UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Machine Learning Powered Mobile HealthCare Unit for Addressing Childhood Vaccination Disparities

Big Ten Augmented Intelligence Bowl

The vAccIne Heroes

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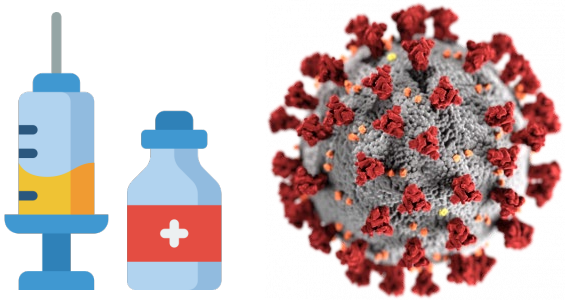
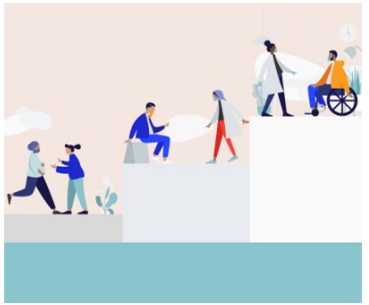
Background: Public Health and Health Disparity Problem

Childhood Immunizations



- Low-income zip codes have ~**40%** vaccination rate
- Childhood rates declined by **68%** in Massachusetts during COVID-19

Health Disparities



- Race, socioeconomic status, location etc.

Approach: OSF Community Care and Care-A-Van

Advantages of Mobile Care Unit

- **Flexible:** take care “on the road”
- **Accessible:** provide care when and where it is needed
- **Technology:** mobile unit can benefit from technology advances
- **Trust-building:** mobile units can be avenues of trust into the community

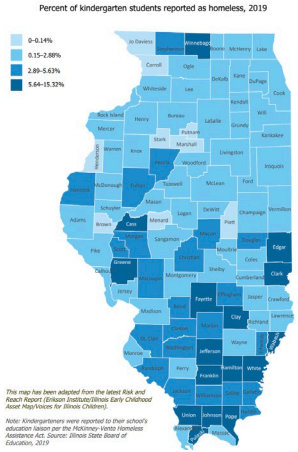
Challenges

- **Site selection:** where to send the care-a-van?
- **Supply estimation:** how to accurate estimation of clinical supply.

Machine Learning Tasks

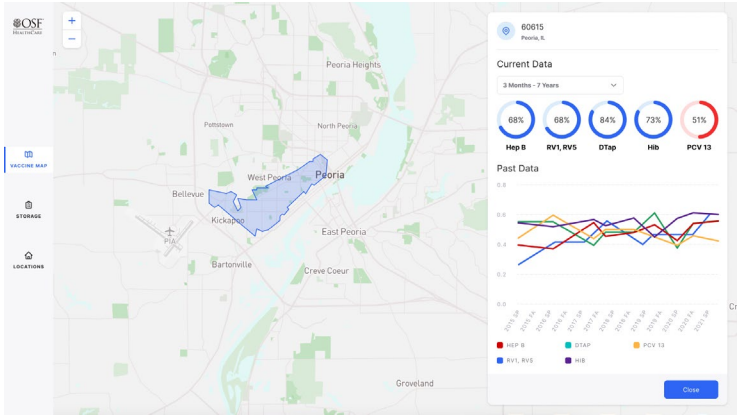
Task 1: Vaccination site selection

- How to select the best sites for vaccination events?
- What are the ranking criteria of different locations?



Task 2: Vaccine supply prediction

- Given the location and time of a vaccination event, how to accurately estimate the vaccine supply?



Visualization interface

Heatmap, basic statistics, prediction results

Data Sources

Pediatric EHRs

Historical Monthly Vaccination Info
(claims data, ~10 years)

Location-Specific Vaccination Statistics
(to be added)

- Previous vaccination event statistics
  - ~7 pediatric vaccination events from this year
  - 16 flu vaccination events from 2018 to 2021
- Other data sets
  - School vaccination statistics
  - 94 census features for each location

Some Past Events:

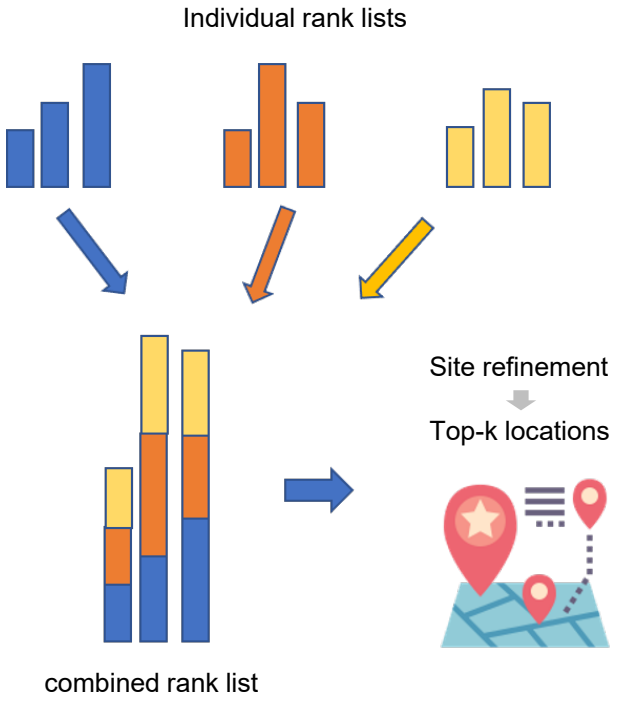
Location & Time	# Patients	Vaccine
Knoxville Peds Physical Event 2806 Knoxville Ave. Peoria 61604, July 17	4	.....
Knoxville Peds Physical Event 2806 Knoxville Ave. Peoria 61604, July 17	17	.....
Dream Center Peoria 714 Hamilton Blvd, Peoria, July 31	7	.....
New Beginnings Worship Center 1910 W Lincoln Ave, Peoria August 14	8	.....

Task1: Vaccination Site Selection

Goal: Identify top-*k* locations for vaccination events

1. Multiple rank lists
   - We create individual rank lists of **diverse ranking criteria**
   - Criteria include
     - Vaccination rate, Vaccination rate change, Population density, Social economic status, Social vulnerability index, …
2. Rank aggregation
   - Create a **combine rank list** that is closest to all the individual rank lists (Markov Chain Type 4 method)
3. Site refinement
   - Further optimize the site candidates from the top ranked locations
   - Consider logistic constraints, previous events, diversity of the locations

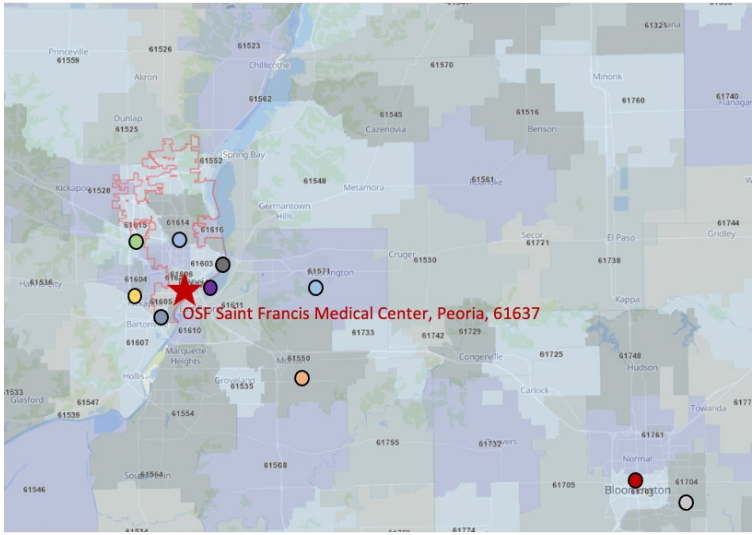
Method Benefits: 1) Interpretable and 2) Extensible



Event Site Selection

Local Map Around Peoria County

* Red contour indicates Peoria county



The figure is from unitedstateszipcodes.org

Top ranked Zip codes and individual rank percentages (top %)

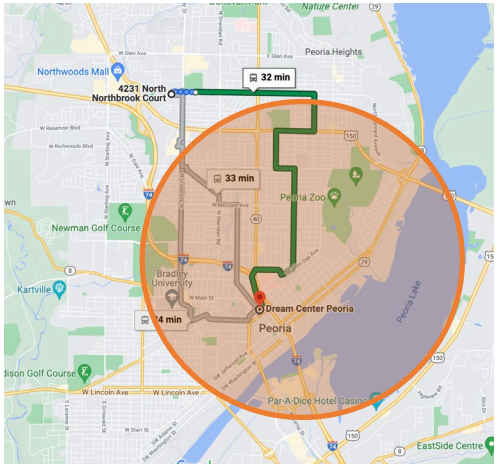
Overall Rank	Zip Code	Vaccination Rate	Change Rate	Pediatric Pop.	Income Status	Driving Dis. to OSF
1	61615	96%	98%	87%	91%	9.896 miles
2	61571	95%	98%	92%	88%	23.959 miles
3	61604	88%	95%	93%	82%	4.719 miles
4	61704	92%	94%	98%	95%	76.449 miles
5	61550	97%	90%	84%	88%	22.935 miles
6	61614	93%	85%	89%	82%	10.365 miles
7	61605	71%	93%	88%	68%	3.604 miles
8	61603	83%	88%	88%	63%	4.373 miles
9	61701	93%	78%	95%	83%	73.91 miles
10	61602	67%	87%	69%	84%	3.445 miles

* Totally 120 zip codes near Peoria

Task2: Vaccination Supply Prediction

Goal: Given upcoming event info, estimate the vaccine supplies

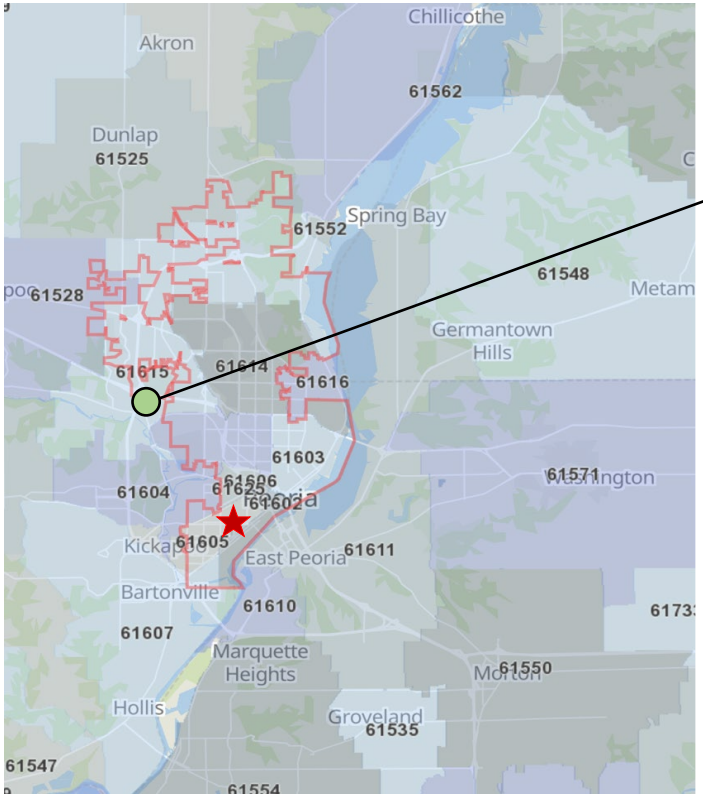
- Challenges:
  - Limited historical data to create the prediction models
- Approach – Spatio-temporal calibration method
  - Estimate the overall unvaccinated population near the selected event based on historical EHR and claims data, **P**
  - Estimate the participating probability
    - α = Func (location, time, weather, marketing, driving distance,…)
  - Vaccine supply = α * **P**
- Benefit: leverage rich data (EHR and claims) to make up for limited historical event data



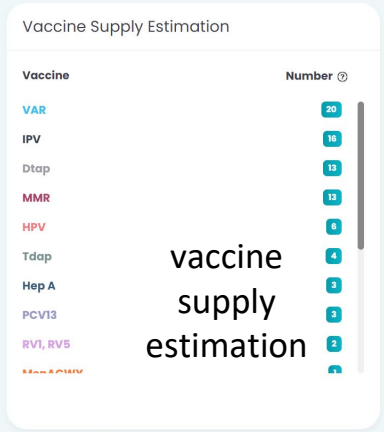
Our First Event
Location: Dream center at Peoria
Time: 9 – 12PM, July 31, 2021

Hep A	HPV	VAR	MMR	IPV	Dtap	Tdap
0	0	4	4	4	4	3

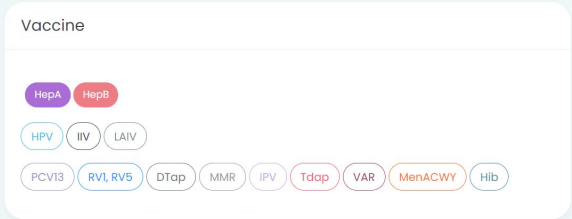
Vaccine Supply Estimation

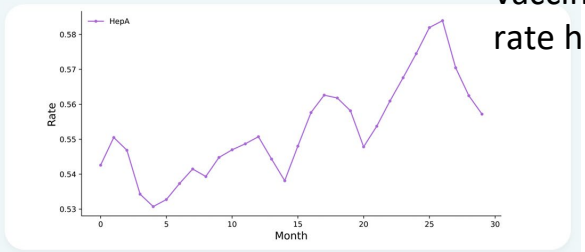


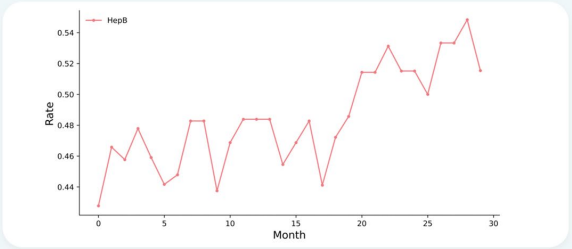
census features



vaccine supply estimation







vaccination rate history

Experimental Results

Prediction of Unvaccinated Population, **P**

	MAPE	R-square	CCC
Hep A	0.1815	0.9891	0.9941
HPV	0.1055	0.9918	0.9958
VAR	0.1541	0.9897	0.9947
MMR	0.1966	0.9898	0.9946
IPV	0.2093	0.9906	0.9952
Dtap	0.1501	0.9887	0.9940
tdap	0.0933	0.9841	0.9921

Supply Prediction (Simulation)

	RMSE	MAPE
Hep A	2.988	0.5089
HPV	4.096	0.5850
VAR	4.859	0.6428
MMR	4.727	0.4905
IPV	6.765	0.5901
Dtap	6.188	0.6714
tdap	3.387	0.4722

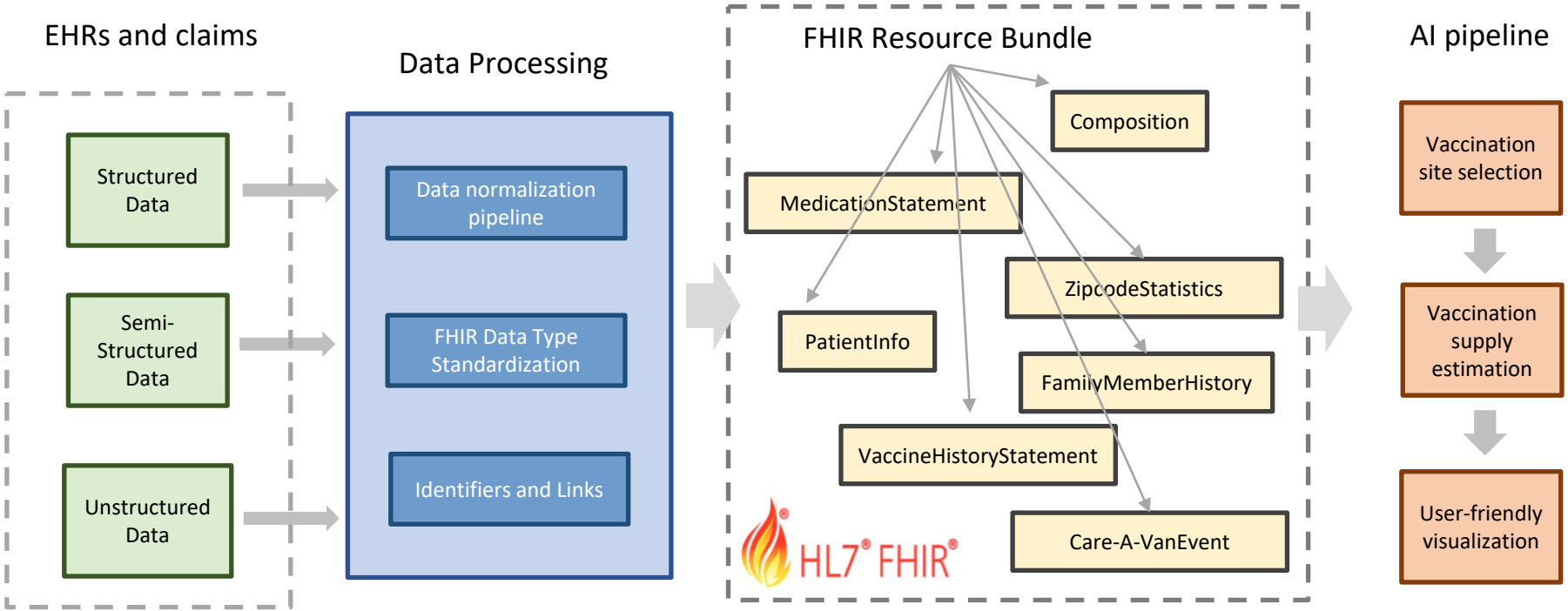
Supply Prediction (Event Data)

	RMSE	MAPE
Hep A	1.291	0.3889
HPV	3.697	1.2500
VAR	4.123	1.3170
MMR	1.826	0.2833
IPV	4.447	0.8754
Dtap	1.732	0.3667
tdap	1.915	0.4222

$$MAPE = \frac{1}{n}\sum_i \frac{|\hat{y}_i - y_i|}{|y_i|} \qquad R^2 = 1 - \frac{\sum_i(\hat{y}_i - y_i)\text{^}2}{\sum_i(\bar{y}_i - y_i)\text{^}2} \qquad RMSE = \sqrt{\frac{\sum_i(\hat{y}_i - y_i)\text{^}2}{n}}$$

Concordance correlation coefficient $CCC = \frac{2\rho\sigma_{\hat{y}}\sigma_y}{\sigma_{\hat{y}}^2 + \sigma_y^2 + (\mu_{\hat{y}} - \mu_y)^2}$

FHIR Supportive Interface (Ongoing Development)



Join us in protecting the health of all children

Future Efforts

Data Acquisition
- Access I-Care data and more real event data

Research Goal
- Submit a manuscript for publication by early 2022

Deployment Goals
- Conduct user study and improve the visualization
- Finish integration with “FHIR for ML” interface
- Customize our AI pipeline for other regions

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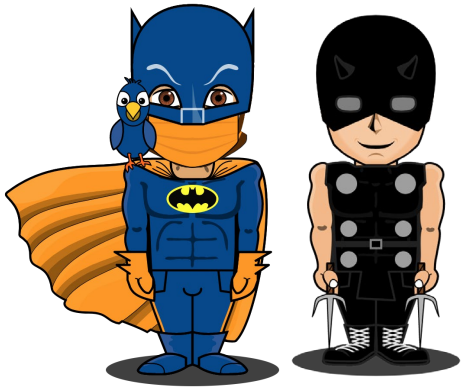
Junyi Gao PhD Student

Jimeng Sun Computer science professor



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