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

Going to New York City
New York City, New York State

Who's going:
Linda Byrns

Questions
Exciting things to do in New York City

Like · 17 responses · Add a Recommendation · about 1 month ago · 

Sync your Gogobot Trip Plans with

YOCHAN LAB, ARIZONA STATE UNIVERSITY
Top of the Rock

Brooklyn Bridge

Times Square
Crowdsourced Planning

**Diagram:**
- **REQUESTER** (Human)
- **COLLABORATION**
  - Task specification
  - Requester's goals - G
  - Preferences
  - Crowd's plan - P_c
  - Sub-goals - S_g
  - New actions
  - Suggestions
  - FORM/MENU INPUT
  - SCHEDULES
- **CROWD** (Turkers)
- **HCI**
- **DISTRIBUTED BLACKBOARD (DBb)**
Is it possible to improve the effectiveness by automated planning?
Planner in Architecture

REQUESTER
(Human)

COLLABORATION

Task specification
Requester’s goals - G Preferences

Crowd’s plan - P_c
Sub-goals - S_g
New actions
Suggestions

FORM/MENU INPUT
SCHEDULES

DISTRIBUTED BLACKBOARD (DBb)

PLANNER

CROWD
(Turkers)

HCI
Spectrum of Domain Models & Planning Capabilities

Planning Support

No Model | Shallow Models | Plan Critiquing/Retrieval | Approximate Models | Plan Creation Management | Full Models

Increasing degree of Completeness of domain models

*Source: Kambhampati 2007
Types of Models (Domain dynamics + Preferences)

- Full model
  - No need for crowd

- No model
  - No need for planner

- Partial model
  - Useful
Challenges: Interpretation

- **REQUESTER** (Human)
- **COLLABORATION**
  - Task specification
  - Requester’s goals - $G$
  - Preferences
- **INTERPRETATION**
  - Crowd’s plan - $P_c$
  - Sub-goals - $S_g$
  - New actions
  - Suggestions
- **HCI**
- **CROWD** (Turkers)
- **FORM/MENU INPUT SCHEDULES**
- **DISTRIBUTED BLACKBOARD (DBb)**
- **PLANNER**
  - $M_p$: Partial Model

YOCHAN LAB, ARIZONA STATE UNIVERSITY
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

Desired goals

Preferences

Natural Language
Break the task into sub goals

- Restaurants
- Nightlife recommendations
- Museums
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.
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.

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

- Overview
- Contributions
- Summary
Our Contributions

- **AI-MIX** (Automated Improvement of Mixed Initiative eXperiences)
  - 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
Tour to Chicago

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

Reward: $0.20 per HIT
HITS Available: 10
Duration: 10 minutes

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 requestor 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.
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
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 speakesies, 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

macys_gettingto

museum

Add new activity »

Critique existing activity »
TOUR REQUEST

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- Visit some iconic places with rich architecture. #architecture
- Have a quick light lunch. Budget is 30$. #lunch
- Do some shopping for a maximum of 2 hours. I can spend up to 100$. #shop
- Take a walk in some touristy place. #walk #touristy
- Have dinner and drinks at a good local restaurant. I want to try a new one this time. #dinner

TO DO Tags:

- macys_whattobuyin
- macys_gettingto
- manhattan_gettingto
- museum
- lunch
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 speakesies, restaurants and night life recommendations would be awesome.

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- Take a walk in some touristy place. #walk #touristy
- 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 »
Interface for Turkers

1. Add Plan Action
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

Entrance fee for ?p
Getting to ?p
Visiting hours of ?p

Sub-Goal-1
Sub-Goal-2
Sub-Goal-3

Visit ?p

Main Action

Visited ?p

Effect
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
TOUR REQUEST

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TO DO Tags:

- macys_whatstobuyin
- macys_gettingto
- manhattan_gettingto
- museum

Existing Activities:

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

Add new activity »

Critique existing activity »
Add a New Suggestion

<table>
<thead>
<tr>
<th>Tag</th>
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<th>Comments/Description</th>
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</tr>
</thead>
<tbody>
<tr>
<td>walk</td>
<td>Manhattan</td>
<td>Walk near the NY public library and the ch</td>
<td>14:00</td>
<td>▼ hours</td>
<td></td>
</tr>
</tbody>
</table>

Select appropriate option from the dropdown list. Click the yellow option to type in your own tag.

*All times must be in 24-hr format.

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.
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 speakeasies, restaurants and night life recommendations would be awesome.
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- 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

TO DO:
- Manhattan_gettingto
- manhattan_gettingto
- Getting to manhattan
- museum
- lunch

Manhattan: Walk near the NY public library and the charging bull (14:00 hrs) #walk
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 speaskies, restaurants and night life recommendations would be awesome.

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TO DO Tags:

macys_whattobuyin
macys_gettingto
manhattan_gettingto
museum

Existing Activities:

Macys: Awesome clothes. #shop
Manhattan: Walk near the NY public library and the charging bull (14.00 hrs) #walk

Critique existing activity »
Add a Critique

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

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<th>Your Critiques</th>
</tr>
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<tbody>
<tr>
<td><strong>Select to provide orderings among activities</strong></td>
<td></td>
</tr>
<tr>
<td>Macys: Awesome clothes and the head quarters (10:00 hrs) (1 hours) #shop</td>
<td></td>
</tr>
<tr>
<td>Manhattan: Walk near the NY public library and the charging bull (14:00 hrs) #walk</td>
<td></td>
</tr>
</tbody>
</table>

*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 fields are required. Hit Submit when you are finished.

Submit Go Back

Submit your hit
Add a Critique

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 speakeasies, restaurants and nightlife recommendations would be awesome.
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<td></td>
</tr>
<tr>
<td>Manhattan: Walk near the NY public library and the charging bull (14:00 hrs) #walk</td>
<td>Description: Awesome clothes and the head quarter</td>
</tr>
<tr>
<td></td>
<td>Time: 10:00</td>
</tr>
<tr>
<td></td>
<td>Duration: 1 Cost: -remove-</td>
</tr>
</tbody>
</table>

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

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 speakeasies, 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

lunch ▼ ▼ touristy ▼ ▼ -remove-

*Select your option

before ▼ after

*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

<table>
<thead>
<tr>
<th>Tag</th>
<th>Location</th>
<th>Comments/Description</th>
<th>Time</th>
<th>Duration</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>museum</td>
<td>Asu Amuseum</td>
<td>You must check this out</td>
<td></td>
<td>3 hours</td>
<td>$0</td>
</tr>
</tbody>
</table>

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

\[
\{\text{activity}(\text{museum}, T_1, MU_1) : \text{time}(T_1)\}^3. \\
?[T, TT, TTT, MU_1]: (\text{activity}(\text{museum}, T, MU_1) \& \text{activity}(\text{museum}, TT, MU_1) \& \text{activity}(\text{museum}, TTT, MU_1) \& T=TT \& TT=TTT \& TTT=T).
\]
Example – New Critique

Tag:  #museum  Location:  ASU AMUSEUM

Description:  You must check this out  Time:  15:00

Duration:  3 hours  Cost:  -remove-

<- activity(\text{museum},T,\text{MU1}) \& T<15.
<- activity(\text{museum},T,\text{MU1}) \& T>17.
Example – New Critique

\[\text{activity}(\text{museum}, T, M) \land \text{activity}(\text{lunch}, TT, L) \land T < TT.\]
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

Auto-Sched + Subgoal

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 $)

piccolo angolo: Italian in the Village - real deal #italiandinner(2 hours)(60.0 $)
Lombard’s Pizza: #italian_dinner #italiandinner_todo1
Ice Cream: http://www.chinatownicecreamfactory.com/ #italiandinner_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

<table>
<thead>
<tr>
<th>Lunch: Alice’s tea cup</th>
</tr>
</thead>
<tbody>
<tr>
<td>#lunch (20$)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Paradis-to-go: Menu is simple, affordable, but certainly worth the time</th>
<th>#lunch (1 hour) (10 $)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Steamer: #lunch</th>
</tr>
</thead>
<tbody>
<tr>
<td>#lunch_whattoeat</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Auto-Sched</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Auto-Sched + Subgoal</th>
</tr>
</thead>
</table>
Role played by the Planner Module

Number of responses

<table>
<thead>
<tr>
<th></th>
<th>C2</th>
<th></th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28</td>
<td></td>
<td>39</td>
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</tbody>
</table>

Critique generation

<table>
<thead>
<tr>
<th>Flaws by</th>
<th>Suggested</th>
<th>Addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Planner</td>
<td>45</td>
<td>7</td>
</tr>
</tbody>
</table>
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