The 37th International Symposium on Automation and Robotics in Construction (ISARC 2020)

OpenBridgeGraph: Integrating Open Government Data for Bridge Management

Jia-Rui Lin, Ph.D. Assistant Professor

Department of Civil Engineering, Tsinghua University

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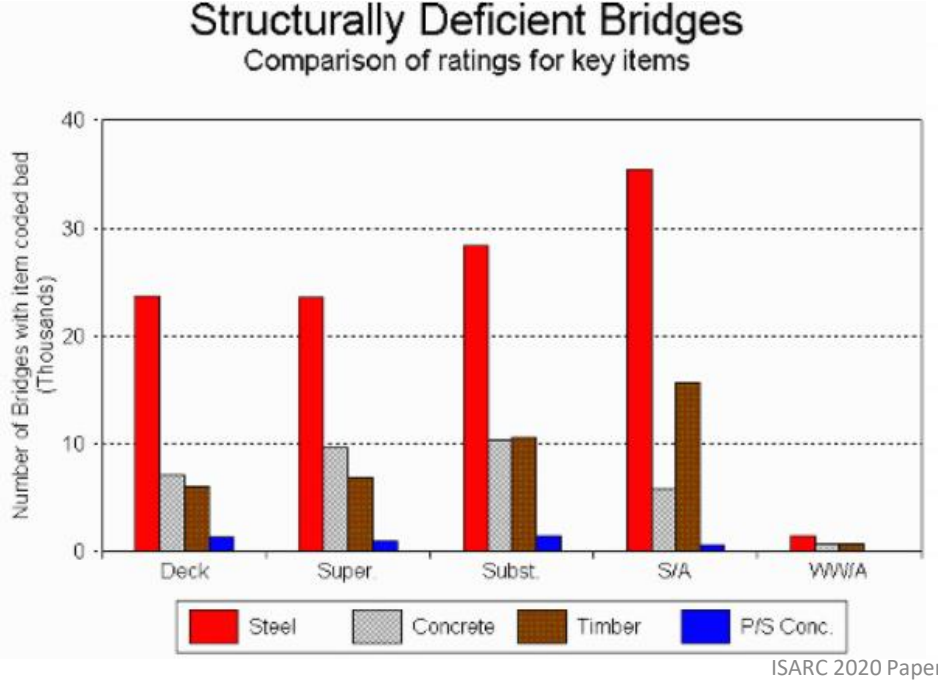
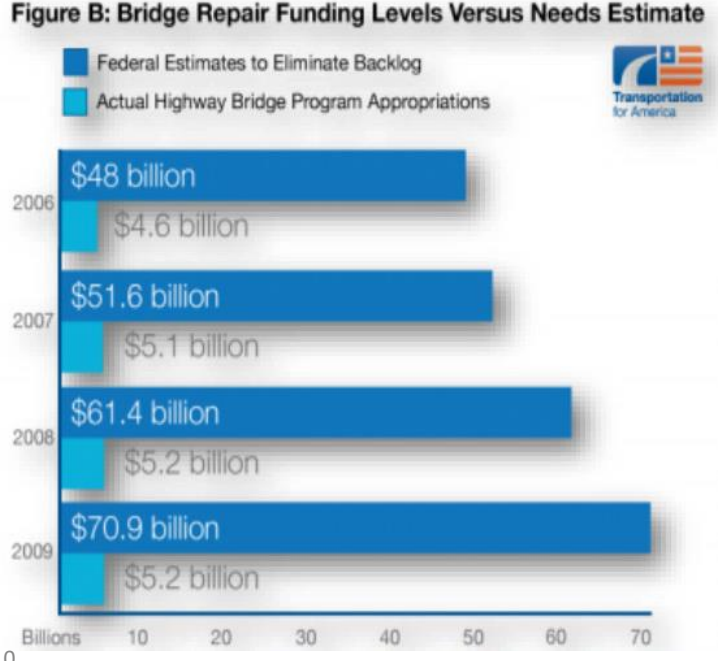
Bridge management is important

- 612, 677 U.S. bridges
  - 9% structural deficient: average age 67yrs, crossed 174 million times/day
  - In 2017, $150 billion is needed, while only $8 billion is available

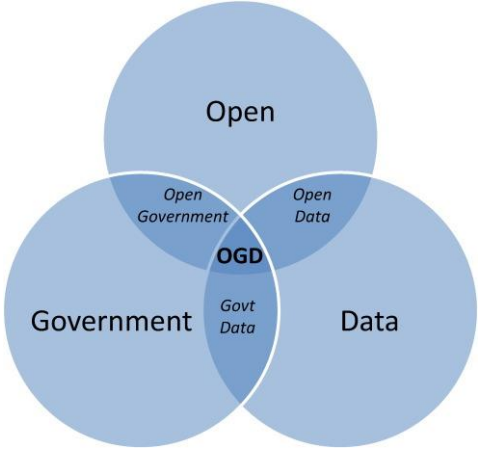


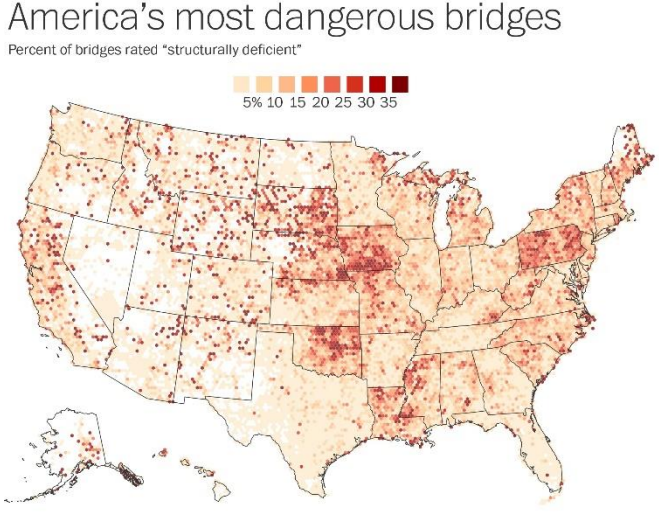


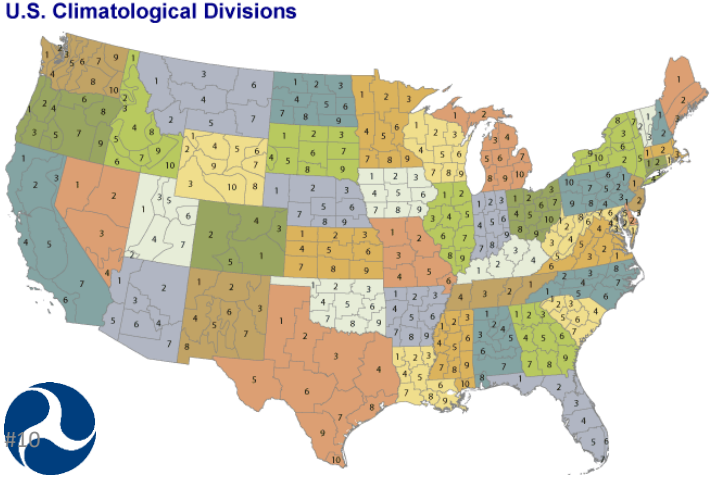
Source : CNN Report , Feb 2018

More open government data are available

- Open government data
  - Transparency and openness
  - Participation in decision-making
  - Cooperation for solving problems
  - Innovation for a better future
- More OGD are available







Objectives

Tsinghua University

- Explore how to integrate open government data and how to use them for bridge management purpose
- Identify potential obstacles in using open government data

Bridge data from NBI

STATE_CODE_001,STRUCTURE_NUMBER_008,RECORD_TYPE_005A,ROUTE_PREFIX_005B,SERVICE_LEVEL_005C,ROUTE_NUMBER_005D,DIRECTION_005E,HIGHWAY_DISTRICT_002,COUN
TY_CODE_003,PLACE_CODE_004,FEATURES_DESC_006A,CRITICAL_FACILITY_006B,FACILITY_CARRIED_007,LOCATION_009,MIN_VERT_CLR_010,KILOPOINT_011,BASE_HWY_NETWORK_01
2,LRS_INV_ROUTE_013A,SUBROUTE_NO_013B,LAT_016,LONG_017,DETOUR_KILOS_019,TOLL_020,MAINTENANCE_021,OWNER_022,FUNCTIONAL_CLASS_026,YEAR_BUILT_027,TRAFFIC_LA
NES_ON_028A,TRAFFIC_LANES_UND_028B,ADT_029,YEAR_ADT_030,DESIGN_LOAD_031,APPR_WIDTH_MT_032,MEDIAN_CODE_033,DEGREES_SKEW_034,STRUCTURE_FLARED_035,RAILIN
GS_036A,TRANSITIONS_036B,APPR_RAIL_036C,APPR_RAIL_END_036D,HISTORY_037,NAVIGATION_038,NAV_VERT_CLR_MT_039,NAV_HORR_CLR_MT_040,OPEN_CLOSED_POSTED_041,SE
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R_UND_REF_054A,VERT_CLR_UND_054B,LAT_UND_REF_055A,LAT_UND_MT_055B,LEFT_LAT_UND_MT_056,DECK_COND_058,SUPERSTRUCTURE_COND_059,SUBSTRUCTURE_COND_060
,CHANNEL_COND_061,CULVERT_COND_062,OPR_RATING_METH_063,OPERATING_RATING_064,INV_RATING_METH_065,INVENTORY_RATING_066,STRUCTURAL_EVAL_067,DECK_GEOME
TRY_EVAL_068,UNDCLRENCE_EVAL_069,POSTING_EVAL_070,WATERWAY_EVAL_071,APPR_ROAD_EVAL_072,WORK_PROPOSED_075A,WORK_DONE_BY_075B,IMP_LEN_MT_076,DATE_OF_
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Weather data from NOAA

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","WESD","WESD_ATTRIBUTES","WESF","WESF_ATTRIBUTES","WSF2","WSF2_ATTRIBUTES","WSF5","WSF5_ATTRIBUTES","WSFG","WSFG_ATTR
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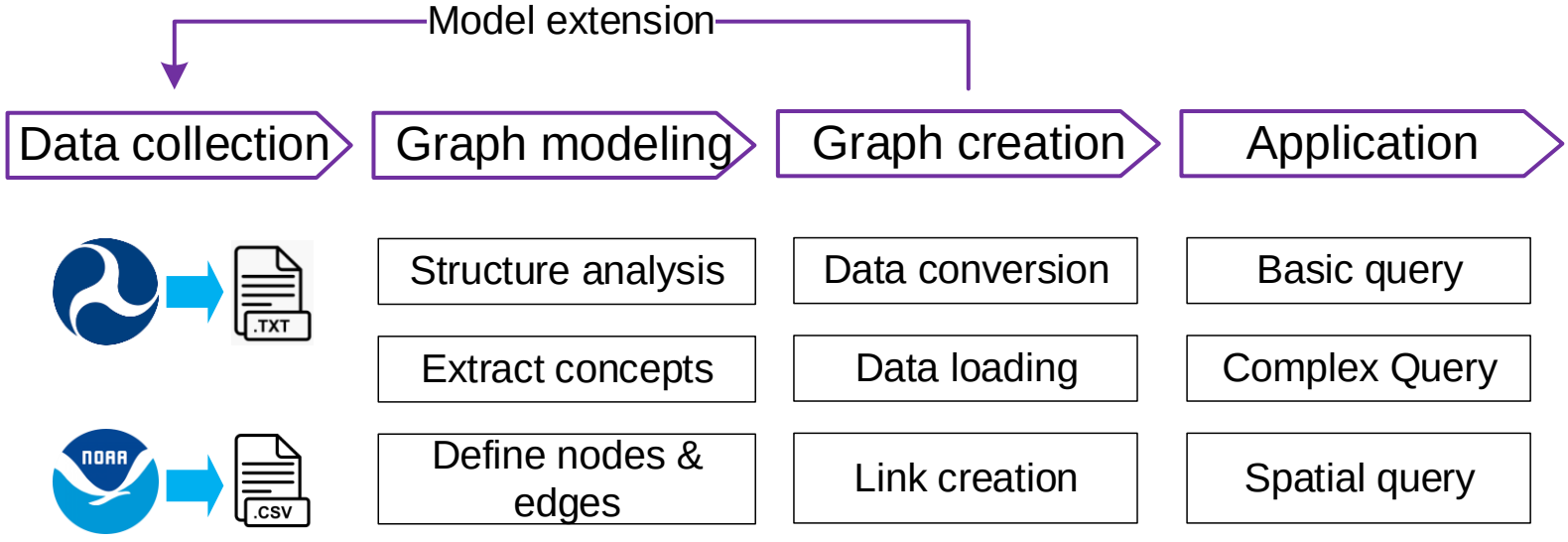
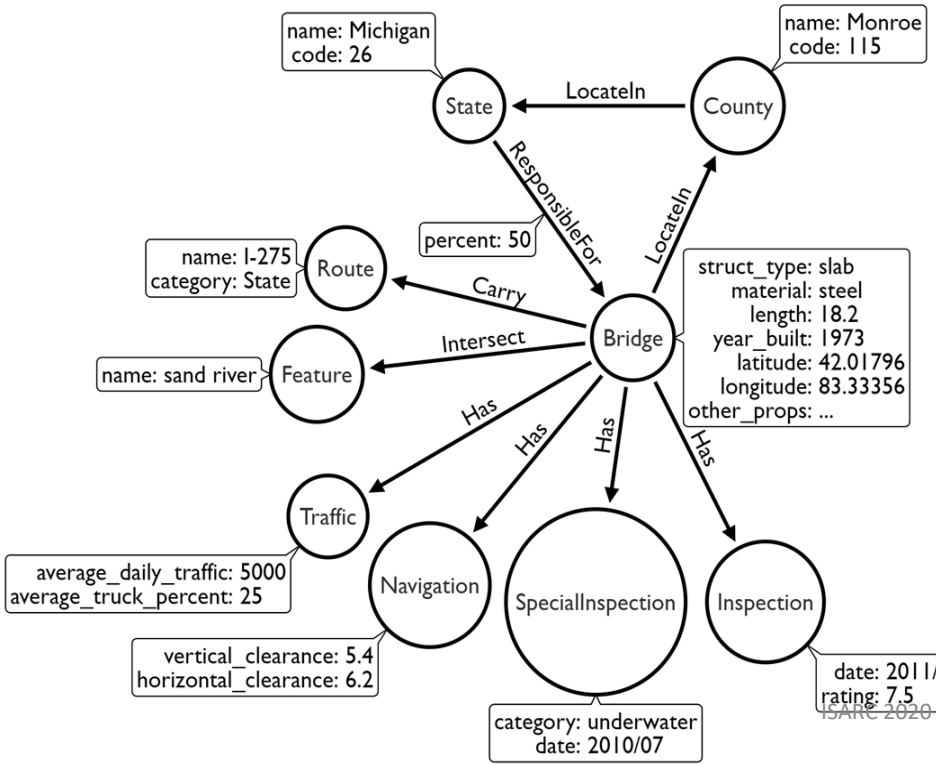
Methodology

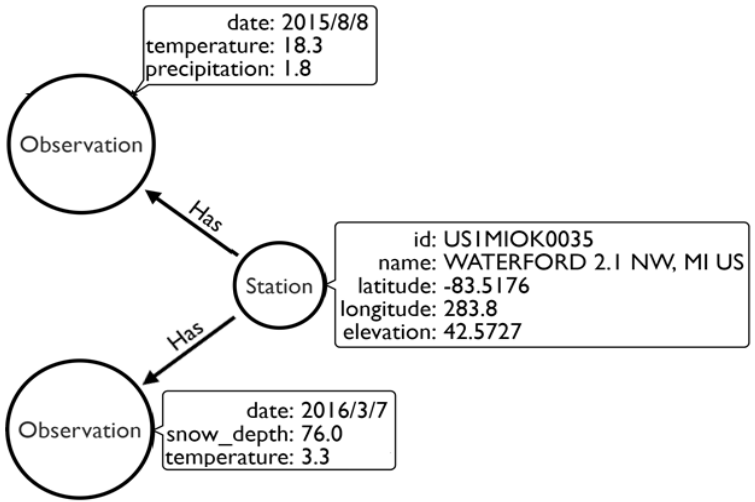
- A four-step framework
  - Utilizes graph based data modeling
  - Iterative model extension and data integration



Methodology

- Graph-based modeling of bridge and environmental data
  - Cares more about relationships
  - Easy to extend





Methodology

- Data integration and graph creation
  - Data mapper for transforming NBI data to graph nodes
  - Scripts to convert properties encoded in NBI
  - Creating graph while loading converted data

```
bridge_mapper=NodeMapperDef(
    label='Bridge',
    id_props=['STATE_CODE_001','STRUCTURE_NUMBER_008'],
    props={
        'structure_number:string':'STRUCTURE_NUMBER_008',
        'location:string':'LOCATION_009',
        'latitude:float':'LAT_016',
        'longitude:float':'LONG_017',
        'year_built:int':'YEAR_BUILT_027',
        'design_live_load:float':'DESIGN_LOAD_031',
    })
node_mappers.append(bridge_mapper)

other_state_responsible_for=EdgeMapperDef(
    label='ResponsibleFor',
    src_label='State',
    src_id_props=['OTHER_STATE_CODE_098A'],
    dst_label='Bridge',
    dst_id_props=bridge_mapper.id_props,
    props={
        'percent:float':'OTHER_STATE_PCNT_098B'
    },
    rel_id='OtherState_ResponsibleFor_Bridge')
edge_mappers.append(other_state_responsible_for
```

Node label

NBI header

Property name & data type

Edge label

Edge property

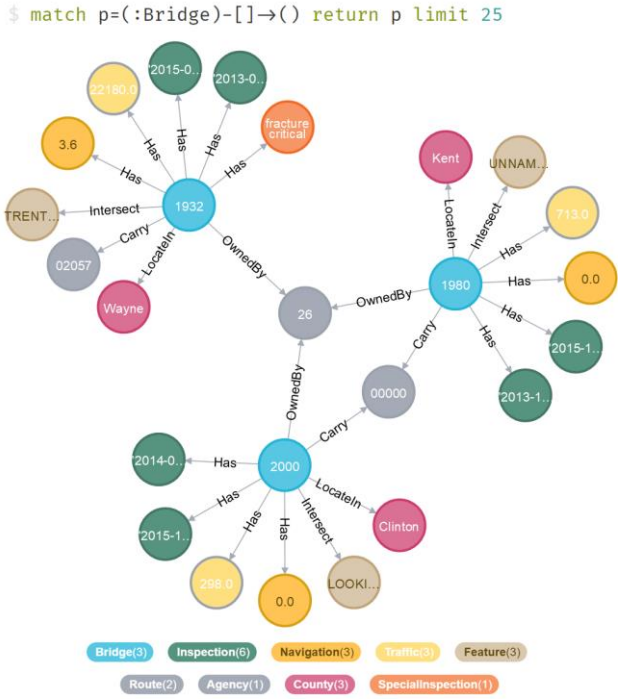
```
def get_latlong(raw_val):
    degree=float(raw_val[:-6])
    minute=float(raw_val[-6:-4])
    second=float(raw_val[-4:])/100.0
    return degree+minute/60.0+second/3600.0

def get_date(raw_val):
    month=int(raw_val[:-2])
    year_str=raw_val[-2:]
    if int(year_str[0])<3:
        year=int('20'+year_str)
    else:
        year=int('19'+year_str)
    return datetime.datetime(year,month,1)
```

```
$ LOAD CSV WITH HEADERS FROM
"file:///Bridge.csv" AS row merge
(n:Bridge{id:row.id}) on match set
n+=row on create set n=row;

$ LOAD CSV WITH HEADERS FROM
"file:///State_To_Bridge.csv" AS row
match (s:State{id:row.src_id}),
(d:Bridge{id:row.dst_id}) merge (s)-
[r:ResponsibleFor]→(d) on match set
r+={percent:row.percent} on create
set r={percent:row.percent};

$ match (a:ConceptA),(b:conceptB) where
a.ID=b.PropB create (a)-[:RelAtoB]→(b)
```

Demonstration

- 2011-2016 MI and 2016 WI bridges from NBI database
- 2015/1/1-2016/12/31 Environmental data of MI and OH

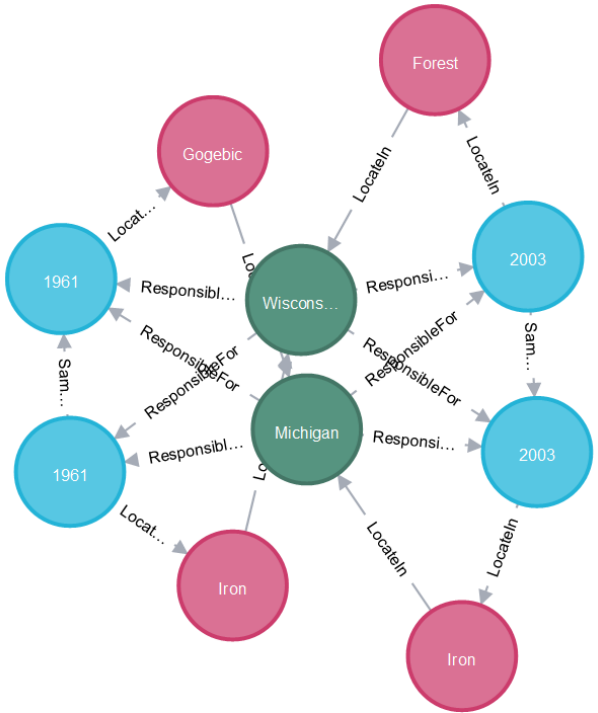
Category	Label	Amount
Node	State	52
Node	County	3, 228
Node	Agency	26
Node	Bridge	25, 410
Node	Route	1, 509
Node	Feature	6, 955
Node	Traffic	25, 747
Node	Navigation	15, 952
Node	Improvement	3, 879
Node	Inspection	30, 737
Node	SpecialInspection	1, 506
Node	Station	179
Node	Observation	75, 345
Relationship	LocateIn	28, 628
Relationship	OwnedBy	25, 411
Relationship	Within	26
Relationship	ResponsibleFor	25, 513
Relationship	Carry	25, 413
Relationship	Intersect	25, 438
Relationship	Has	153, 166
Relationship	SameAs	21



Demonstration

- Scenario 1: query bridges linking two states

```
$ match p=(s:State)←[:LocateIn*..2]-(b:Bridge)-[:SameAs]-
(b2:Bridge)-[:LocateIn*..2]→(s1:State) return p limit 2
```




```
$ match p=(b:Bridge)-[:Has]→
(ins:SpecialInspection{category:'underwater inspection'}),
q=(s:Station)-[:Has]→(o:Observation) where ins.date=o.date
and o.precipitation>0 and exists(o.temperature) return
b.structure_number,ins.date,o.temperature,o.precipitation,di
stance(b.loc_point,s.loc_point)/1000 as distance order by
distance limit 5
```

Bridge No.	Date	Temperature/°C	Precipitation /mm	Distance/km
000000000011328	2015/4/1	1.7	0.3	5.92
B27007400000000	2015/11/1	6.1	3.8	24.05
000000000011884	2015/4/1	-2.2	0.3	27.90

- Scenario 2: query nearby environmental data of bridges

Conclusions

- A framework to integrate open government data for bridge management
  - Labeled graph model based on neo4j
  - Open data from NBI and NOAA are integrated
  - Queries supporting different scenarios
- Future work
  - More open data with high quality are needed
  - Framework integrating both open and private data
  - More explorations and applications
- Scripts available at: https://github.com/smartaec/OpenBridgeGraph

Thank You for Your Attention!

Jia-Rui Lin, Ph.D. Assistant Professor

Department of Civil Engineering, Tsinghua University

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