



AI-MIX: Using Automated Planning to Steer Human Workers Towards Better Crowdsourced Plans

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Talk Outline

- Overview
- Contributions
- Summary



Talk Outline

- **Overview**
- Contributions
- Summary



Crowdsourcing

- Process of obtaining ideas or needed service from a crowd of people.
- Crowd + Outsourcing
 - Take work and outsource it to a crowd of workers.





Example: Gogobot



Who's going:



Linda Byrns

Questions

Exciting things to do in New York City

Art & Design Lovers

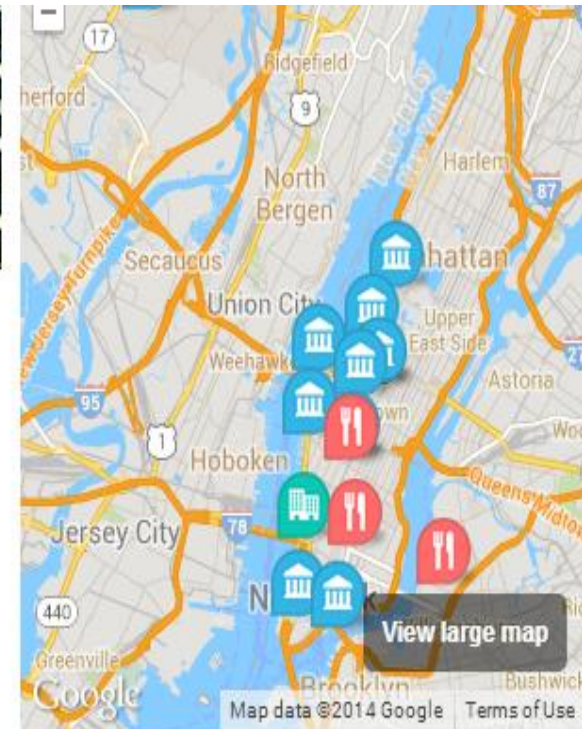
Foodies

Luxury Travelers

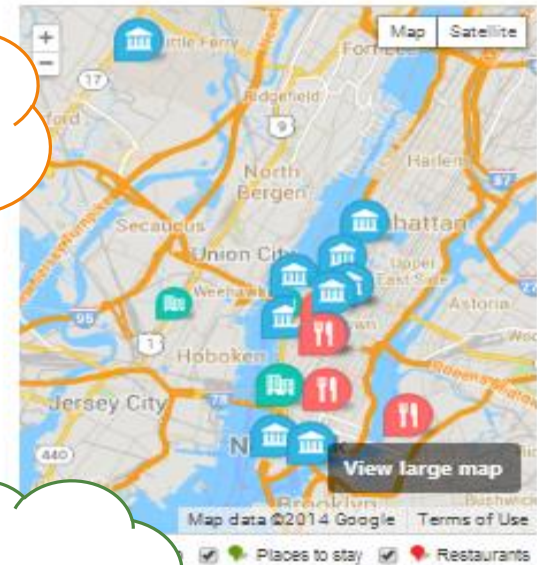
Nightlife Lovers

Trendsters

♥ Like • 17 responses • [Add a Recommendation](#) • about 1 month ago • ↗



Sync your Gogobot Trip Plans with



Top of the Rock



Top of the Rock

West 50th Street, New York, NY 10112



Elvira Vanag recommended Top of the Rock

★★★★★

The views from the Top of The Rock are so majestic of this amazing city. It's better than you can see far-far away. My favorite view

Like · Comment · about 1 month ago · Report

1 person likes this.



Brooklyn Bridge

Brooklyn, NY, USA



James Nelson recommended Brooklyn Bridge

★★★★★

A great way of getting an awesome view of NYC is by very little time and its free. I'd recommend going on a very crowded on the weekend.

Like · Comment · about 1 month ago · Report

Brooklyn Bridge



Times Square

43rd Street and 7th Avenue, New York, NY 10036



James Nelson recommended Times Square

★★★★★

Unless your going to a musical production I really don't see the point. I guess massive advertisements for M&Ms, tgi fridays, and aeropostle stores don't really do it for me. I can think of a lot ... [read more](#)

Like · Comment · about 1 month ago · Report

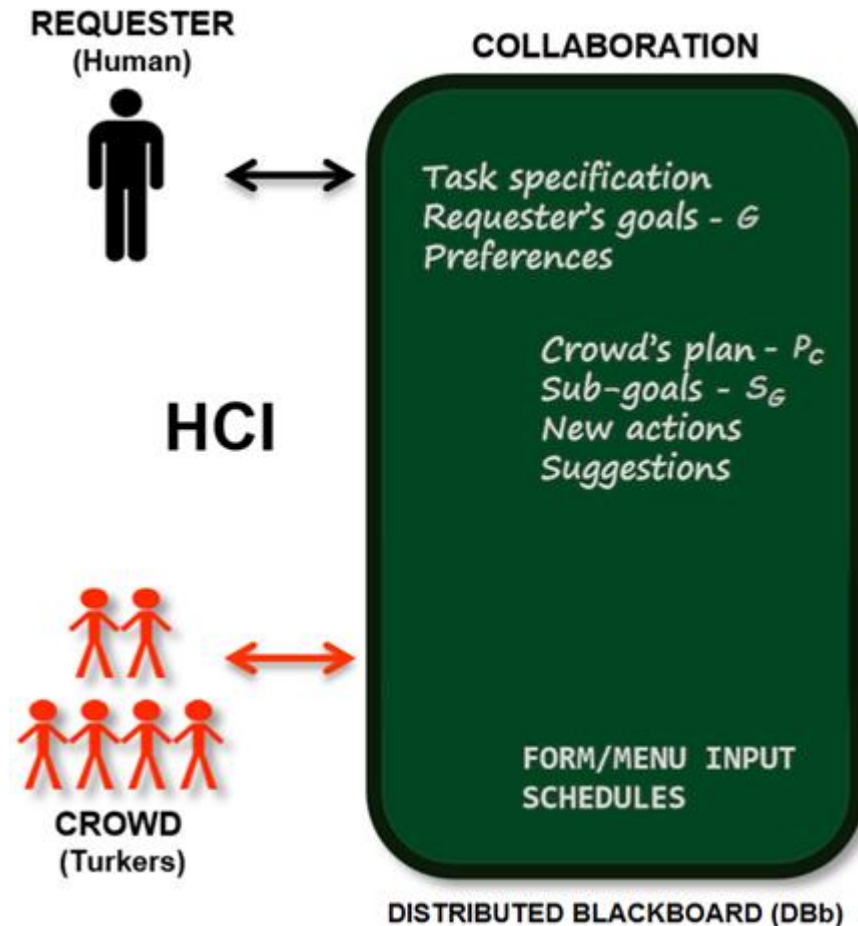


Yogic Traveler recommended Times Square

★★★★★

Times Square

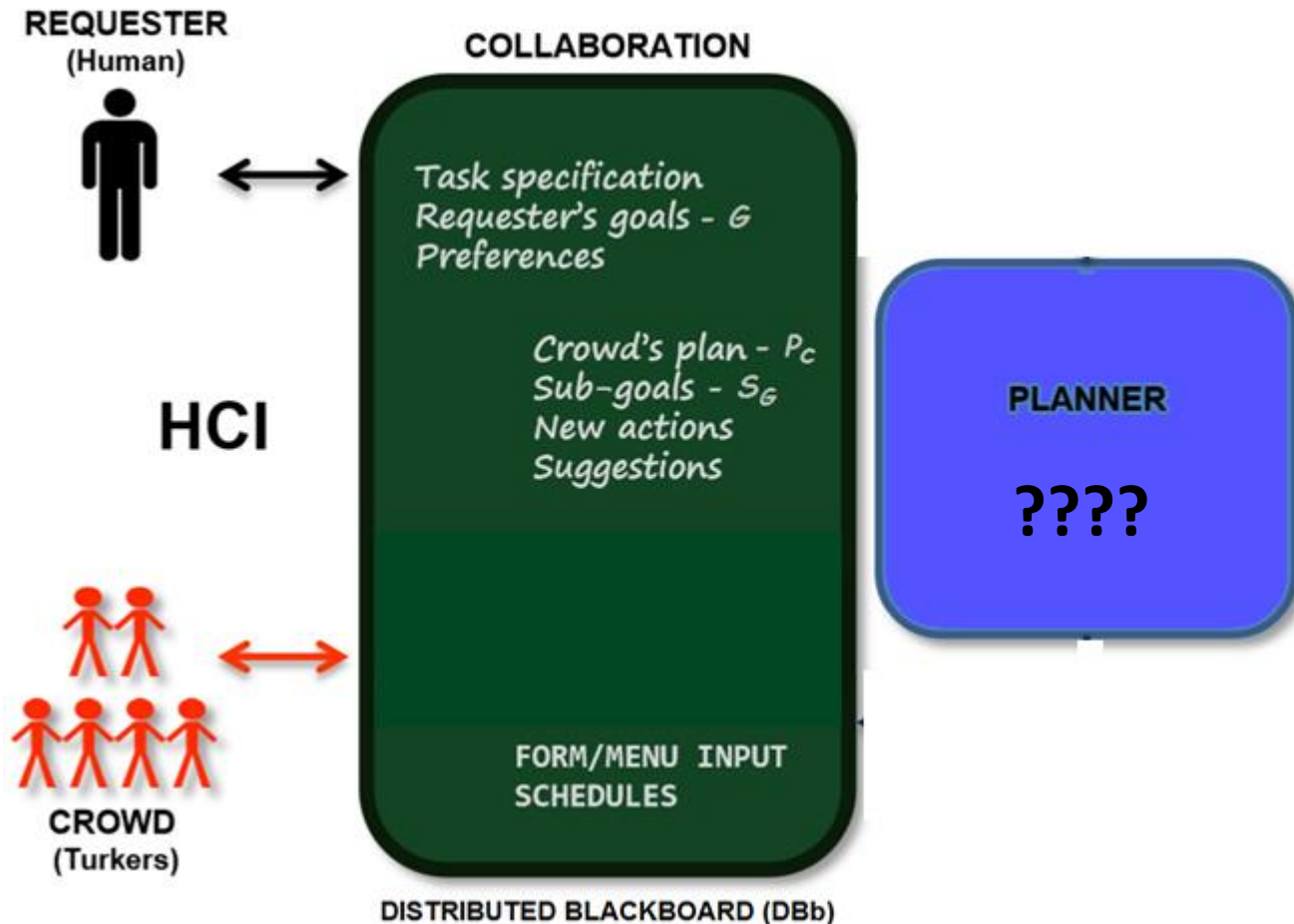
Crowdsourced Planning





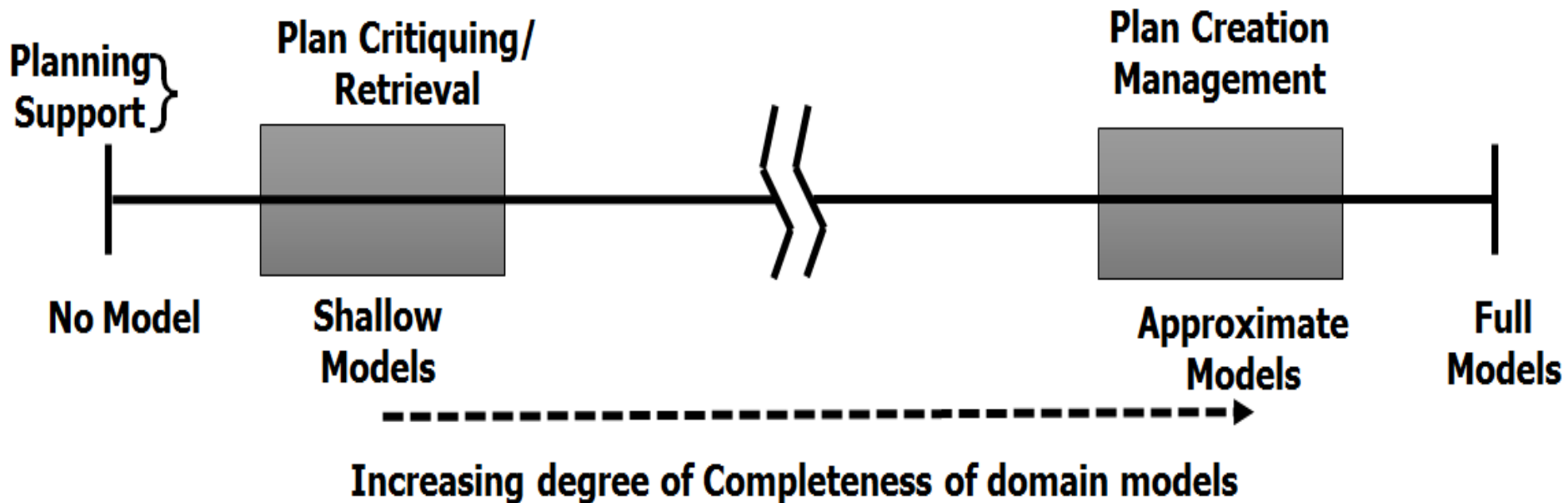
Is it possible to improve the effectiveness by automated planning?

Planner in Architecture





Spectrum of Domain Models & Planning Capabilities



*Source: Kambhampati 2007

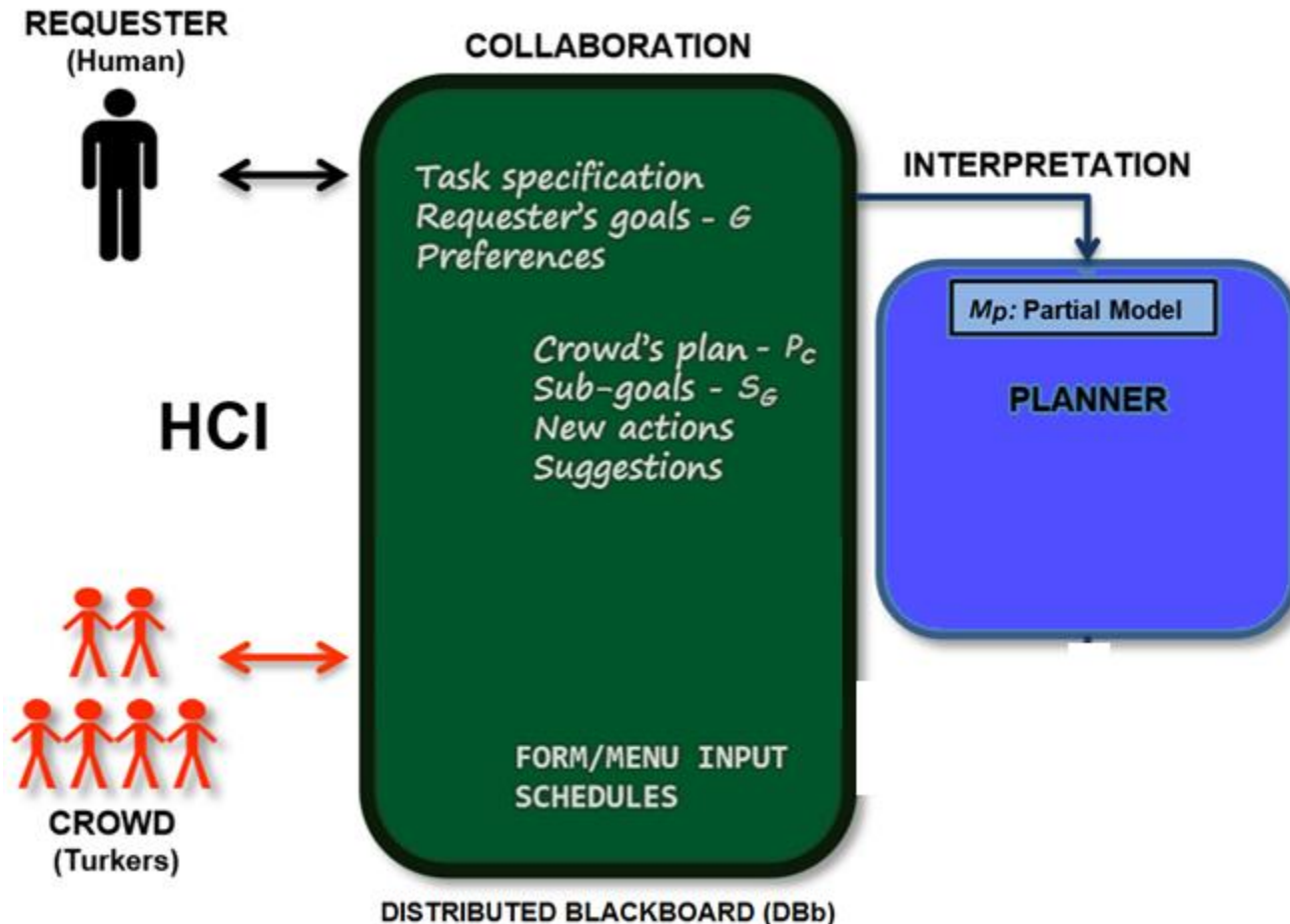


Types of Models (Domain dynamics + Preferences)

- Full model
 - No need for crowd
- No model
 - No need for planner
- Partial model
 - Useful

Model-lite Planning

Challenges: Interpretation





Interpretation

- Understanding the goals and plans from **semi-structured** or **unstructured** text
- Challenging
 - Humans use natural language
 - Automated planners use structured plans and actions



Interpretation of Crowd's Evolving Plan

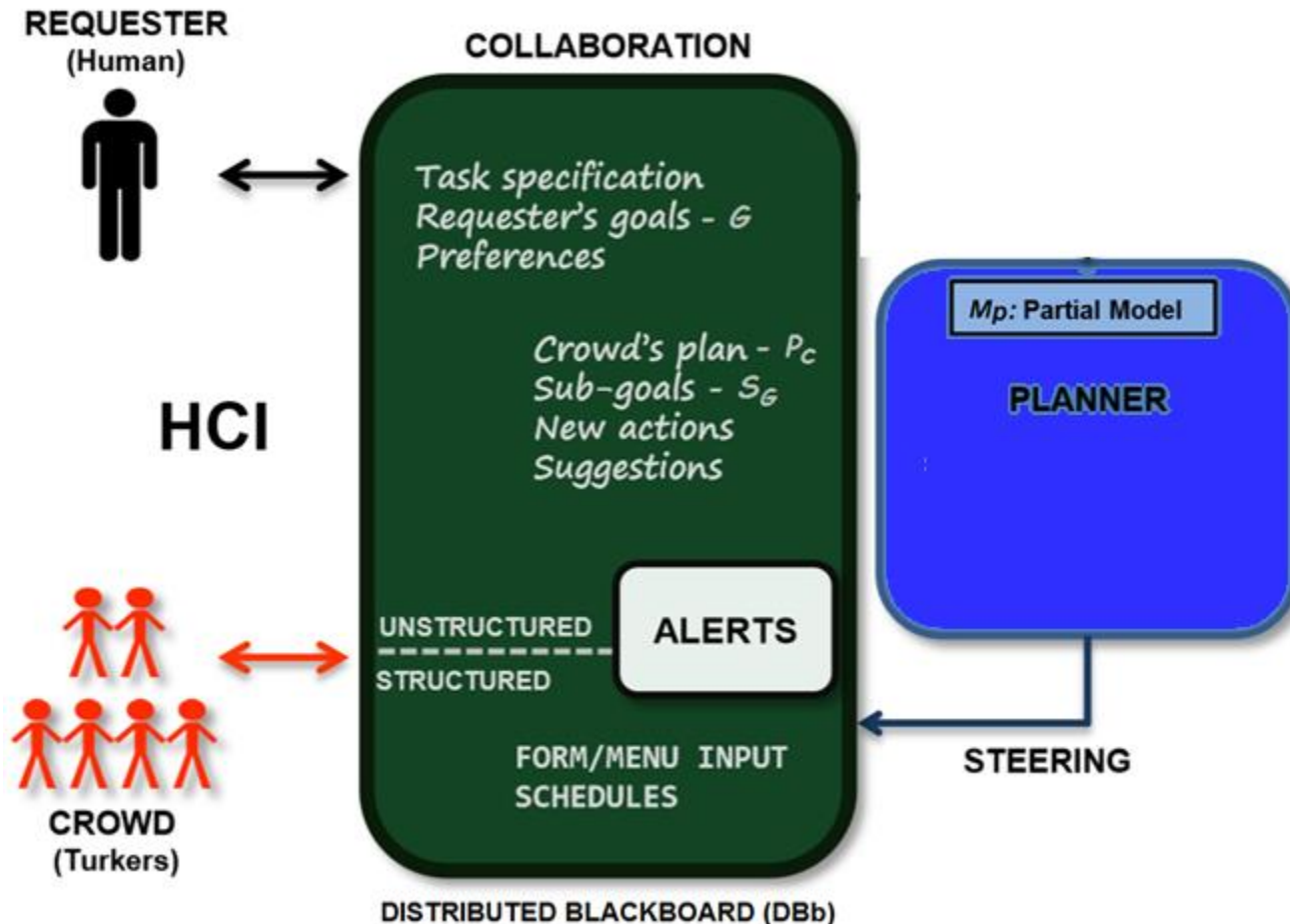
➤ Force Structure

- Reduces flexibility
- In tour planning scenario: Turkers explicitly mention the goals their plans are referring to.

➤ Extract Structure

- Identify the goal a specific plan is looking to achieve
- Plans from textual descriptions rather than actions
- Impedance mismatch

Challenges: Steering





Steering with Incompleteness

- Collaborative plan generation with **incomplete models** of the scenario dynamics and preferences
- Challenging:
 - Cannot expect complete domain model and preferences



Steering the Crowd

- Constraint Checking
 - Quantitative constraints
 - In tour planning scenario: Cost; Duration
- Constructive Critiques
 - Actively help creation and refinement of a plan
 - Suggestions like new plan fragments, new ways of decomposing the current plan or set of goals



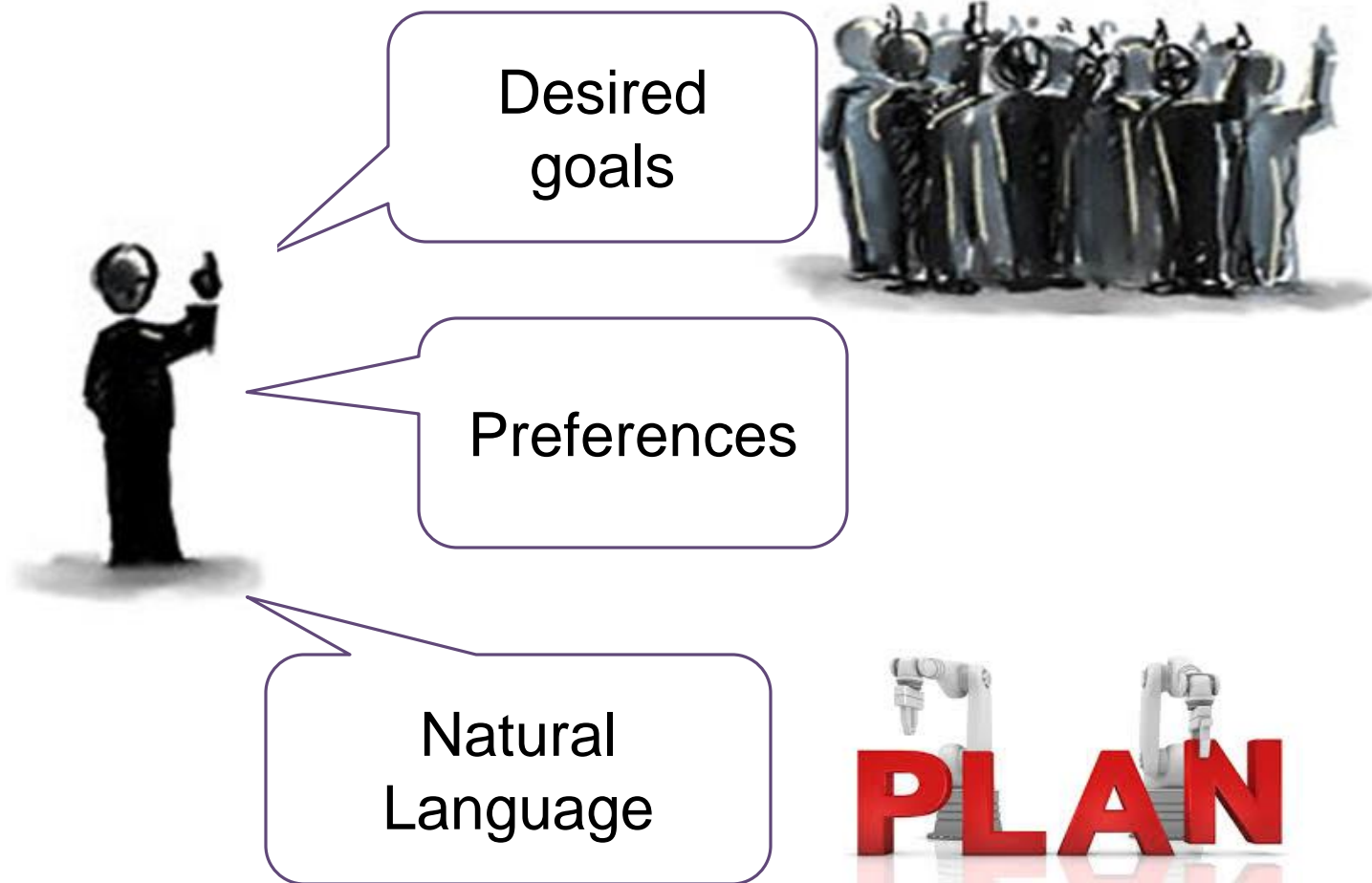
Specifies task at hand



What must I do, eat and see in NYC?
I've been to NYC before, so perhaps
new speakeasies, restaurants and
nightlife recommendations would be
awesome.



Specifies task at hand



Break the task into sub goals



Restaurants



Nightlife
recommendations

Museums

Two white robotic arms are positioned behind the word 'PLAN'. The word 'PLAN' is written in large, bold, red 3D letters. The entire scene is set against a white background with a reflection effect below the letters.

Provide suggestions



Magnolia Bakery: If you haven't tasted a Magnolia cupcake, your NYC visit doesn't count.



Katz's Deli has certainly kept its status as the best deli in New York City serving the Lower East Side. Best pastrami sandwich in town.



Critique Existing Actions



Katz's Deli: Its overhyped and over priced. I did not like it. Other places nearby are much better.



Katz's Deli has certainly kept its status as the best deli in New York City serving the Lower East Side. Best pastrami sandwich in town.



Generate a Plan



- Katz's Deli
- Times Square
- Central Park
- Magnolia Bakery
- Statue of Liberty
- Brooklyn Bridge
- ..
- ..



Steer the Crowd – Sub goals



How to go to
Magnolia
Bakery?



What are the
timings of the
Magnolia
Bakery?



PLAN

Steer the Crowd - Constraints



Duration exceeds
the requested time
of 2 hours.



Cost of expenditure
exceeds the
threshold of \$200.





How does planning help?

- Sub-goal generation
- Constraint checking
- Scheduling



Talk Outline

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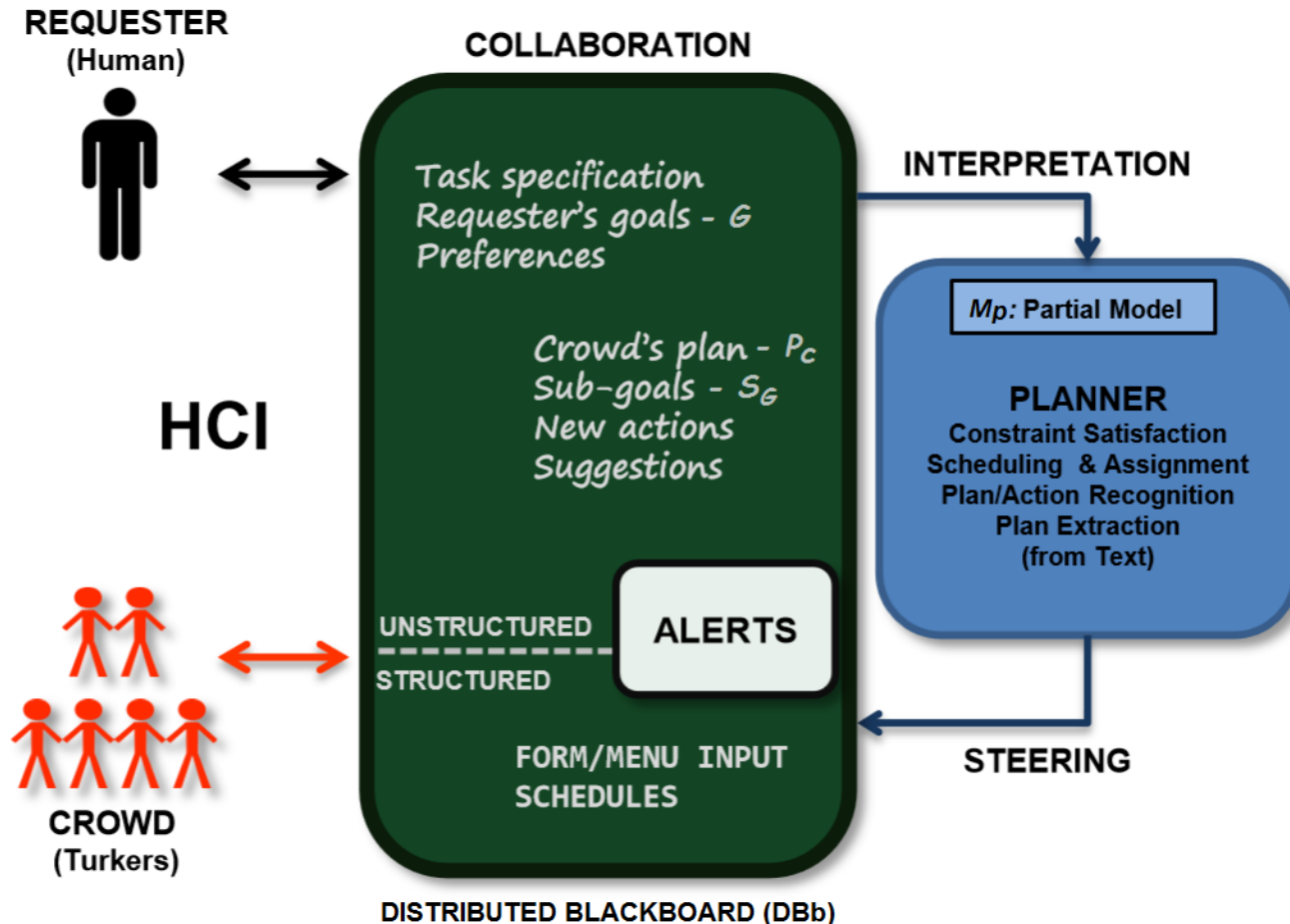


Our Contributions

- **AI-MIX** (**A**utomated **I**mprovement of **M**ixed Initiative **eX**periences)
 - General architecture for human computation systems
 - Roles of an automated planner
 - Addresses the challenges



Generalized Architecture





System Description

- Amazon Mechanical Turk
- Google App Engine
- High-level task description by requester
- Crowd are **turkers**
- **Human Intelligence Task** (HIT) – Individual task that the turkers work on



System Description

- System is similar to state-of-the-art in terms of
 - Inputs it can handle
 - Constraint and quantity checks
- Can parse natural text and reference it against relevant actions



Dinner

Breakfast

Leisure
Activities

Fun places
to see

Find HITS containing

that pay at least \$ 0.00

☐ for which you are qualified☐ require Master Qualification

GO

Timer: 00:00:00 of 10 minutes

Want to work on this HIT?

Want to see other HITS?

Accept HIT

Skip HIT

Total Earned: Unavailable
Total HITS Submitted: 0

Tour to Chicago

Requester: Lydia

Reward: \$0.20 per HIT

HITS Available: 10

Duration: 10 minutes

Qualifications Required: HIT approval rate (%) is greater than 50, Location is US

TourPlanner Instructions

TOUR REQUEST

Going to New York City for only about a month. Where is a must to eat at that I can make reservations at? With so little time, I don't exactly want to spend it waiting for hours to get seated/get food. Also, what are things I should do and see in NYC? Off the beaten path things are preferred! :) I've been to NYC before, so perhaps new speakasies, restaurants and night life recommendations would be great. Thanks so much!

- Have a breakfast at a good local restaurant. #breakfast
- Maybe a museum to visit for around 2 hours maximum. #museum
- Visit some iconic places with rich architecture. #architecture
- Have a quick light lunch. Budget is 30\$. #lunch
- Do some shopping for a maximum of 1 hour.
- Take a walk in some touristy place.
- Have dinner and drinks at a good place.

HOW TO SUBMIT A HIT

You can contribute by

- Suggesting a new activity
- Critiquing an existing activity

The "TO DO Tags" column contains information about the **requester demands**, and **plan critiques** that are yet to be satisfied.

- To add a new activity, click on the "Add new activity" button, fill out the title, description and approximate duration, attach the tag corresponding to this activity and click "Submit".
- To critique an existing activity, click on the "Critique existing activity" button, click on the activity that you want to critique, enter your note, attach an appropriate tag (which will then be added to the list of TO DO Tags) and click "Submit".

For each option you may add more than one suggestion if you wish. Activities with existing suggestions appear in green; otherwise, they are red.

TO DO Tags:

macys_whattobuyin

macys_gettingto

manhattan_gettingto

museum

Add new activity



Major Components

TourPlanner Instructions ▾

TOUR REQUEST

I am taking my teenage daughter to NYC in a few weeks for a mother and daughter getaway. We are looking for places to shop and visit -- my daughter loves fashion and design, so suggestions along those lines are most helpful. We are not big on the touristy places, but instead, finding amazing dessert is a must! :) I have also always wanted to see a Broadway show, so suggestions for shows to see would be helpful. Thanks so much! In planning our trip, please pay attention to our wishes below:

- have exactly 1 simple lunch (not fast-food) activity. #lunch
- have exactly 1 Italian for dinner activity. #italian_dinner
- have exactly 1 Broadway shows activity. #broadway_show
- have at least 2 amazing desserts activities. #dessert
- spend at least 3 hours on fashion or design. #fashion #design

TO DO Tags:

broadwayshow_showing

Where is story maguire novel showing

fashion_what_to_buy_in

design

fashion

broadwayshow

Existing Activities:

Italian dinner at Marea #italiandinner

Fashion: Go to Fashion Place (1 hour) #fashion

Fashion: FIT tour #fashion(2 hours)(0.0 \$)

Wicked: The untold musical story of The Wizard of Oz's Wicked Witch of the West and Glinda the Good... before Dorothy dropped in. Based on the imaginative Gregory Maguire novel, Wicked through the unseen side of Oz, sharing a tale of love. #broadwayshow(3 hours)(76.25 \$)

Peanut Butter and Co.: Lunch #lunch(20.0 \$)

Spontaneous Serendipity #dessert(1 hours)(0.0 \$)

Add new activity »

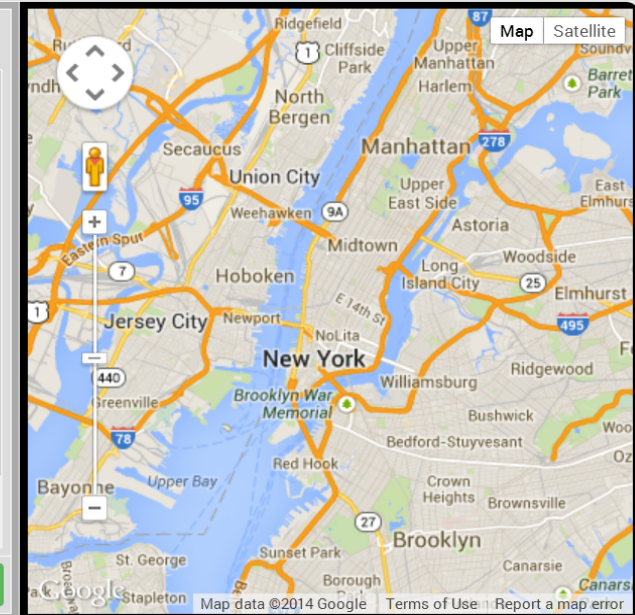
Critique existing activity »

4 Planner Critique

1 Requester Spec

2 Turker Inputs

3 Turker Response



TOUR REQUEST

Going to New York City for only a day in about a month. Where is a must to eat at that I can make reservations at? With so little time, I don't exactly want to spend it waiting for hours to get seated/get food. Also, what are the must things I should do and see in NYC? Off the beaten path things are preferred! :) I've been to NYC before, so perhaps new speaskasies, restaurants and night life recommendations would be awesome.

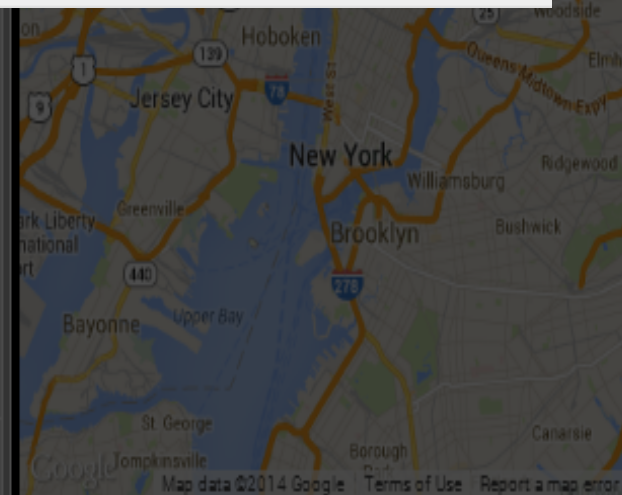
TOUR REQUEST

Going to New York City for only a day in about a month. Where is a must to eat at that I can make reservations at? With so little time, I don't exactly want to spend it waiting for hours to get seated/get food. Also, what are the must things I should do and see in NYC? Off the beaten path things are preferred! :) I've been to NYC before, so perhaps new speaskasies, restaurants and night life recommendations would be awesome.

- Have a breakfast at a good local restaurant. #breakfast
- Maybe a museum to visit for around 2 hours maximum. #museum
- Visit some iconic places with rich architecture. #architecture
- Have a quick light lunch. Budget is 30\$. #lunch
- Do some shopping for a maximum of 2 hours. I can spend upto 300\$ on shopping. #shop
- Take a walk in some touristy place. #walk #touristy
- Have dinner and drinks at a good local restaurant. I want to spend a maximum time of 3 hours here. #dinner

#shop

Manhattan: Walk near the NY public library and the charging bull (14:00 hrs) #walk



Add new activity ▸

Critique existing activity ▸

TOUR REQUEST

Going to New York City for only a day in about a month. Where is a must to eat at that I can make reservations at? With so little time, I don't exactly want to spend it waiting for hours to get seated/get food. Also, what are the must things I should do and see in NYC? Off the beaten path things are preferred! :) I've been to NYC before, so perhaps new speaskasies, restaurants and night life recommendations would be awesome.

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- Visit some iconic places with rich architecture. #architecture
- Have a quick light lunch. Budget is 30\$. #lunch
- Do some shopping for a maximum of 2 hours. I can spend up to 2 hours.
- Take a walk in some touristy place. #walk #touristy
- Have dinner and drinks at a good local restaurant. I want to

TO DO Tags:

macys_whattobuyin

macys_gettingto

manhattan_gettingto

museum

lunch

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macys_whattobuyin

macys_gettingto

manhattan_gettingto

museum

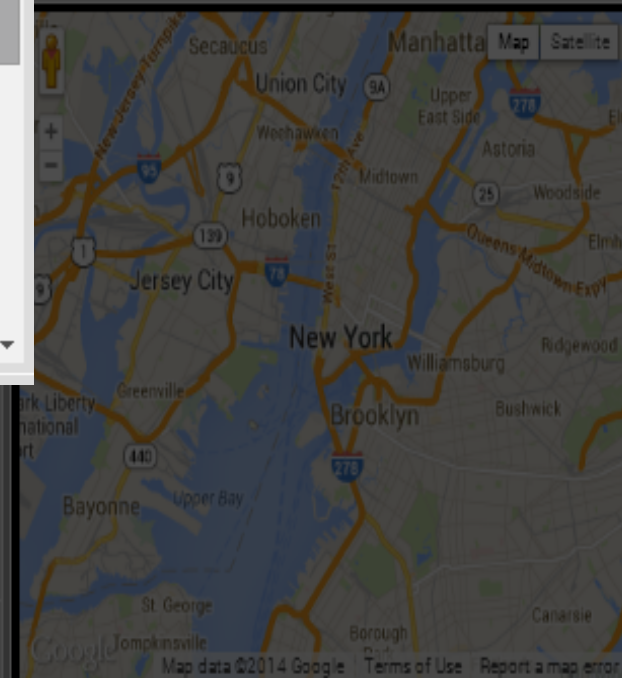
Existing Activities

Macys: Awesome shopping
#shop

Manhattan: Walking tour
(hrs) #walk

Add new activity ▸

Critique existing activity ▸



TOUR REQUEST

Going to New York City for only a day in about a month. Where is a must to eat at that I can make reservations at? With so little time, I don't exactly want to spend it waiting for hours to get seated/get food. Also, what are the must things I should do and see in NYC? Off the beaten path things are preferred! :) I've been to NYC before, so perhaps new speaskasies, restaurants and night life recommendations would be awesome.

- Have a breakfast at a good local restaurant. #breakfast
- Maybe a museum to visit for around 2 hours maximum. #museum
- Visit some iconic places with rich architecture. #architecture
- Have a quick light lunch. Budget is 30\$. #lunch
- Do some shopping for a maximum of 2 hours. I can't wait to see the city.
- Take a walk in some touristy place. #walk #tourist
- Have dinner and drinks at a good local restaurant.

TO DO Tags:

macys_whattobuyin

macys_gettingto

manhattan_gettingto

museum

Add new activity »

Critique existing activity »

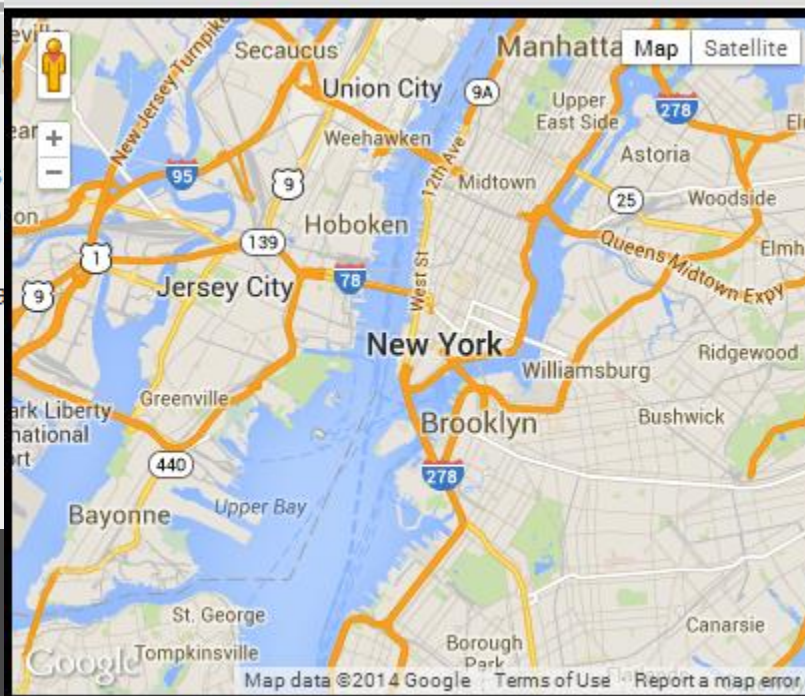
Existing

Macys

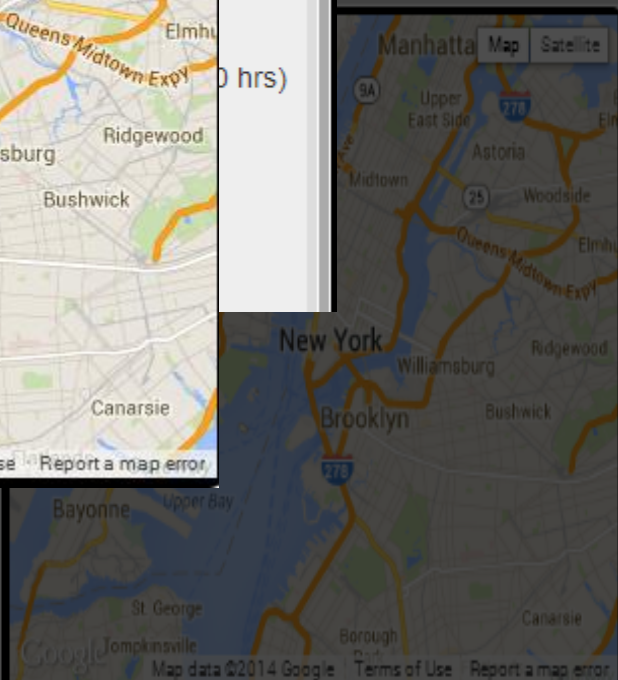
#shop

Manha

#walk



2 hrs)





Interface for Turkers

TO DO Tags:

- dinner
- shop
- lunch
- historic2

1 Add Plan Action

Activity Title	Description	Duration	Cost	Tag
Dinner	Dinner at the Source	▼ hours 80	\$	dinner ▼ -add-
		▼ hours	\$	▼ -add- -remove-

- dinner
- shop
- lunch
- historic2
- historic1

Existing Activities

Museum: Visit the Lincoln memorial (1 hour) #historic1

Dinner: Dinner at Source (100 \$) #dinner

Submit Go Back

Click 'add' to enter new

Your Critiques

Parent Tag: #dinner Child Tag: #price

Note/Critique: Dinner at Source is unlikely to be below \$100 -remove-

2 Critique Action



Activity Addition

- Turker can provide any number of activity suggestions
- Unstructured and structured text are handled
- To-do tag
- After submission:
 - constraint violations
 - critiques by planner

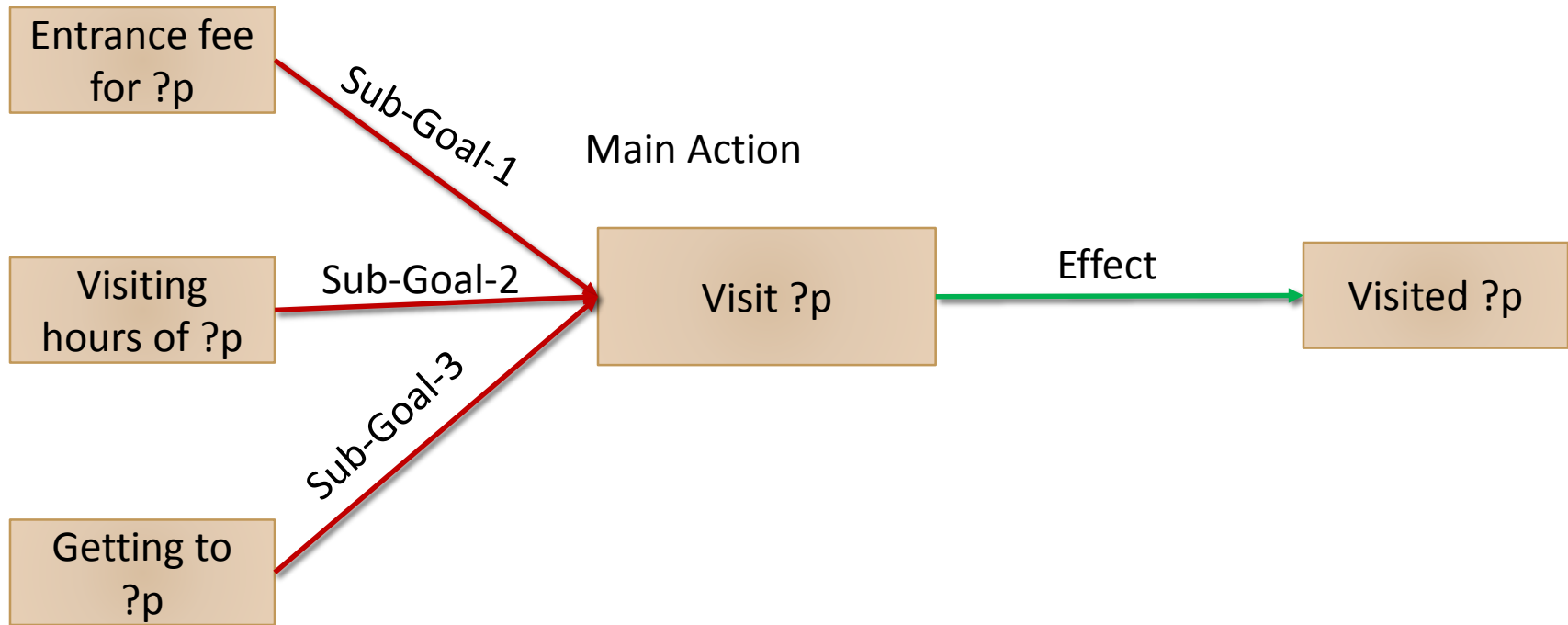


Sub-goal Generation

- Planner uses PDDL action model M_p
- Examples include:
 - visit, lunch, shop, etc
- Generic preconditions
- Unsatisfied sub-goals are alerts



Example of “visit” action description





Input Validation

- Constraints on quantitative values of states given by requester
- If violated, added to to-do stream
- Future turkers resolve the violations



Adding Turker Critiques

- Turkers can critique the existing actions
- New tag will be attached to the new critique
- Future turkers resolve these critiques

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TO DO Tags:

macys_whattobuyin

macys_gettingto

manhattan_gettingto

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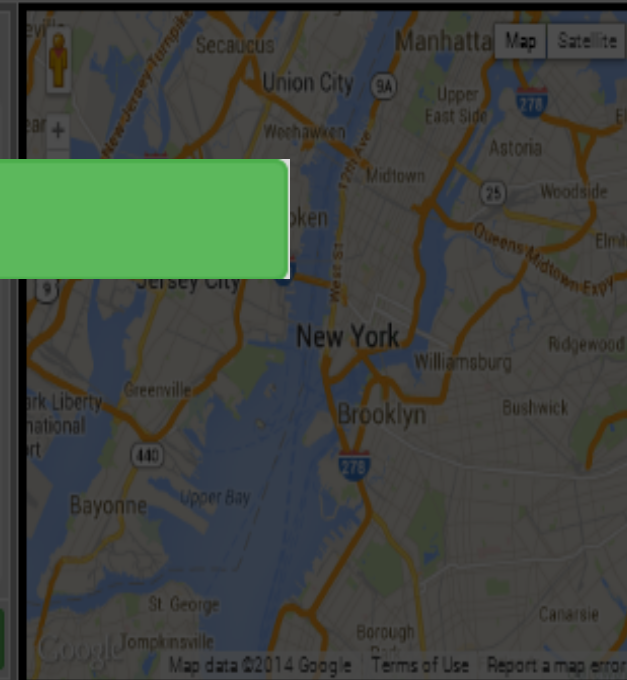
Add new activity »

Existing Activities:

Manhattan: Walk near the NY public library and the charging bull (14:00 hrs) #walk

Critique existing activity »

Add new activity »





Add a New Suggestion

TO DO Tags:

museum

lunch

dinner

architecture

Add new activity »

Tag	Location	Comments/Description	Time	Duration	Cost
<p>*Select appropriate option from the dropdown list. Click the yellow option to type in your own tag.</p> <p>*All times must be in 24-hr format.</p> <div><div>walk</div><div>Manhattan</div><div>Walk near the NY public library and the ch</div><div>14:00</div><div></div><div>hours</div><div></div><div>\$</div><div>-add-</div></div>					

Click 'add' to enter new suggestions or 'remove' to delete one of your entries. Duration and cost is optional. Hit Submit after completing all your suggestions.

Submit

Go Back

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- Have dinner and drinks at a good local restaurant. I want to spend a maximum time of 3 hours here. #dinner

Manhattan_gettingto

TO DO T

s:

manhattan_gettingto

Getting to manhattan

museum

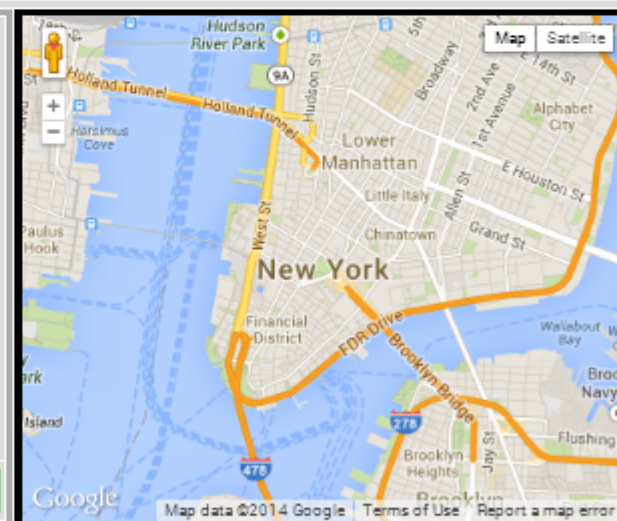
lunch

Add new activity »

Macys: Awesome clothes and the head quarters (10:00 hrs) (1 hours)
#shop

Manhattan: Walk near the NY public library and the charging bull (14:00 hrs) #walk

Critique existing activity »



TOUR REQUEST

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TO DO Tags:

macys_whattobuyin

macys_gettingto

manhattan_gettingto

museum

Add new activity »

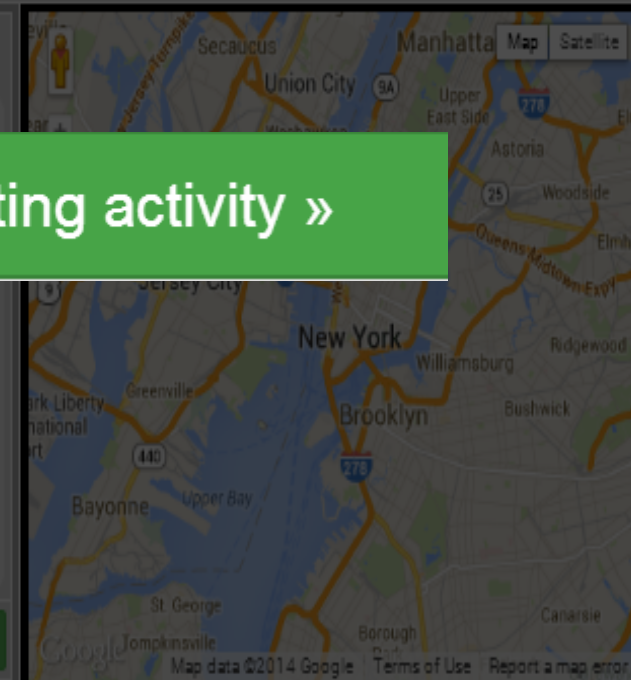
Existing Activities:

Macys: Awesome clothes
#shop

Manhattan: Walk near the NY public library and the charging bull (14:00 hrs) #walk

Critique existing activity »

Critique existing activity »



Add a Critique



TourPlanner Instructions ▾

TOUR REQUEST

Going to New York City for only a day in about a month. Where is a must to eat at that I can make reservations at? With so little time, I don't exactly want to spend it waiting for hours to get seated/get food. Also, what are the must things I should do and see in NYC? Off the beaten path things are preferred! :) I've been to NYC before, so perhaps new speakasies, restaurants and night life recommendations would be awesome.

- Have a breakfast at a good local restaurant. #breakfast

Existing Activities

Select to provide orderings
among activities

Macys: Awesome clothes and
the head quarters (10:00 hrs) (1
hours) #shop

Manhattan: Walk near the NY
public library and the charging
bull (14:00 hrs) #walk

Your Critiques

*Select your options from the column on the left.

*All times must be in 24-hr format.



Click on the existing activities to enter your critique. All fields are required. Hit Submit when you are finished.

Submit

Go Back

Submit your hit

Add a Critique



TourPlanner Instructions ▾

TOUR REQUEST

Going to New York City for only a day in about a month. Where is a must to eat at that I can make reservations at? With so little time, I don't exactly want to spend it waiting for hours to get seated/get food. Also, what are the must things I should do and see in NYC? Off the beaten path things are preferred! :) I've been to NYC before, so perhaps new speakasies, restaurants and night life recommendations would be awesome.

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Existing Activities

Select to provide orderings among activities

Macys: Awesome clothes and the head quarters (10:00 hrs) (1 hours) #shop

Manhattan: Walk near the NY public library and the charging bull (14:00 hrs) #walk

Your Critiques

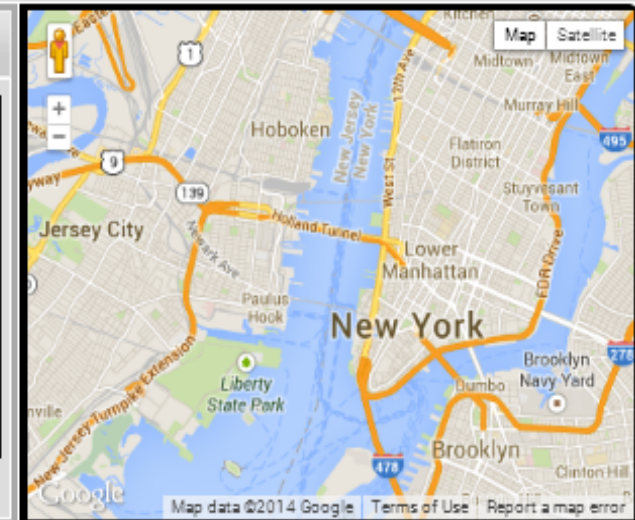
Tag: #shop Location: Macys

Description: Awesome clothes and the head quarters Time: 10:00

Duration: 1 Cost: -remove-

*Select your options from the column on the left.

*All times must be in 24-hr format.



Click on the existing activities to enter your critiques. All form fields are required. Hit Submit when you are finished.

Submit Go Back

Add an Order



TourPlanner Instructions ▾

TOUR REQUEST

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- Have a breakfast at a good local restaurant. #breakfast

Existing Activities

Select to provide orderings among activities

Macys: Awesome clothes and the head quarters (10:00 hrs) (1 hours) #shop

Manhattan: Walk near the NY public library and the charging bull (14:00 hrs) #walk

Your Critiques

lunch ▾

before
after

touristy ▾

-remove-

*Select your option from the column on the left.

*All times must be in 24-hr format.



Click on the existing activities to enter your critiques. All form fields are required. Hit Submit when you are finished.

Submit

Go Back



Which Planner to Use?

- Allows not only dynamics but also kinds of declarative constraints
- Ability to take various constraint specifications
- Answer Set Programming



Generating Plans

- Knowledge base that models common sense information
- Knowledge base:
 - Object declarations
 - State declarations
 - Effect and preconditions of actions
 - Domain independent axioms
- Answer Set Programming to put together the suggested activities to a schedule



Travel Planning Domain

- Temporal constraints on actions
 - Typical time ranges for breakfast, lunch, dinner
- Existential constraints
 - Atleast one instance of each requested activity
- Uniqueness
 - Same activity occurring over multiple time points should occur at same place
- Contiguity
 - Same activity occurring at two points imply it is also occurring in between
- No concurrency
 - All actions are assumed to be non-concurrent



Example – New Activity

Tag	Location	Comments/Description	Time	Duration	Cost
<input type="text" value="museum"/>	<input type="text" value="Asu Amuseum"/>	<input type="text" value="You must check this out"/>	<input type="text" value="hh:mm"/>	<input type="text" value="3"/> hours	<input type="text" value="\$"/> <input type="button" value="-add-"/>



```
actions(lunch;museum;walk;breakfast;dinner).  
poi_museum(asuamuseum).
```



```
{activity(museum,T1,MU1) : time(T1)}3.  
?[T, TT, TTT, MU1]:(activity(museum,T,MU1) & activity(museum,TT,MU1) & activity(museum,TTT,MU1) & T!=TT & TT!=TTT & TTT!=T).
```

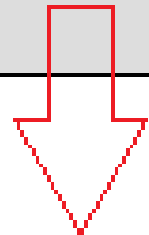
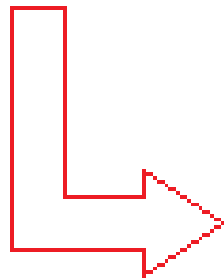


Example – New Critique

Tag: **Location:**

Description: **Time:**

Duration: **Cost:**



```
<- activity(museum,T,MU1) & T<15.  
<- activity(museum,T,MU1) & T>17.
```



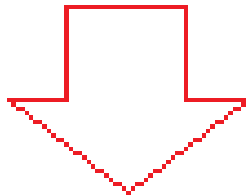
Example – New Critique

museum ▼

after ▼

lunch ▼

-remove-



```
<- activity(museum,T,M) & activity(lunch,TT,L) & T<TT.
```



Generated Plan

- Activity(breakfast,8,Café Orlin)
- Activity(fashion,10,Garment District)
- Activity(fashion,11,Garment District)
- Activity(lunch,12,Sapporo)
- Activity(lunch,13,Sapporo)
- Activity(dinner,18,Ai Fiori)
- Activity(dinner,19,Ai Fiori)
- Activity(broadway,20,musical)
- Activity(broadway,21,musical)



Experimental Setup

- Human Intelligence Tasks (HITs) were available only to the turkers
 - from United States
 - approval rate $> 50\%$
 - paid 20 cents for each HIT
- Tour planning for six major US cities:
Washington DC; Chicago; New York; San Francisco; Los Angeles; Las Vegas
- 150 turkers



Experimental Conditions

➤ No-Auto

- No automated critiques
- Suggestions in free text format

➤ Auto-Sched

- Constraint violation checks in terms of cost and duration

➤ Auto-Sched + Subgoal

- In addition to C2, system processed unstructured text
- Generate alerts for missing preconditions



Tour Plan Quality

Auto-Sched

Show: Go to TKTS half ticket discount booth. You have to stand in line early but it's an authentic nyc experience #show(3 hours)(200.0 \$)
Show: Go to show #show(3 hours)(200.0 \$)
Show: ABSOLUTELY CANNOT go wrong with Phantom of the Opera #show(3 hours)(200.0 \$)
Lunch: Alice's Tea Cup #lunch(20.0 \$)
Design: Walk around the Garment District (go into shops) just south of Times Square. They often print their own fabrics. #design(2 hours)(0.0 \$)
Dessert: Serendipity #dessert(1 hours)(10.0 \$)

Auto-Sched + Subgoal

piccolo angelo: Italian in the Village - real deal #italiandinner(2 hours)(60.0 \$)
Lombardi's Pizza: #italian_dinner #italiandinner_todo1
Ice Cream: <http://www.chinatownicecreamfactory.com/> #italiandin-ner_todo0
#lunch: Mangia Organics #lunch_todo0
watch Wicked (musical): Do watch Wicked the musical. It's a fantastic show and one of the most popular on Broadway right now! #broadwayshow(3 hours)(150.0 \$)
watch How to Succeed in Business: Also a great show, a little less grand than Wicked. #broadwayshow(3 hours)(150.0 \$)
Activity Steamer: #lunch #lunch_todo1
Paradis To-Go: Turkey & Gruyere is pretty delicious. The menu is simple, affordable, but certainly worth the time #lunch(1 hours)(10.0 \$)
cupcakes!: Magnolia Bakery on Bleecker in the Village #dessert(1 hours)(10.0 \$)



Tour Plan Quality

Lunch: Alice's tea cup
#lunch (20\$)

Auto-Sched

Paradis-to-go: Menu is simple,
affordable, but certainly worth
the time #lunch (1 hour) (10 \$)

Steamer: #lunch
#lunch_whattoeat

Auto-Sched + Subgoal



Role played by the Planner Module

➤ Number of responses

C2	C3
28	39

➤ Critique generation

Flaws by	Suggested	Addressed
Human	8	0
Planner	45	7



Talk Outline

- Overview
- Motivation
- Contributions
- **Summary**



Summary

- Automated planning in crowdsourced planning
 - Interaction between Requester, Crowd, Planner
- Interpretation and steering
 - Unstructured text
 - Impedance mismatch
 - Incomplete domain models and preferences
- For effective plan generation
 - Sub-goal generation
 - Constraint verification
 - Constructive critiquing
- Scheduling the overall plan using Answer Set Programming
- Preliminary empirical results over tour planning domain
 - Effective steering in terms of – Number of turker responses; critiques addressed; detailed suggestions