Peeking Beneath the Hood of Uber

Le Chen, Alan Mislove, Christo Wilson
Northeastern University
What is Uber?
What is Uber?
What is Uber?

Type pickup location
What is Uber?

Type pickup location
What is Uber?

Type pickup location

Choose type of car
What is Uber?

Type pickup location

Choose type of car
- UberX: basic sedans
What is Uber?

Type pickup location

Choose type of car
- UberX: basic sedans
- UberBlack: luxury cars
What is Uber?
What is Uber?
What is Uber?

Request!

Request uberX
Simple and smooth! But …
Simple and smooth! But ...
Blackbox algorithm
Blackbox algorithm

- Transparent marketplaces
Blackbox algorithm

• Transparent marketplaces
Blackbox algorithm

- Transparent marketplaces

 Prices are set by the suppliers
Blackbox algorithm

- Transparent marketplaces

**eBay**  **Amazon.com** Prices are set by the suppliers

- Uber is not a transparent marketplace
Blackbox algorithm

• Transparent marketplaces

• Uber is not a transparent marketplace

Prices are set by the suppliers

Prices are dynamically calculated by an algorithm based on supply, demand, etc.
Blackbox algorithm
Blackbox algorithm

WHAT IS SURGE PRICING?
Blackbox algorithm

WHAT IS SURGE PRICING?

Is Uber Surge Pricing Fair?

How to never get slammed with Uber surge pricing again

Detest Uber's surge pricing? Some drivers don't like it either

The practice of tripling, quadrupling and quintupling ride fares in times of high demand may face limits from New York City officials. Many drivers might be OK with that.
Blackbox algorithm

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How to never be overcharged on surge pricing again

Detests drivers

The practice of tripling surge prices in crowded areas and may face limits from New York City.

Tech Uber

Uber's surge pricing is good for you, Uber study says

by Kia Kikalitcheva  @imkialikethecar  SEPTEMBER 17, 2015, 8:58 PM EDT
Goal of this study
Goal of this study

• How does the surge pricing algorithm work?
Goal of this study

- How does the surge pricing algorithm work?
  - Verify if it works as Uber claimed
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- How does the surge pricing algorithm work?
  - Verify if it works as Uber claimed
  - Responsiveness of the algorithm
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- How does the surge pricing algorithm work?
  - Verify if it works as Uber claimed
  - Responsiveness of the algorithm
- Can the surge values be predicted?
Goal of this study

• How does the surge pricing algorithm work?
  - Verify if it works as Uber claimed
  - Responsiveness of the algorithm

• Can the surge values be predicted?

• Impact on passengers and drivers
Outline of Uber study

• Motivation

• Data collection

• Surge pricing

• Summary
Data collection
Data collection

• Uber official patent: supply, demand, etc.
Data collection

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• Option 1: Uber API
Data collection

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• Option 1: Uber API
  - Pros: easy to use; has surge values and EWT
Data collection

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  - Cons: no car/demand/supply information
Data collection

- Uber official patent: supply, demand, etc.
- Option 1: Uber API
  - Pros: easy to use; has surge values and EWT
  - Cons: no car/demand/supply information
- Option 2: Uber client app
Uber client app
Uber client app
Uber client app

• Pings the server every 5 seconds
Uber client app

- Pings the server every 5 seconds
- 8 nearest cars
Uber client app

- Pings the server every 5 seconds
- 8 nearest cars
- Estimated Wait Time (EWT)
Uber client app

- Pings the server every 5 seconds
- 8 nearest cars
- Estimated Wait Time (EWT)
- Surge multiplier
Uber client app

• Pings the server every 5 seconds
• 8 nearest cars
• Estimated Wait Time (EWT)
• Surge multiplier
• More information (supply/demand)
Uber client app limitations
Uber client app limitations

- Supply and demand are estimations
Uber client app limitations

- Supply and demand are estimations
  - Supply = number of cars on the road
Uber client app limitations

• Supply and demand are estimations
  - Supply = number of cars on the road
  - Fulfilled demand = number of cars go offline
Uber client app limitations

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  ▸ Got booked
Uber client app limitations

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    ‣ Got booked
    ‣ Logged out
Uber client app limitations

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    - Got booked
    - Logged out
    - Driving out of boundary
Uber client app limitations

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    ‣ Got booked
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    ‣ Driving out of boundary

Upper bound of fulfilled demand!
Uber client app limitations
Uber client app limitations

• Limited visibility
Uber client app limitations

• Limited visibility
  - Only 8 nearest cars
Uber client app limitations

• Limited visibility
  - Only 8 nearest cars
  - Limited number of measuring points
Uber client app limitations

• Limited visibility
  - Only 8 nearest cars
  - Limited number of measuring points

• How far away between points?
Limited visibility
Limited visibility
Limited visibility
Limited visibility
Limited visibility
Limited visibility

Radius $r$
Limited visibility
Limited visibility
Limited visibility
Limited visibility
Limited visibility

Radius $r$
Radius measurement
Radius measurement

- Measuring radius (details in paper)
Radius measurement

- Measuring radius (details in paper)
  - Midtown Manhattan: 247m
Radius measurement

• Measuring radius (details in paper)
  - Midtown Manhattan: 247m
  - Downtown San Francisco: 387m
Radius measurement

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  - Use the NYC taxi data to validate that 97% of supply and 95% of the demand are covered
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- NYC and SF are the targets for collecting data
Radius measurement

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• NYC and SF are the targets for collecting data
  - 2nd and 3rd largest Uber market
Radius measurement

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• NYC and SF are the targets for collecting data
  - 2nd and 3rd largest Uber market
  - Different access to public transportation
The measurement grid
The measurement grid
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Ethics
Ethics

• We did not collect personal information of passengers and Uber drivers
Ethics

• We did not collect personal information of passengers and Uber drivers

• We never booked Uber rides
Ethics

• We did not collect personal information of passengers and Uber drivers

• We never booked Uber rides

• We did not induce surges
Outline of Uber study

- Motivation
- Data collection
- Surge pricing
- Summary
Research questions
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• How much and how often does it surge on Uber?
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• How long do surge lasts?
Research questions

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• How long do surge lasts?
• How do surge prices vary by location?
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• How long do surge lasts?
• How do surge prices vary by location?
• What features does Uber use to calculate surge multipliers?
Research questions

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• What features does Uber use to calculate surge multipliers?
• Can we predict surges? If not, can we avoid surges?
Research questions

• How much and how often does it surge on Uber?
• How long do surge lasts?
• How do surge prices vary by location?
• What features does Uber use to calculate surge multipliers?
• Can we predict surges? If not, can we avoid surges?
• What is the impact of surge pricing?
How much and how often does it surge on Uber?
How much and how often does it surge on Uber?

CDF

Surge multiplier

Manhattan
San Francisco
How much and how often does it surge on Uber?

CDF

Surge multiplier

Manhattan
San Francisco
How much and how often does it surge on Uber?

- 14% of time surging in Manhattan
How much and how often does it surge on Uber?

- 14% of time surging in Manhattan
How much and how often does it surge on Uber?

- 14% of time surging in Manhattan
- 57% of time surging in San Francisco
How much and how often does it surge on Uber?

- 14% of time surging in Manhattan
- 57% of time surging in San Francisco
- SF has higher surge values
How long do surges last?
How long do surges last?

CDF

Surge duration

1 min 5 mins 10 mins 1 hour
How long do surges last?

CDF of surge duration:
- 1 min: 0%
- 5 mins: 100%
- 10 mins: 90%
- 1 hour: 100%
How long do surges last?

- Noisiness: 70% of surges last less than 10 mins
How long do surges last?

- Noisiness: 70% of surges last less than 10 mins
- Staircase CDF: multiple times of 5 minutes
How long do surges last?

- Noisiness: 70% of surges last less than 10 mins
- Staircase CDF: multiple times of 5 minutes
- Uber updates surge values every 5 minutes
How do surge prices vary by location?
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Surge areas
Surge areas

• Chicago
• Los Angeles
• Miami
• Seattle
• NYC, including all 5 boroughs
• Boston
• DC
• London
• Paris
What features does Uber use to calculate surge multipliers?
What features does Uber use to calculate surge multipliers?

- Find variables that correlate with surge pricing
What features does Uber use to calculate surge multipliers?

- Find variables that correlate with surge pricing
  - Supply, demand, EWT, etc.
What features does Uber use to calculate surge multipliers?

- Find variables that correlate with surge pricing
  - Supply, demand, EWT, etc.
  - Cross-correlation
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![Diagram showing surge calculation over time with a 5-minute window and variables related to surge and variance.](image-url)
What features does Uber use to calculate surge multipliers?

- Find variables that correlate with surge pricing
  - Supply, demand, EWT, etc.
  - Cross-correlation

![Graph showing surge and variance over time with a 5 minute window and a time difference of 0.](image-url)
What features does Uber use to calculate surge multipliers?

- Find variables that correlate with surge pricing
  - Supply, demand, EWT, etc.
  - Cross-correlation Time Difference = 0
What features does Uber use to calculate surge multipliers?

- Find variables that correlate with surge pricing
  - Supply, demand, EWT, etc.
  - Cross-correlation, \textbf{Time Difference} = 0
What features does Uber use to calculate surge multipliers?

- Find variables that correlate with surge pricing
  - Supply, demand, EWT, etc.
  - Cross-correlation **Time Difference = -5**
What features does Uber use to calculate surge multipliers?

- Find variables that correlate with surge pricing
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What features does Uber use to calculate surge multipliers?

• Find variables that correlate with surge pricing
  
  - Supply, demand, EWT, etc.
  
  - Cross-correlation  \textbf{Time Difference} = +5
(Supply - demand) vs surge multipliers
(Supply - demand) vs surge multipliers

![Graph showing correlation coefficients and p-values for NYC and SF over time difference in minutes.](image-url)
(Supply - demand) vs surge multipliers

![Graph showing correlation coefficients and probability over time difference in minutes for NYC and SFC.](image-url)
EWT vs surge multipliers
EWT vs surge multipliers

![Graph showing correlation coefficients and time differences in minutes.](image)
EWT vs surge multipliers

![Graph showing correlation coefficients and probability over time difference in minutes for NYC and SFC.](image)
Features correlated with surge multipliers
Features correlated with surge multipliers

(Supply - demand) vs surge

EWT vs surge
Features correlated with surge multipliers

(Supply - demand) vs surge

- Moderate correlation when time difference is 0

EWT vs surge
Features correlated with surge multipliers

(Supply - demand) vs surge

- Moderate correlation when time difference is 0

- Zero correlation in other windows: responsive but noisy

EWT vs surge
Can we predict surge multipliers?
Can we predict surge multipliers?

• Useful variables
Can we predict surge multipliers?

• Useful variables
  - Supply/demand difference, EWT, surge history
Can we predict surge multipliers?

• Useful variables
  - Supply/demand difference, EWT, surge history

• Model
Can we predict surge multipliers?

• Useful variables
  - Supply/demand difference, EWT, surge history

• Model
  - Linear regression
Can we predict surge multipliers?

• Useful variables
  - Supply/demand difference, EWT, surge history

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• Performance
Can we predict surge multipliers?

- Useful variables
  - Supply/demand difference, EWT, surge history

- Model
  - Linear regression

- Performance
  - R^2 scores range from 0.37 — 0.57
Can we predict surge multipliers?

• Useful variables
  - Supply/demand difference, EWT, surge history

• Model
  - Linear regression

• Performance
  - $R^2$ scores range from 0.37 — 0.57
  - Poor predicative power: missing variable (unfulfilled demand)
Can we avoid surge pricing?
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Can we avoid surge pricing?
Can we avoid surge pricing?
Can we avoid surge pricing?
Can we avoid surge pricing?

No Surge! EWT = 6min

No Surge! EWT = 5min

EWT = 2min

5 minutes

3 minutes

7 minutes
Can we avoid surge pricing?

No Surge!
EWT = 6min

No Surge!
EWT = 5min

EWT = 2min
Can we avoid surge pricing?

- No Surge! EWT = 6min
- No Surge! EWT = 5min
- EWT = 2min
Can we avoid surge pricing?

No Surge!
EWT = 6min

No Surge!
EWT = 5min

EWT = 2min
Avoiding surge
Avoiding surge
Avoiding surge
Avoiding surge

- 10% — 15% of chances saving money
Avoiding surge

• 10% — 15% of chances saving money
• On average, we can save 50% of prices
Avoiding surge

- 10% — 15% of chances saving money
- On average, we can save 50% of prices
- We built an app, but cannot release it
What is the impact of surge pricing? Does it conform with Uber’s claim?
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What is the impact of surge pricing? Does it conform with Uber’s claim?

- Supply
What is the impact of surge pricing? Does it conform with Uber’s claim?

- **Supply**
  - New: more new log-in cars in surging area
What is the impact of surge pricing? Does it conform with Uber’s claim?

- **Supply**
  - New: more new log-in cars in surging area
  - Move-in: more move-in cars from nearby areas
What is the impact of surge pricing? Does it conform with Uber’s claim?

- **Supply**
  - New: more new log-in cars in surging area
  - Move-in: more move-in cars from nearby areas
  - Move-out: less cars leaving the surging area
What is the impact of surge pricing? Does it conform with Uber’s claim?

• Supply
  - New: more new log-in cars in surging area
  - Move-in: more move-in cars from nearby areas
  - Move-out: less cars leaving the surging area

• Demand
What is the impact of surge pricing? Does it conform with Uber’s claim?

- Supply
  - New: more new log-in cars in surging area
  - Move-in: more move-in cars from nearby areas
  - Move-out: less cars leaving the surging area

- Demand
  - Booked: less cars getting booked in the surging area
What is the impact of surge pricing? Does it conform with Uber’s claim?

- **Supply**
  - New: more new log-in cars in surging area
  - Move-in: more move-in cars from nearby areas
  - Move-out: less cars leaving the surging area

- **Demand**
  - Booked: less cars getting booked in the surging area
  - Old: more old cars staying the surging area
Impact on supply and demand, in reality

<table>
<thead>
<tr>
<th>State</th>
<th>During surge</th>
<th>Expected?</th>
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Impact on supply and demand, in reality

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Summary of Uber study
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• Presented the first in-depth analysis of Uber
  - Covered dynamics of supply, demand, surge, etc.
  - Detailed implementation of surge pricing algorithm
Summary of Uber study

- Presented the first in-depth analysis of Uber
  - Covered dynamics of supply, demand, surge, etc.
  - Detailed implementation of surge pricing algorithm
- Showed impact of surge on supply and demand
Thanks!

• Questions?