2018)	NLP	Semantic analysis
(Patel et al., 2018)	ML and Map-Reduce	Graph completion
(Cheng et al., 2018)	Data Mining and NLP	Graph completion
(C. Wang et al., 2018)	NLP	Graph completion
(Kartsaklis et al., 2018)	Deep Learning and NLP	Graph completion
(Luan et al., 2018)	Dataset (NLP)	Entity analysis
(Guo et al., 2018)	Deep Learning (DL)	Entity analysis
(Kampffmeyer et al., 2018)	ML	Entity analysis
(Palumbo et al., 2018)	NLP	Graph completion
(Z. Wang et al., 2018)	DL	Graph completion
(Yantao Jia et al., 2018)	NLP	Graph completion
(Bean et al., 2018)	ML	Entity classification analysis
(Annervaz et al., 2018)	DL	Semantic analysis
(Lin et al., 2018)	ML	Semantic analysis with graph completion
(Meilicke et al., 2018)	ML	Graph completion
(Alam et al., 2018)	NLP	Semantic analysis
(Hong et al., 2018)	NLP	Uncertainty analysis in Q/A
(Somayeh Asadifar, 2018)	NLP	Entity analysis (IE)
(He et al., 2018)	NLP	Semantic analysis
(Wu et al., 2018)	NLP	Keyword analysis
(J. Chen et al., 2018)	NLP	Semantic path analysis
(Arnaout & Elbassuoni, 2018)	NLP	RDF analysis
(Sawant et al., 2018)	DL and NLP	Natural language query analysis
(J.-Z. Zhu et al., 2018)	NLP	Link analysis or Graph completion
(Liang et al., 2018)	NLP and ML	Image based analysis
(Song & Park, 2018)	NLP and ML	Natural language based analysis
(Gottschalk & Demidova, 2018)	NLP	Temporal historic relation analysis

(Garcia-Duran et al., 2018)	DL	Temporal relationship analysis
(Sun, Deng, Nie, & Tang, 2019)	Graph theoretic ML	Link prediction and graph completion analysis
(Huang, Zhang, Li, & Li, 2019)	NLP	Embedding optimization
(Q. Zhang et al., 2019)	NLP	Semantic analysis
(Guan, Song, & Liao, 2019)	NLP	Semantic analysis
(Pengyang Wang, Liu, Jiang, Li, & Fu, 2020)	Data wrangling and ML	Spatial-temporal analysis
(Leblay, Chekol, & Liu, 2020)	NLP	Temporal analysis
(Aryan et al., 2021)	Event analysis	Energy events analysis
(Jung, Jung, & Kang, 2021)	DL (Attention)	Temporal analysis
(Messner, Abboud, & Ceylan, 2021)	NLP	Temporal analysis
(J. Zhang, Liang, Deng, & Shao, 2021)	DL	Spatial-temporal analysis
(Ji, Pan, Cambria, Marttinen, & Yu, 2021)	NLP, ML and DL	Survey on temporal, knowledge-aware and graph completion analysis

Table 2 depicts the literatures surveyed in this study on Knowledge Graphs. For survey we considered works of literature that introduced either novel Knowledge Graph, Knowledge Graph completion approach, temporal Knowledge Graph or spatial-temporal Knowledge Graph.

This part of paper will focus discuss on some recent works of literature from the perspective of spatial-temporal Knowledge Graph embedding schemes. (Pengyang Wang et al., 2020) literature discussed the integration of data fusion with spatial-temporal Knowledge Graph. For data acquisition author utilized two sources namely mobile data and travelling notes. For dealing with long paths within Knowledge Graph authors implemented attenuation based embedding. (Sun et al., 2019) introduced a novel approach for graph embedding or completion named RotatE. RotatE model utilized core concepts of graph theory like symmetry vs non-symmetry, inversion and composition. Using vector space based representation each pf the relationship was modeled to represent knowledge in Knowledge Graph. Authors of RotatE also proposed self-adversarial negative sampling technique to aid training and prediction. Experiments show that RotatE is not scalable but it can effectively infer and model relationships within Knowledge Graph. (Huang et al., 2019) introduced a novel Knowledge Graph for dealing natural language question-answers. Proposed model targets to represent entities of Knowledge Graph in low-dimension. The mentioned task has built-in challenges as Q/A can be done is several ways. So in the study (Huang et al., 2019) authors dealt with simple questions like yes or no, true or false or one word or one liner answers. To optimize the learning process authors proposed joint distance based approach for representing entities and their relationships within Knowledge Graph vector space. Experiments show that the proposed model outperformed former Q/A based model. In literature (Q. Zhang et al., 2019) authors re-visited the problem of entity embedding in Knowledge Graph. Authors proposed a novel method to deal with multiple views of entity. Authors also worked on cross Knowledge Graph alignment method that is based on inferencing mechanism. Experiments show that the proposed model out-performed the formal entity alignment approaches for Knowledge Graphs. (Guan et al., 2019) authors proposed a common sense concept graph based Knowledge Graph. Proposed model works on relevance across entities to achieve semantic embedding. For validation of proposed model authors piloted two tasks namely Knowledge Graph completion and entity classification. Authors also claimed that proposed model successfully compete baselines for the aforementioned tasks. Authors in (Jung et al., 2021) proposed a novel attention based encoder-decoder model for dealing with temporal events stored in Knowledge Graph. Authors claimed previous studies lack different challenges like relevant events temporally and path based inferential reasoning. Proposed model T-GAP efficiently models graph structure and temporal information for Knowledge Graph. T-GAP is flexible enough that it can deal with generalized queries without complete temporal information. In (Leblay et al., 2020) authors proposed an embedding approach for temporal Knowledge Graph. Proposed model can handle temporal data with granularity like year, month and day level. Formal approaches lack in modeling temporal data with granularity. Authors also claimed that proposed model is generic enough so it can deal and incorporate non-temporal models. (Messner et al., 2021) proposed a box embedding technique for modeling temporal Knowledge Graph. Classical embedding models fails to deal with dynamics of temporal data. However, proposed model effectively deals with temporal data. Experiments show that proposed model achieved exceptional results on different temporal benchmarks. (J. Zhang et al., 2021) introduced a novel approach for dealing with Knowledge Graph in spatial-temporal settings. Proposed model adopted attention based mechanism for graph completion task. Authors also validated proposed model over three different datasets. (Ji et al., 2021) authors surveyed on Knowledge Graphs in contrast to four different areas including implementations, temporal analysis, graph completion and knowledge-aware applications. Proposed work of literature provides complete picture of recent achievements in the respective areas including future directions. Authors also provided in-depth hierarchy for each of the mentioned areas of Knowledge Graphs. In this section we discussed the current trends in Knowledge Graphs and mentioned how research community is leveraging it. The following section will discuss proposed hypothetical view on methodology.

III. Methodology

The hypothetical framework is proposed in figure 5. However, for working and implementing CPS based smart environment some assumptions are made like (i) We have access to social profile data of users, (ii) We have access to key physical locations with the help of cameras, switches, routers and RaspberryPi module, (iii) For this complete experiment campus environment is used as an alternative to smart city. For obtaining the mentioned objectives and hypothesis from study following research questions have been identified:

RQ1) To integrate CPS in spatial-temporal and social settings.

RQ2) To propose a framework for addressing the integration of identified areas with CPS.

RQ3) To make robust data acquisition for profiling physical entity(ies) in smart environment.

RQ4) To propose a Knowledge Graph based CPS framework for smart environments.

These research questions were also deeply investigated through literature review and it revealed that there is very few work which integrated CPS with spatial and temporal aspect. However, none of the study integrated the spatial, temporal, social aspect in CPS. So this was the gap which we analyzed and to achieve or fill this gap following steps are crucial.

1. **Data Gathering (Thesis I and II):**

   The first and the most crucial step for any system in today's world is data. Hence, the proposed framework will have multiple data sources including surveillance and sousveillance sources (respberrypi, PiCam/ other camera, router data access, mobile application etc.), social media logs. From the collective data sources, we will extract a semantic triple of (person/ entity identity, timestamp, location). Having multiple sources will robust data acquisition.

2. **Federation of Knowledge Graphs (Thesis II):**

   The semantic triples extracted from multi-source will be stored in Knowledge Graph. Depending on the situation we will have specialized Knowledge Graphs for individual data source. Which builds up the federation of Knowledge Graphs. This federation will be responsible for handling semantics and competency questions.

3. **Network Analysis (Thesis III):**

   The federation of Knowledge Graph will then be lead towards network analysis module. Network analysis will help to identify the insights related to knowledge hidden in Knowledge Graph like node significance, bridge analysis, community detection, influencer identification, prime locations or location of interest.

4. **Interface (Thesis IV):**

   Finally, the gathered insights from network analysis will be represented into a suitable interface that can be a web application, mobile application, or both. With the help of this interface administrator/ authorized user will be able to query knowledge or information stored in Knowledge Graphs.

Here the division of complete study is also mentioned with the respective timespan. Furthermore, in thesis (V) or remaining parts we will focus on publishing our results into international reputed journals and conferences.

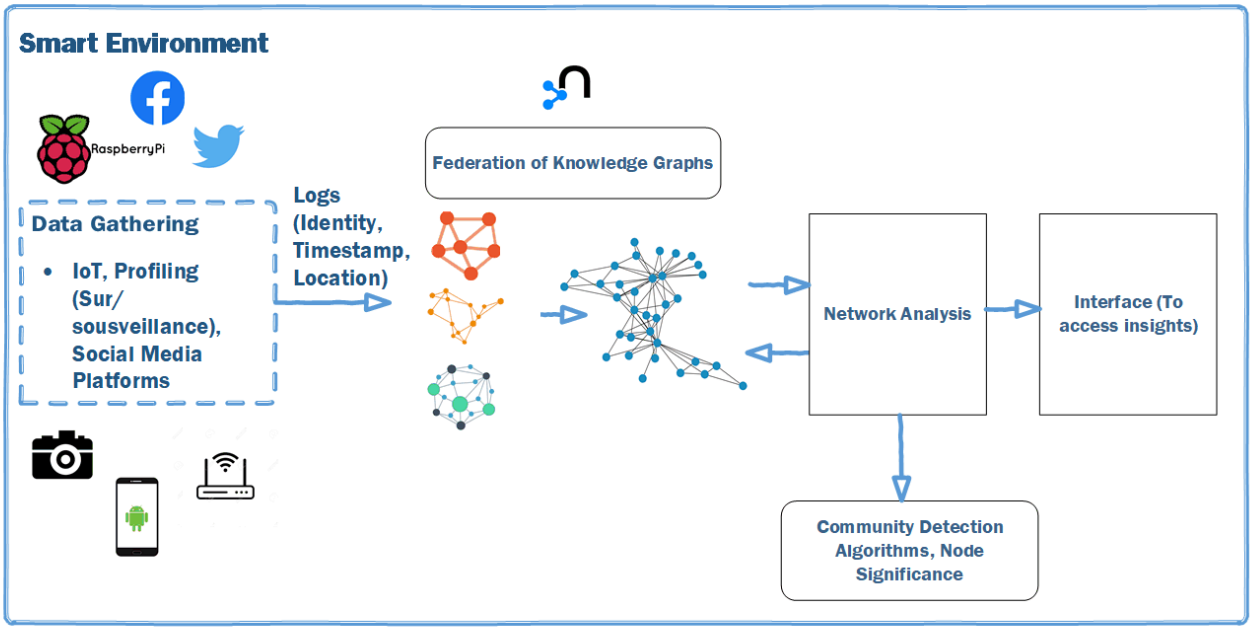

Figure 5: Framework for spatial-temporal based socio-CPS

A. Expected Results

For the development of the proposed framework we will need (i) Access to cameras, router or switch data, (ii) Python will be used as programming language for development of web interface, and (iii) Neo4j will be used for development and querying Knowledge Graphs. Having the required data from heterogeneous sources the proposed framework will be able to handle following intelligent and semantic queries.

1. How many people are present at X location?
2. How many students are present at X location?
3. How many teachers are present at X location?
4. How many people are following SOP's?
5. How many people are COVID-19 vaccinated?
6. How many time does X person visit X location?
7. Who is or are friend(s) of X?
8. Who is not following rules and regulations?
9. What is the daily route of person X?
10. What should I recommend to person X?
11. What will person X buy in upcoming sale?
12. Where will person X go for lunch or vice versa?
13. How many members were present when president gave speech?
14. How many people belongs to X organization?
15. How many people were present when X incident happens?
16. How many people discussed X incident?
17. How many people likes X location?

18. How many people operate or access X equipment?
19. How people reacted on X event?
20. How many locations or people are suspicious or expected for X event?

The list for possible queries is exhaustive here some sample queries are included to show the depth and importance of proposed framework.

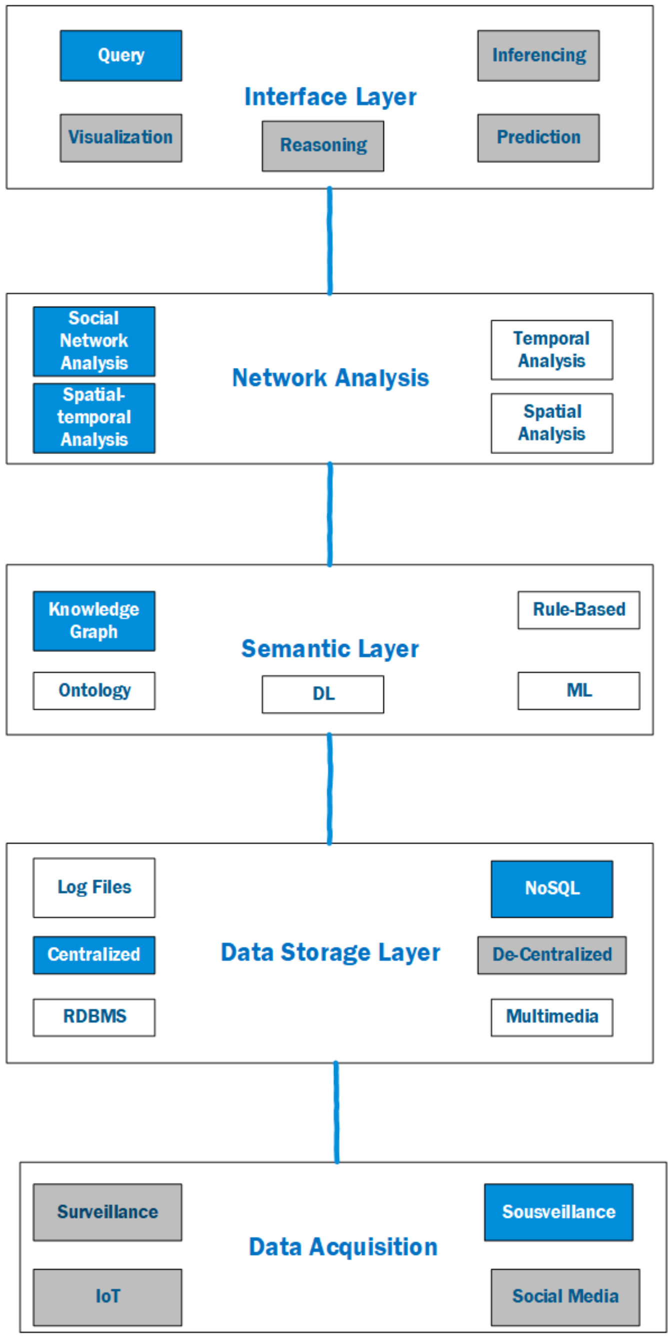

Figure 6: Layered Research Area Distribution

Here figure 6 depicts possible research area distribution for achieving specific task in layered fashion. The regions of layers colored with grey represents the areas which will be partially incorporated in conduct of this research. Additionally, the regions colored with blue represents topics of interest for this research.

IV. Conclusion

The industry 4.0 revolution depends on different technological aspects out of one is Cyber-Physical Systems (CPS). The goal of CPS is to provide a boilerplate for smart city or digital twin adaption. This research is focused on enabling smart environment based on CPS for profiling of physical entities like people, smart machines, etc. With the integration of multiple sources for data acquisition like surveillance, sousveillance, social media tracking of above mentioned entities will help to enable CPS based smart environment. Besides this proposed framework has a lot of implications in real-world scenarios like provenance of events, citizen profiling, entity profiling, parental monitoring, locality based monitoring, locality based recommendation, locality based advertisement, locality based digital marketing, locality based branding and many more. However, multi-agent systems can also be integrated to the proposed framework for in-depth reasoning and inferencing. For proof of concept we will implement proposed framework on digital advertisement domain. Where we will try to analyze and see the impact of proposed framework.

References

Ajiboye, S. O., Birch, P., Chatwin, C., & Young, R. (2015). *Hierarchical video surveillance architecture: a chassis for video big data analytics and exploration.* Paper presented at the SPIE/IS&T Electronic Imaging.

Alam, M., Gangemi, A., Presutti, V., & Reforgiato Recupero, D. (2018). *Semantic Role Labeling for Knowledge Graph Extraction from Text*.

Amin, F., & Choi, G. S. (2020). Hotspots Analysis Using Cyber-Physical-Social System for a Smart City. *IEEE Access, 8*, 122197-122209. doi: 10.1109/ACCESS.2020.3003030

Anda, A. A. (2018, 20-24 Aug. 2018). *Modeling Adaptive Socio-Cyber-Physical Systems with Goals and SysML.* Paper presented at the 2018 IEEE 26th International Requirements Engineering Conference (RE).

Annervaz, K. M., Chowdhury, S. B. R., & Dukkipati, A. (2018). *Learning beyond datasets: Knowledge Graph Augmented Neural Networks for Natural language Processing.* Paper presented at the NAACL-HLT.

Arnaout, H., & Elbassuoni, S. (2018). Effective searching of RDF knowledge graphs. *Journal of Web Semantics, 48*, 66-84. doi: https://doi.org/10.1016/j.websem.2017.12.001

Aryan, P. R., Ekaputra, F. J., Sabou, M., Hauer, D., Mosshammer, R., Einfalt, A., . . . Rauber, A. (2021). *Explainable cyber-physical energy systems based on knowledge graph*. Paper presented at the Proceedings of the 9th Workshop on Modeling and Simulation of Cyber-Physical Energy Systems, Virtual Event. https://doi.org/10.1145/3470481.3472704

Bean, D. M., Wu, H., Iqbal, E., Dzahini, O., Ibrahim, Z. M., Broadbent, M., . . . Dobson, R. J. B. (2018). Author Correction: Knowledge graph prediction of unknown adverse drug reactions and validation in electronic health records. *Scientific Reports, 8*(1), 4284. doi: 10.1038/s41598-018-22521-4

Chahyati, D., Fanany, M. I., & Arymurthy, A. M. (2017, 17-19 May 2017). *Man woman detection in surveillance images.* Paper presented at the 2017 5th International Conference on Information and Communication Technology (ICoIC7).

Chen, J., Chen, Y., Zhang, X., Du, X., Wang, K., & Wen, J.-R. (2018). Entity set expansion with semantic features of knowledge graphs. *Journal of Web Semantics, 52-53*, 33-44. doi: https://doi.org/10.1016/j.websem.2018.09.001

Chen, P., Lu, Y., Zheng, V. W., Chen, X., & Yang, B. (2018). KnowEdu: A System to Construct Knowledge Graph for Education. *IEEE Access, 6*, 31553-31563. doi: 10.1109/ACCESS.2018.2839607

Cheng, B., Zhang, Y., Cai, D., Qiu, W., & Shi, D. (2018, 22-24 Aug. 2018). *Construction of traditional Chinese medicine Knowledge Graph using Data Mining and Expert Knowledge.* Paper presented at the 2018 International Conference on Network Infrastructure and Digital Content (IC-NIDC).

Chory, R. M., Vela, L. E., & Avtgis, T. A. (2016). Organizational Surveillance of Computer-Mediated Workplace Communication: Employee Privacy Concerns and Responses. *Employee Responsibilities and Rights Journal, 28*(1), 23-43. doi: 10.1007/s10672-015-9267-4

Chun, S., Jin, X., Seo, S., Lee, K., Shin, Y., & Lee, I. (2018, 15-17 Jan. 2018). *Knowledge Graph Modeling for Semantic Integration of Energy Services.* Paper presented at the 2018 IEEE International Conference on Big Data and Smart Computing (BigComp).

CPS, B. (2021). Cyber-Physical Systems. 2021, from https://ptolemy.berkeley.edu/projects/cps/

Dou, J., Qin, J., Jin, Z., & Li, Z. (2018). Knowledge graph based on domain ontology and natural language processing technology for Chinese intangible cultural heritage. *Journal of Visual Languages & Computing, 48*, 19-28. doi: https://doi.org/10.1016/j.jvlc.2018.06.005

Doucek, P., Pavlicek, A., & Luc, L. (2018, 2018//). *Internet of Things or Surveillance of Things?* Paper presented at the Research and Practical Issues of Enterprise Information Systems, Cham.

Duncan, J. (2018). Uncertainty and Desire: Big Data Surveillance and Digital Citizenship. *The iJournal: Graduate Student Journal of the Faculty of Information, 3*.

Ehrlinger, L., & Wöß, W. (2016). *Towards a Definition of Knowledge Graphs.* Paper presented at the SEMANTiCS.

F. Noy, N., & McGuinness, D. (2001). *Ontology Development 101: A Guide to Creating Your First Ontology* (Vol. 32).

Fathalla, S., & Lange, C. (2018, 2018//). *EVENTSKG: A Knowledge Graph Representation for Top-Prestigious Computer Science Events Metadata.* Paper presented at the Computational Collective Intelligence, Cham.

Fescioglu-Unver, N., Choi, S. H., Sheen, D., & Kumara, S. (2015). RFID in production and service systems: Technology, applications and issues. *Information Systems Frontiers, 17*(6), 1369-1380. doi: 10.1007/s10796-014-9518-1

Franco, J., Aris, A., Canberk, B., & Uluagac, A. S. (2021). A Survey of Honeypots and Honeynets for Internet of Things, Industrial Internet of Things, and Cyber-Physical Systems. *IEEE Communications Surveys & Tutorials*, 1-1. doi: 10.1109/COMST.2021.3106669

Fularz, M., Kraft, M., Schmidt, A., & Niechciał, J. (2016). *The PUT Surveillance Database*, Cham.

Garcia-Duran, A., Dumancic, S., & Niepert, M. (2018). *Learning Sequence Encoders for Temporal Knowledge Graph Completion*.

Google. (2012). Introducing the Knowledge Graph: things, not strings. Retrieved 28, 2018

Gottschalk, S., & Demidova, E. (2018). *EventKG: A Multilingual Event-Centric Temporal Knowledge Graph*. Paper presented at the In Proceedings of the 15th Extended Semantic Web Conference (ESWC 2018). https://arxiv.org/abs/1804.04526

Guan, N., Song, D., & Liao, L. (2019). Knowledge graph embedding with concepts. *Knowledge-Based Systems, 164*, 38-44. doi: https://doi.org/10.1016/j.knosys.2018.10.008

Guo, L., Zhang, Q., Ge, W., Hu, W., & Qu, Y. (2018). *DSKG: A Deep Sequential Model for Knowledge Graph Completion*.

Gürdür Broo, D., Boman, U., & Törngren, M. (2021). Cyber-physical systems research and education in 2030: Scenarios and strategies. *Journal of Industrial Information Integration, 21*, 100192. doi: https://doi.org/10.1016/j.jii.2020.100192

He, L., Shao, B., Xiao, Y., Li, Y., Liu, T., Chen, E., & Xia, H. (2018). Neurally-Guided Semantic Navigation in Knowledge Graph. *IEEE Transactions on Big Data*, 1-1. doi: 10.1109/TBDATA.2018.2805363

Hong, S., Park, N., Chakraborty, T., Kang, H., & Kwon, S. (2018, 2018//). *PAGE: Answering Graph Pattern Queries via Knowledge Graph Embedding.* Paper presented at the Big Data – BigData 2018, Cham.

Huang, X., Zhang, J., Li, D., & Li, P. (2019). *Knowledge Graph Embedding Based Question Answering*. Paper presented at the Proceedings of the Twelfth ACM International Conference on Web Search and Data Mining, Melbourne VIC, Australia. https://doi.org/10.1145/3289600.3290956

Hussain, N., Wang, H. H., Buckingham, C. D., & Zhang, X. (2020). Software Agent-Centric Semantic Social Network for Cyber-Physical Interaction and Collaboration. *International Journal of Software Engineering and Knowledge Engineering, 30*(06), 859-893. doi: 10.1142/s0218194020400100

Ji, S., Pan, S., Cambria, E., Marttinen, P., & Yu, P. S. (2021). A Survey on Knowledge Graphs: Representation, Acquisition, and Applications. *IEEE Transactions on Neural Networks and Learning Systems*, 1-21. doi: 10.1109/TNNLS.2021.3070843

Jia, Y., Qi, Y., Shang, H., Jiang, R., & Li, A. (2018). A Practical Approach to Constructing a Knowledge Graph for Cybersecurity. *Engineering, 4*(1), 53-60. doi: https://doi.org/10.1016/j.eng.2018.01.004

Jia, Y., Wang, Y., Jin, X., & Cheng, X. (2018). Path-specific knowledge graph embedding. *Knowledge-Based Systems, 151*, 37-44. doi: https://doi.org/10.1016/j.knosys.2018.03.020

Jimenez, J. I., Jahankhani, H., & Kendzierskyj, S. (2020). Health Care in the Cyberspace: Medical Cyber-Physical System and Digital Twin Challenges. In M. Farsi, A. Daneshkhah, A. Hosseinian-Far & H. Jahankhani (Eds.), *Digital Twin Technologies and Smart Cities* (pp. 79-92). Cham: Springer International Publishing.

Jung, J., Jung, J., & Kang, U. (2021). *Learning to Walk across Time for Interpretable Temporal Knowledge Graph Completion*. Paper presented at the Proceedings of the 27th ACM SIGKDD Conference on Knowledge Discovery & Data Mining, Virtual Event, Singapore. https://doi.org/10.1145/3447548.3467292

Kampffmeyer, M., Chen, Y., Liang, X., Wang, H., Zhang, Y., & P. Xing, E. (2018). *Rethinking Knowledge Graph Propagation for Zero-Shot Learning*.

Kartsaklis, D., Pilevar, M. T., & Collier, N. (2018). *Mapping Text to Knowledge Graph Entities using Multi-Sense LSTMs*.

Kulchandani, J. S., & Dangarwala, K. J. (2015, 8-10 Jan. 2015). *Moving object detection: Review of recent research trends.* Paper presented at the 2015 International Conference on Pervasive Computing (ICPC).

Leblay, J., Chekol, M. W., & Liu, X. (2020). *Towards Temporal Knowledge Graph Embeddings with Arbitrary Time Precision*. Paper presented at the Proceedings of the 29th ACM International Conference on Information & Knowledge Management, Virtual Event, Ireland. https://doi.org/10.1145/3340531.3412028

Li, X., Sun, C., & Zia, M. (2020). Social influence based community detection in event-based social networks. *Information Processing & Management, 57*, 102353. doi: 10.1016/j.ipm.2020.102353

Liang, Y., Xu, F., Zhang, S.-H., Lai, Y.-K., & Mu, T. (2018). Knowledge graph construction with structure and parameter learning for indoor scene design. *Computational Visual Media, 4*(2), 123-137. doi: 10.1007/s41095-018-0110-3

Liguo, Y. (2018). Short History of Social Networking and Its Far-Reaching Impact. In D. B. A. Mehdi Khosrow-Pour (Ed.), *Encyclopedia of Information Science and Technology, Fourth Edition* (pp. 7116-7125). Hershey, PA, USA: IGI Global.

Lin, V., Socher, R., & Xiong, C. (2018). *Multi-Hop Knowledge Graph Reasoning with Reward Shaping*.

Liu, S., & Young, S. D. (2018). A survey of social media data analysis for physical activity surveillance. *Journal of Forensic and Legal Medicine, 57*, 33-36. doi: https://doi.org/10.1016/j.jflm.2016.10.019

Liu, Z., Cai, H., Yu, H., Shen, B., & Jiang, L. (2021, 5-7 May 2021). *Constructing the Sequential Event Graph for Event Prediction towards Cyber-Physical Systems.* Paper presented at the 2021 IEEE 24th International Conference on Computer Supported Cooperative Work in Design (CSCWD).

Luan, Y., He, L., Ostendorf, M., & Hajishirzi, H. (2018). *Multi-Task Identification of Entities, Relations, and Coreference for Scientific Knowledge Graph Construction*.

Mann, S. (2004). *"Sousveillance": inverse surveillance in multimedia imaging*. Paper presented at the Proceedings of the 12th annual ACM international conference on Multimedia, New York, NY, USA.

Mann, S. (2016, 26 June-1 July 2016). *Surveillance (Oversight), Sousveillance (Undersight), and Metaveillance (Seeing Sight Itself).* Paper presented at the 2016 IEEE Conference on Computer Vision and Pattern Recognition Workshops (CVPRW).

Meilicke, C., Fink, M., Wang, Y., Ruffinelli, D., Gemulla, R., & Stuckenschmidt, H. (2018, 2018//). *Fine-Grained Evaluation of Rule- and Embedding-Based Systems for Knowledge Graph Completion.* Paper presented at the The Semantic Web – ISWC 2018, Cham.

Messner, J., Abboud, R., & Ceylan, I. I. (2021). Temporal Knowledge Graph Completion using Box Embeddings. *ArXiv, abs/2109.08970*.

Mishra, P. K., & Saroha, G. P. (2016, 16-18 March 2016). *A study on video surveillance system for object detection and tracking.* Paper presented at the 2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom).

Monostori, L. (2018). Cyber-Physical Systems. In S. Chatti & T. Tolio (Eds.), *CIRP Encyclopedia of Production Engineering* (pp. 1-8). Berlin, Heidelberg: Springer Berlin Heidelberg.

Müller, T., Jazdi, N., Schmidt, J.-P., & Weyrich, M. (2021). Cyber-physical production systems: enhancement with a self-organized reconfiguration management. *Procedia CIRP, 99*, 549-554. doi: https://doi.org/10.1016/j.procir.2021.03.075

Munir, S., & Jami, S. (2019). Research Trends in Surveillance through Sousveillance. *International Journal of Advanced Computer Science and Applications, 10*, 433-437. doi: 10.14569/IJACSA.2019.0101258

Munir, S., Jami, S. I., & Wasi, S. (2021). Towards the Modelling of Veillance based Citizen Profiling using Knowledge Graphs. *Open Computer Science, 11*(1), 294-304. doi: doi:10.1515/comp-2020-0209

Napoleone, A., Macchi, M., & Pozzetti, A. (2020). A review on the characteristics of cyber-physical systems for the future smart factories. *Journal of Manufacturing Systems, 54*, 305-335. doi: https://doi.org/10.1016/j.jmsy.2020.01.007

Ohn-Bar, E., Tawari, A., Martin, S., & Trivedi, M. M. (2015). On surveillance for safety critical events: In-vehicle video networks for predictive driver assistance systems. *Computer Vision and Image Understanding, 134*, 130-140. doi: https://doi.org/10.1016/j.cviu.2014.10.003

Oldman, D., & Tanase, D. (2018, 2018//). *Reshaping the Knowledge Graph by Connecting Researchers, Data and Practices in ResearchSpace.* Paper presented at the The Semantic Web – ISWC 2018, Cham.

Palumbo, E., Rizzo, G., Troncy, R., Baralis, E., Osella, M., & Ferro, E. (2018, 2018//). *Knowledge Graph Embeddings with node2vec for Item Recommendation.* Paper presented at the The Semantic Web: ESWC 2018 Satellite Events, Cham.

Patel, H., Paraskevopoulos, P., & Renz, M. (2018, 28-31 Aug. 2018). *GeoTeGra: A System for the Creation of Knowledge Graph Based on Social Network Data with Geographical and Temporal Information.*

Paper presented at the 2018 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM).
Ponce, P., Méndez, J. I., Medina, A., Mata, O., Meier, A., Peffer, T., & Molina, A. (2021, 18-20 March 2021). *Smart Cities Using Social Cyber-Physical Systems Driven by Education.* Paper presented at the 2021 IEEE European Technology and Engineering Management Summit (E-TEMS).
Pujara, J., & Singh, S. (2018). *Mining Knowledge Graphs From Text*. Paper presented at the Proceedings of the Eleventh ACM International Conference on Web Search and Data Mining, Marina Del Rey, CA, USA.
Ríos, S. A., Aguilera, F., Nuñez-Gonzalez, J. D., & Graña, M. (2019). Semantically enhanced network analysis for influencer identification in online social networks. *Neurocomputing, 326-327*, 71-81. doi: https://doi.org/10.1016/j.neucom.2017.01.123
RMIT. (2021). What are Cyber-physical systems? , from https://www.rmit.edu.au/news/c4de/what-are-cyber-physical-systems
Saemi, M. M., See, J., & Tan, S. (2015, 19-21 Oct. 2015). *Lost and found: Identifying objects in long-term surveillance videos.* Paper presented at the 2015 IEEE International Conference on Signal and Image Processing Applications (ICSIPA).
Sajjanar, S., Mankani, S. K., Dongrekar, P. R., Kumar, N. S., Mohana, & Aradhya, H. V. R. (2016, 13-14 Aug. 2016). *Implementation of real time moving object detection and tracking on FPGA for video surveillance applications.* Paper presented at the 2016 IEEE Distributed Computing, VLSI, Electrical Circuits and Robotics (DISCOVER).
Sawant, U., Chakrabarti, S., & Ramakrishnan, G. (2018). "Open-domain question answering using a knowledge graph and web corpus" by Uma Sawant, Soumen Chakrabarti and Ganesh Ramakrishnan with Martin Vesely as coordinator. *SIGWEB Newsl.*(Winter), 1-8. doi: 10.1145/3183639.3183643
Silva, V., Freitas, A., & Handschuh, S. (2017). *Building a Knowledge Graph from Natural Language Definitions for Text Entailment Recognition*.
Somayeh Asadifar, M. K., Saeedeh Shekarpour. (2018). HCqa: Hybrid and Complex Question Answering on Textual Corpus and Knowledge Graph.
Song, H., & Park, S. (2018). Enriching Translation-Based Knowledge Graph Embeddings Through Continual Learning. *IEEE Access, 6*, 60489-60497. doi: 10.1109/ACCESS.2018.2874656
Su, D., Liu, J., Wang, W., Wang, X., Du, X., & Guizani, M. (2018). Discovering communities of malapps on Android-based mobile cyber-physical systems. *Ad Hoc Networks, 80*, 104-115. doi: https://doi.org/10.1016/j.adhoc.2018.07.015
Sun, Z., Deng, Z., Nie, J.-Y., & Tang, J. (2019). RotatE: Knowledge Graph Embedding by Relational Rotation in Complex Space. *ArXiv, abs/1902.10197*.
Tan, Y., Vuran, M. C., & Goddard, S. (2009, 22-26 June 2009). *Spatio-Temporal Event Model for Cyber-Physical Systems.* Paper presented at the 2009 29th IEEE International Conference on Distributed Computing Systems Workshops.
Tsakanikas, V., & Dagiuklas, T. (2018). Video surveillance systems-current status and future trends. *Computers & Electrical Engineering, 70*, 736-753. doi: https://doi.org/10.1016/j.compeleceng.2017.11.011
Walia, G. S., & Kapoor, R. (2016). Robust object tracking based upon adaptive multi-cue integration for video surveillance. *Multimedia Tools and Applications, 75*(23), 15821-15847. doi: 10.1007/s11042-015-2890-0
Walker-Roberts, S., Hammoudeh, M., Aldabbas, O., Aydin, M., & Dehghantanha, A. (2020). Threats on the horizon: understanding security threats in the era of cyber-physical systems. *The Journal of Supercomputing, 76*(4), 2643-2664. doi: 10.1007/s11227-019-03028-9

Wang, C., Ma, X., Chen, J., & Chen, J. (2018). Information extraction and knowledge graph construction from geoscience literature. *Computers & Geosciences, 112*, 112-120. doi: https://doi.org/10.1016/j.cageo.2017.12.007

Wang, P., Liu, K., Jiang, L., Li, X., & Fu, Y. (2020). *Incremental Mobile User Profiling: Reinforcement Learning with Spatial Knowledge Graph for Modeling Event Streams*. Paper presented at the Proceedings of the 26th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining, Virtual Event, CA, USA. https://doi.org/10.1145/3394486.3403128

Wang, P., Yang, L. T., Li, J., Chen, J., & Hu, S. (2019). Data fusion in cyber-physical-social systems: State-of-the-art and perspectives. *Information Fusion, 51*, 42-57. doi: https://doi.org/10.1016/j.inffus.2018.11.002

Wang, R., Yan, Y., Wang, J., Jia, Y., Zhang, Y., Zhang, W., & Wang, X. (2018). *AceKG: A Large-scale Knowledge Graph for Academic Data Mining*. Paper presented at the Proceedings of the 27th ACM International Conference on Information and Knowledge Management, Torino, Italy.

Wang, Z., Lv, Q., Lan, X., & Zhang, Y. (2018, 2018//). *Cross-lingual Knowledge Graph Alignment via Graph Convolutional Networks.* Paper presented at the Proceedings of the 2018 Conference on Empirical Methods in Natural Language Processing.

Wu, P., Zhou, Q., Lei, Z., Qiu, W., & Li, X. (2018, 16-17 July 2018). *Template Oriented Text Summarization via Knowledge Graph.* Paper presented at the 2018 International Conference on Audio, Language and Image Processing (ICALIP).

Xia, H., Xiao, F., Zhang, S. S., Cheng, X. G., & Pan, Z. K. (2020). A Reputation-Based Model for Trust Evaluation in Social Cyber-Physical Systems. *IEEE Transactions on Network Science and Engineering, 7*(2), 792-804. doi: 10.1109/TNSE.2018.2866783

Yaacoub, J.-P. A., Salman, O., Noura, H. N., Kaaniche, N., Chehab, A., & Malli, M. (2020). Cyber-physical systems security: Limitations, issues and future trends. *Microprocessors and Microsystems, 77*, 103201. doi: https://doi.org/10.1016/j.micpro.2020.103201

Yang, S., Yang, H., Li, J., & Zhu, J. (2017, 2017//). *An Effective Crowd Property Analysis System for Video Surveillance Application.* Paper presented at the Digital TV and Wireless Multimedia Communication, Singapore.

Yang, Y., Wang, S., Wen, M., & Xu, W. (2021). Reliability modeling and evaluation of cyber-physical system (CPS) considering communication failures. *Journal of the Franklin Institute, 358*(1), 1-16. doi: https://doi.org/10.1016/j.jfranklin.2018.09.025

Yilma, B. A., Panetto, H., & Naudet, Y. (2019, 2019//). *A Meta-Model of Cyber-Physical-Social System: The CPSS Paradigm to Support Human-Machine Collaboration in Industry 4.0.* Paper presented at the Collaborative Networks and Digital Transformation, Cham.

Yilma, B. A., Panetto, H., & Naudet, Y. (2021). Systemic formalisation of Cyber-Physical-Social System (CPSS): A systematic literature review. *Computers in Industry, 129*, 103458. doi: https://doi.org/10.1016/j.compind.2021.103458

Zacchia Lun, Y., D'Innocenzo, A., Smarra, F., Malavolta, I., & Di Benedetto, M. D. (2019). State of the art of cyber-physical systems security: An automatic control perspective. *Journal of Systems and Software, 149*, 174-216. doi: https://doi.org/10.1016/j.jss.2018.12.006

Zhang, D., Wang, Q.-G., Feng, G., Shi, Y., & Vasilakos, A. V. (2021). A survey on attack detection, estimation and control of industrial cyber–physical systems. *ISA Transactions, 116*, 1-16. doi: https://doi.org/10.1016/j.isatra.2021.01.036

Zhang, J., Liang, S., Deng, Z., & Shao, J. (2021, 2021//). *Spatial-Temporal Attention Network for Temporal Knowledge Graph Completion.* Paper presented at the Database Systems for Advanced Applications, Cham.

Zhang, Q., Sun, Z., Hu, W., Chen, M., Guo, L., & Qu, Y. (2019). Multi-view Knowledge Graph Embedding for Entity Alignment. *ArXiv, abs/1906.02390*.

Zhu, J.-Z., Jia, Y.-T., Xu, J., Qiao, J.-Z., & Cheng, X.-Q. (2018). Modeling the Correlations of Relations for Knowledge Graph Embedding. *Journal of Computer Science and Technology, 33*(2), 323-334. doi: 10.1007/s11390-018-1821-8

Zhu, T., Xiong, P., Li, G., Zhou, W., & Yu, P. S. (2020). Differentially private model publishing in cyber physical systems. *Future Generation Computer Systems, 108*, 1297-1306. doi: https://doi.org/10.1016/j.future.2018.04.016

Annexure:

Gantt Chart with research work distribution is mention in figure 7.

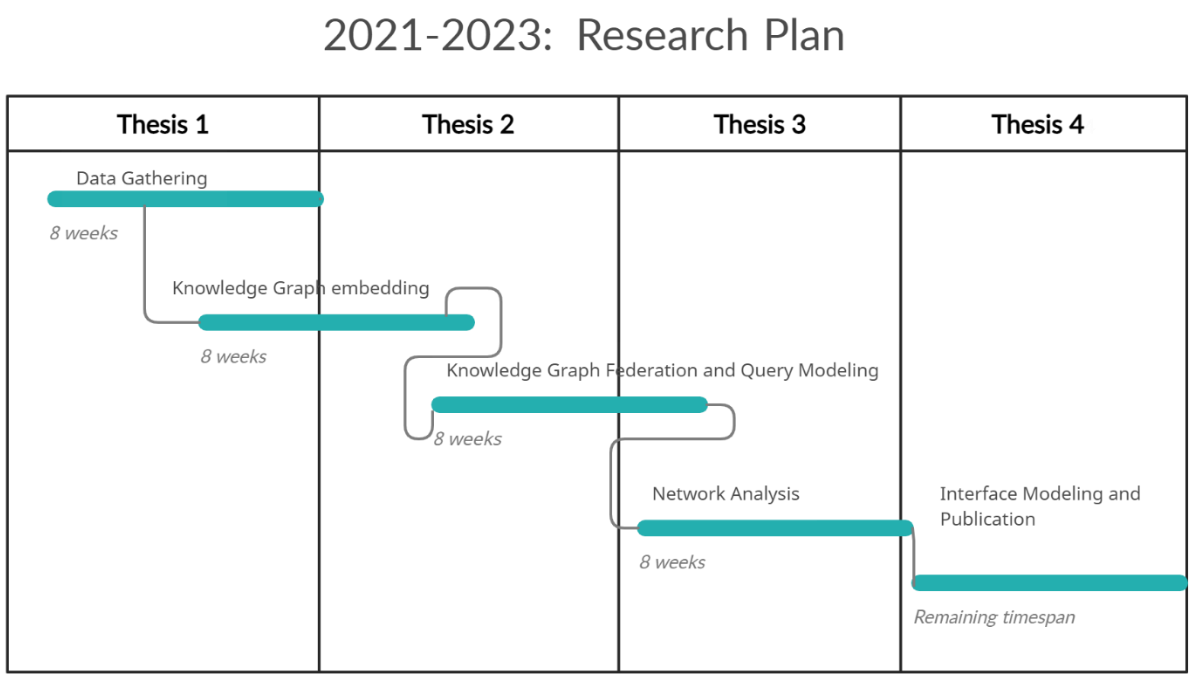

Figure 7: Gantt Chart