COSMOS Testbed Response to COVID-19 Pandemic

Mahshid Ghasemi, Zoran Kostic, Javad Ghaderi, Gil Zussman
Department of Electrical Engineering, Columbia University

Abstract

Smart city intersections will be at the core of an AI-powered traffic management system for crowded metropolises. COSMOS deploys a variety of infrastructure sensors, including street-level and bird's eye cameras, whose data will be aggregated by the servers. The servers will run real-time algorithms to monitor and manage traffic. COSMOS technologies can also help us combat the coronavirus pandemic, better understand the impacts of social distancing protocols on people's daily life, and determine how well they follow the unprecedented rules. We utilized these infrastructures to design a fully automated multi-stage social distancing analyzer pipeline that monitors the distance between pedestrians and decides whether or not they are maintaining a proper distance. This pipeline removes all the distortions caused by the cameras and converts pixel distance to on-ground distance with high accuracy (less than 10 cm error). The pipeline is also capable of detecting groups of people walking together and exclude them from social distancing violation. We applied this pipeline on videos recorded from COSMOS pilot site and analyzed how social distancing protocols are impacting people's social life. The results show that after COVID-19 crisis, only 10-23 % of people do not comply with the social distancing rules, also only around 10 % of pedestrians tend to walk as a group.

This work is an initial step toward overcoming the challenges of potential deployment of autonomous vehicles, including a large number of vehicles moving at various speeds, obstructions which are opaque to in-vehicle sensors, and chaotic behavior of pedestrians.

Motivation

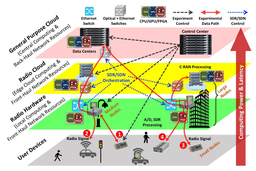
Smart cities can help us manage post-COVID life. The globally deployed traffic cameras can be used to monitor the evolution of people's social life, and to make sure that the guidelines regarding social distancing and lockdown rules are obeyed. So we can exploit these cameras to measure the effectiveness of the new protocols and better plan for reducing the spread of COVID-19 virus.

COSMOS-Testbed

- ***C**loud enhanced **O**pen **S**oftware defined **MO**bile wireless testbed for city-**S**cale deployment* (COSMOS) is a city-scale programmable testbed for experimentation with advanced wireless technologies in New York City.
- COSMOS is a joint project involving Rutgers, Columbia, and NYU along with several partner organizations including New York City, CCNY, University of Arizona, Silicon Harlem, and IBM.
- COSMOS architecture has a particular focus on ultra-high bandwidth and low latency wireless communication tightly coupled with edge cloud computing.
- We utilized these infrastructure to build a video analytic pipeline that monitors whether pedestrians comply with social distancing guidelines.

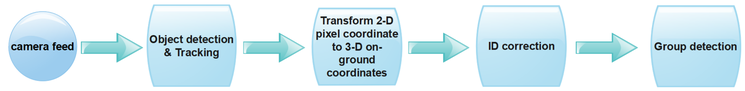
COSMOS pilot site with cameras and edge-cloud node.

COSMOS testbed deployment area.



COSMOS' computing architecture.

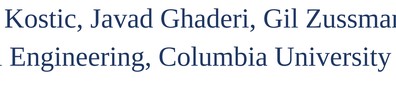
Fully Automated Multi-Stage Social Distancing Analyzer Pipeline



- Social Distancing Analyzer consists of multiple modules.
  - YOLOV3 object detector locates the pedestrians and Nvidia DCF tracker assigns an ID to each of them.
  - To find real distances between pedestrians 2-D pixel coordinates need to be converted to 3-D on-ground coordinates.
  - Precision of DCF tracker can degrade due to oblique view of traffic cameras, obstacle like vehicles, buildings, traffic lights, etc.
    - ID correction module compensates for these imperfections.
  - Group detection module distinguishes people that belong to a single social group and excludes them from social distancing breach.

Camera Calibration and 3-D Reconstruction

- Intrinsic and extrinsic parameters of the cameras are required to convert pixel distances to on-ground distances.
  - (i) Intrinsic parameters:
    - Principal point
    - Focal length in pixel units
    - Radial distortion coefficients
    - Tangential distortion coefficients
  - (ii) Extrinsic parameters:
    - Rotation vector R
    - Translation vector t
- Calibration can be done using a checkerboard and OpenCV modules.
- For high accuracy the scene needs to be divided into multiple areas and their corresponding extrinsic parameters (R, t) must be extracted individually.
- Having these parameters the 3-D model is obtained by solving the corresponding photogrammetry equations.



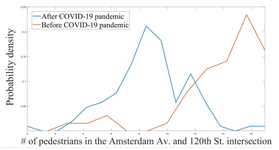
Calibration with checkerboard.

Dividing the scene into 10 areas for higher precision calibration.

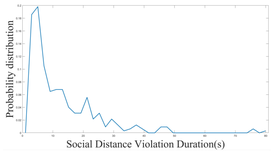
Group Detection

- Friends and families walking together should be excluded from social distancing breach.
- These social groups can be detected by extracting pedestrians' trajectory and their correlation.
- Those pedestrians with correlated trajectory who maintain a consistent distance throughout their path, and are relatively close to each other are grouped together.

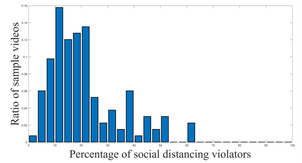
Impact of COVID-19 Crisis on Our Social Life



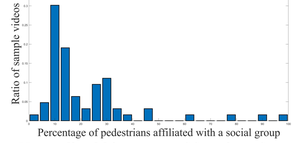
Comparison between density of pedestrians walking at the Amsterdam Av. and 120th St. intersection before and after COVID-19 outbreak.



Probability density of breaking social distancing rules for a certain amount of time by an individual walking on Amsterdam Av. and 120th St., New York City after COVID-19 outbreak.



This histogram shows how much percentage of recorded videos have a certain amount of people violating social distancing protocols. This represents that in majority of the videos recorded from COSMOS pilot site, 10−23% of pedestrians are violating the social distancing rules.



Normalized histogram of fraction of people walking in a group. This shows that most often, during COVID-19 pandemic, around 10% of pedestrians tend to walk in a social group.

Future Work

- Distributed edge/cloud video analytics.
- Support cloud-connected vehicles to overcome the limitations of autonomous vehicles.
- Enable vehicles to wirelessly share in-vehicle sensor data with other vehicles and the edge/cloud servers.
- Low-latency AR edge/cloud.
- Managing heterogeneous bandwidth and computing resources, and providing seamless service mobility.
- Provide performance guidelines for future edge/cloud deployments.

References

1. Joseph Redmon and Ali Farhadi. Yolov3: An incremental improvement. arXiv preprint arXiv:1804.02767, 2018.
2. Cong T Nguyen, Yuris Mulya Saputra, Nguyen Van Huynh, Ngoc-Tan Nguyen, Tran Viet Khoa, Bui Minh Tuan, Diep N Nguyen, Dinh Thai Hoang, Thang X Vu, Eryk Dutkiewicz, et al. Enabling and emerging technologies for social distancing: A comprehensive survey. arXiv preprint arXiv:2005.02816, 2020.
3. Maanak Gupta, Mahmoud Abdelsalam, and Sudip Mittal. Enabling and enforcing social distancing measures using smart city and its infrastructures: a covid-19 use case. arXiv preprint arXiv:2004.09246, 2020.
4. Dongfang Yang, Ekim Yurtsever, Vishnu Renganathan, Keith A Redmill, and Umit Ozgüner. A vision-based social distancing and critical density detection system for COVID-19. arXiv preprint arXiv:2007.03578, 2020.
5. Marco Cristani, Alessio Del Bue, Vittorio Murino, Francesco Setti, and Alessandro Vinciarelli. The visual social distancing problem. arXiv preprint arXiv:2005.04813, 2020

This work was supported in part by NSF grant CNS-1827923, NSF-BSF grant CNS-1910757, and ARO grant W911NF1910