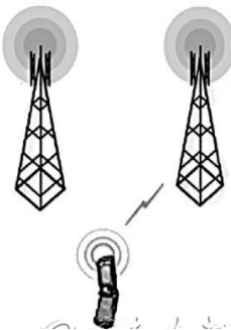




# 电信定位



- 利用手机与电信蜂窝基站连接的信号强度信息推测用户位置



	LA	SF	NY
Total unique phones	318K	241K	267K
Total unique CDRs	1395M	701M	1095M
Median CDRs/phone/day	18	12	18
Median calls/phone/day	6	5	7
Median texts/phone/day	6	3	5

Each dataset spans 91 consecutive days from April 1 to June 30, 2011



(a) Los Angeles



(b) San Francisco



(c) New York

Median daily range of cellphone users who live in central LA, SF, and NY (darker yellow areas). The radii of the inner, middle, and outer circles represent the 25th, 50th, and 75th percentiles of these ranges across all users in that 3 area

Richard A. Becker, Ramón Cáceres, Karrie Hanson, Sibren Isaacman, Ji Meng Loh, Margaret Martonosi, James Rowland, Simon Urbanek, Alexander Varshavsky, Chris Volinsky: **Human mobility characterization from cellular network data**. Commun. ACM 56(1): 74-82 (2013)

## GPS/北斗等卫星定位(终端定位技术)

- 用户群体覆盖面窄
- 持续性低(用户主动关闭GPS传感器)
- 特定区域不工作(如地下)

## 电信数据具有独一无二的优点

- 具有覆盖范围广
- 收集成本低
- 持续性高等

2020年新型冠状病毒疫情  
基于电信数据的用户14天行程追踪技术

# 电信定位方法

一个示例电信测量报告 (Measurement Record: MR)

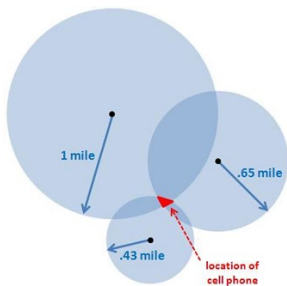
MRTIME	IMSI	SRNC_ID	BestCellID	LCS_BIT	...
2016/5/3 16:19	1234567890	103330	1	300	
RNCID_1	CellID_1	EcNo_1	RSCP_1	RTT_1	UE_Rx_Tx_1
103330	1	-14.38	-98.88	37900	333
RNCID_2	CellID_2	EcNo_2	RSCP_2	RTT_2	UE_Rx_Tx_2
103330	3	-20	-104.88	37900	335
RNCID_3	CellID_3	EcNo_3	RSCP_3	RTT_3	UE_Rx_Tx_3
103333	1	-19	-104.13	37900	235
RNCID_4	CellID_4	EcNo_4	RSCP_4	RTT_4	UE_Rx_Tx_4
103333	2	-18.38	-104.25	37900	236

电信基站

电信信号强度

主基站

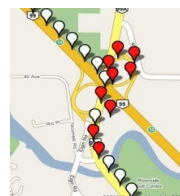
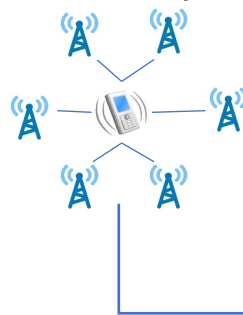
4个基站的  
信号信息



三角定位

电信测量报告MR (训练数据)

GPS 位置标签



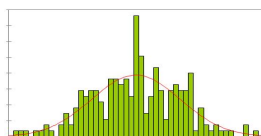
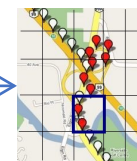
电信测量报告MR (测试数据)

offline训练

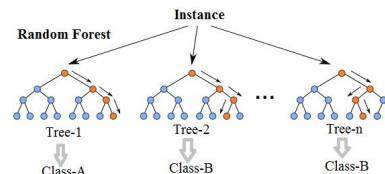
online预测

定位模型

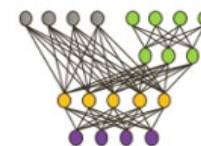
预测位置



指纹定位  
CellSense



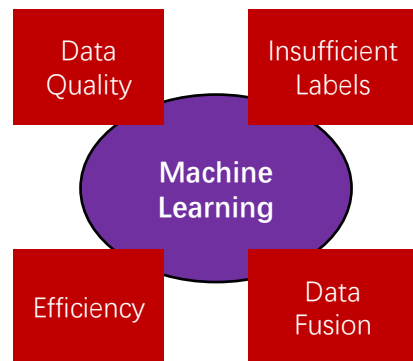
机器学习模型



深度学习模型

数据驱动的电信定位技术

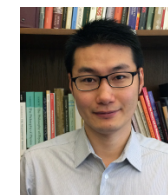
# 工作小结



**Nokia Chair in Data Science**  
Prof. Pan Hui (ACM Distinguished Scientist & IEEE Fellow)

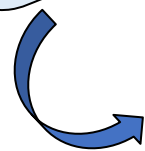


Prof. Dr.-Ing. Jörg Ott



Prof. Kun Zhang

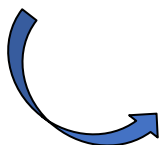
2016 **2-Layer RaF Regression**  
**Error: 80-200米 (回归模型)**



2017 **Multi-Classification (RaF, MLP)**  
**Error: 30-40米 (多分类模型)**



2017 **Data Repair**  
**Error: 10-20 meter (数据噪音修复技术)**



2020 **Transfer Learning, HMM, CNN**  
**Error: 20 meters (位置标注数据稀疏)**



**Current Work**  
**Deep Reinforcement Learning**  
**Error → ?**

经过近6年的努力, 本团队在电信定位方向取得国际领先的工作

- 华为杰出合作成就奖
- 多次国际学术会议最佳论文奖
- 研究成果在国际顶级期刊和会议录用



# Experimental Study of Telco Localization Methods

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# Introduction

- Telco localization is a technique which uses measurement report data from Telco networks to calculate the position of a mobile device.
- Advantages:
  - ① Energy-efficient
  - ② Available in most mobile phones or devices
  - ③ Better network coverage
  - ④ Active when making calls or mobile broadband services
  - ⑤ Crowd spatiotemporal behavior analysis without bringing any burden to mobile devices.

# Contributions

- Comprehensive performance study
- Comparing different data sources
- Gridding mechanism

# Background

- MR data

TABLE II: An example of the 2G MR record.

Field	Example	Field	Example
Time	2016/5/3 13:34:36	MS	MS1
Frame Number	80121	Direction	UL
Message Type	Measurement Report	Event	NULL
Event Info	NULL	<b>LAC</b>	6243
<b>Cell Id</b>	61954	BSIC(Num)	33
<b>ARFCN BCCH</b>	579	<b>RxLev Full (dBm)</b>	-71
RxLev Sub (dBm)	-64	RxQual Full	6
RxQual Sub	0	MS TxPower (dBm)	30
<b>LAC [1]</b>	6205	<b>Cell Id [1]</b>	61954
BSIC (Num) [1]	34	<b>ARFCN [1]</b>	571
<b>RxLev [1]</b>	-53	<b>LAC [2]</b>	6243
...	...	...	...
<b>Cell Id [6]</b>	53395	BSIC (Num) [6]	64
<b>ARFCN [6]</b>	575	<b>RxLev (dBm) [6]</b>	-80

TABLE III: An example of the 4G MR record.

Field	Example	Field	Example
MRTIME	2016/5/3 19:16:34	IMSI	****058
<b>Serving eNodeBID</b>	99129	<b>Serving CellID</b>	1
<b>eNodeBID_1</b>	99130	<b>CellID_1</b>	1
<b>RSRP_1</b>	-96.63	<b>RSSI_1</b>	-57.13
<b>RSRQ_1</b>	-19.63	<b>eNodeBID_2</b>	99130
<b>CellID_2</b>	3	<b>RSRP_2</b>	-98.75
<b>RSSI_2</b>	-44.88	<b>RSRQ_2</b>	-20
...	...	...	...
...	...	<b>eNodeBID_6</b>	99167
<b>CellID_6</b>	3	<b>RSRP_6</b>	-88.5
<b>RSSI_6</b>	-44.25	<b>RSRQ_6</b>	-19.75



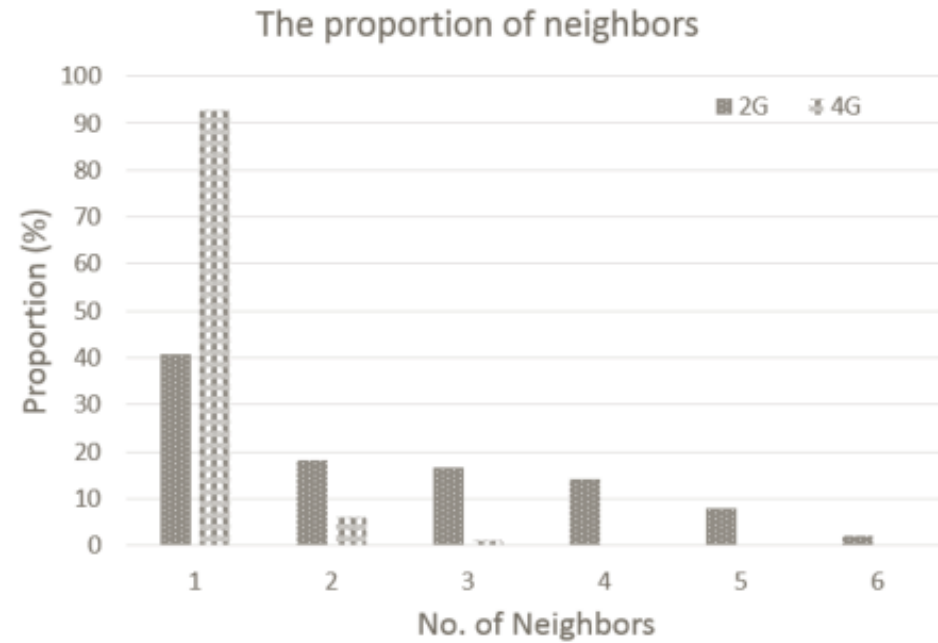
# Telco Localization Algorithms

- ML Estimator
- Cellsense
- Random Forest
- Multilayer perceptron
- XGBoost

# Experimental Setup

- Hardware
- Datasets

# Statistics

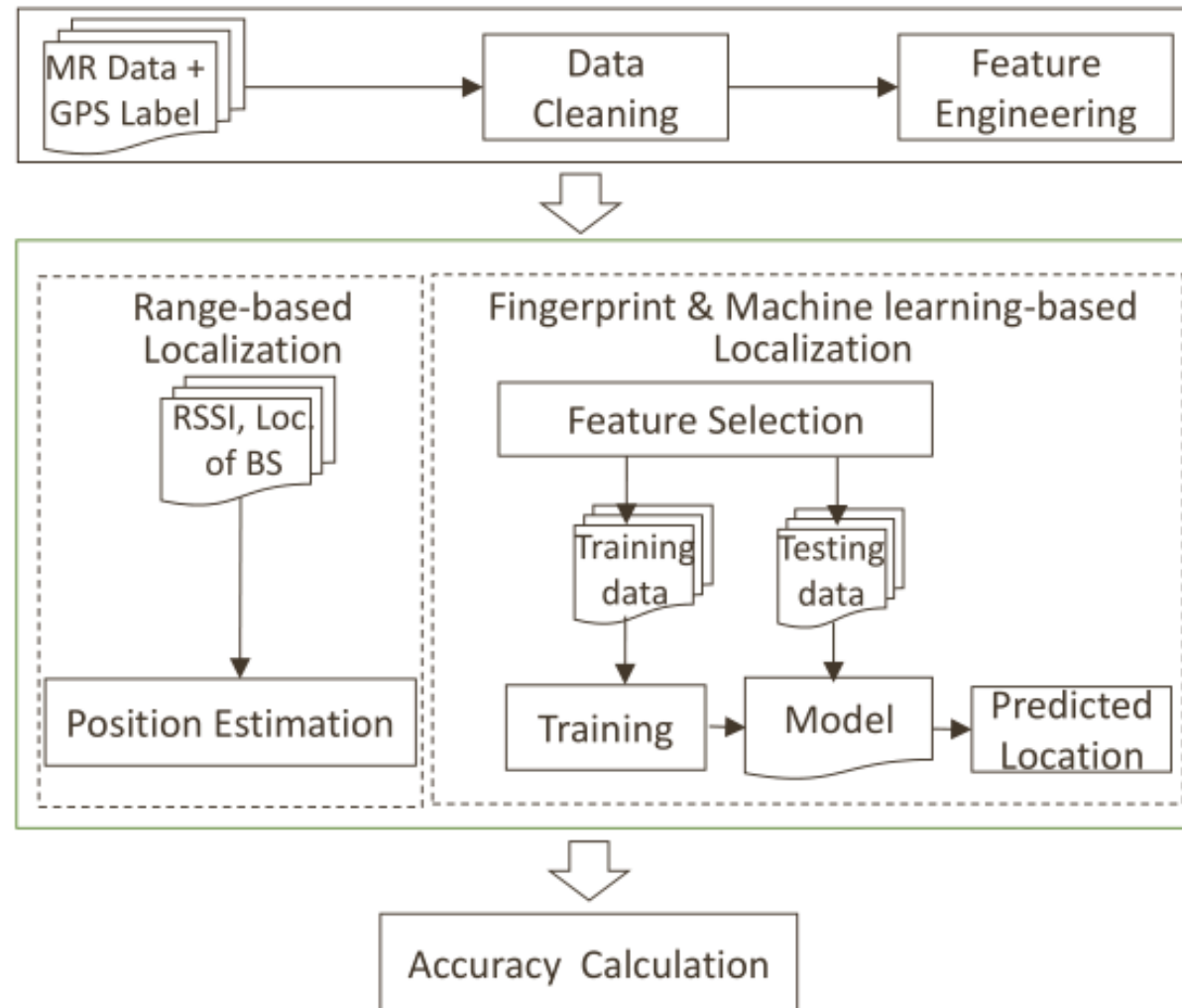


Dataset	record cnt	Distance to srv BS		Avg. RSSI of srv BS
		Avg.	Median	
GSM	46133	286.7 m	182.3 m	-64.3 dB
LTE	46641	187.0 m	157.0 m	-71.2 dB

	BS cnt	RSSIs of all BSs		Avg. dist. btw BS
		Avg.	Median	
GSM	618	-66 dBm	-66 dBm	512.9 m
LTE	973	-84.8 dBm	-74.6 dBm	277.5 m

# Telco Localization Experiment Flow



# EXPERIMENTAL RESULTS

## Accuracy comparison

TABLE IX: Median error (m) under different data sources

	2G	4G
ML	172.8	174.6
Cellsense	64.8	41.3
RF	67.3	31.8
MLP	74.3	35.7
XGBoost	65.7	41.3

### A. Accuracy comparison

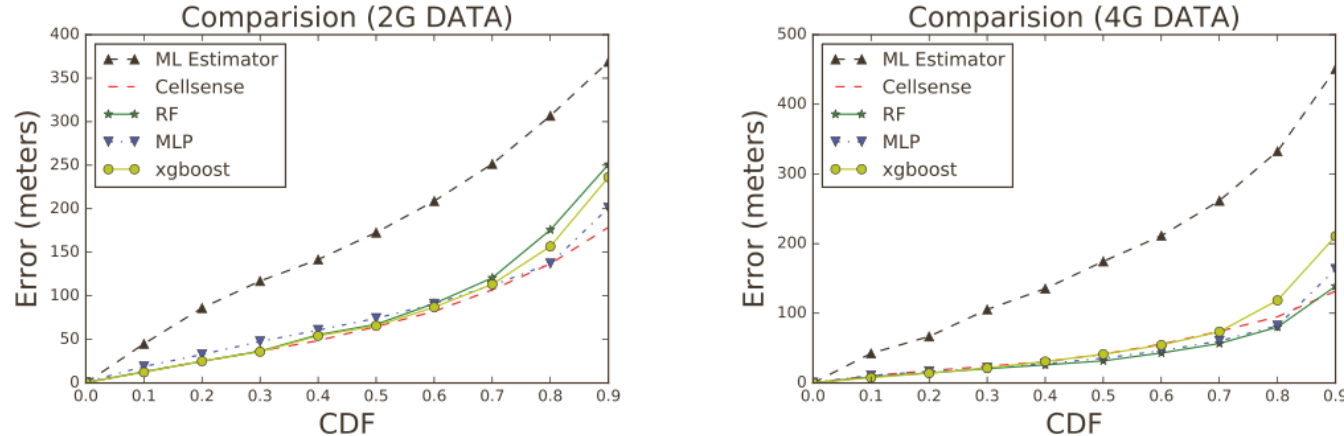


Fig. 4: Comparison of all algorithms. left: 2G; right: 4G

# Data Source, Volume and Quality

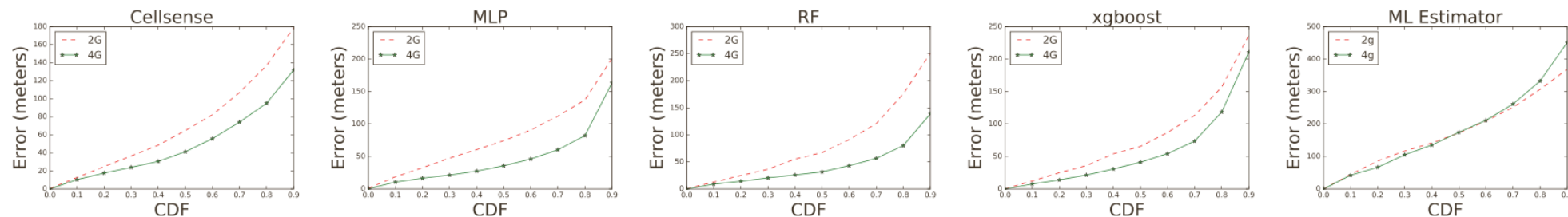


Fig. 5: Comparison between 2G and 4G data sources

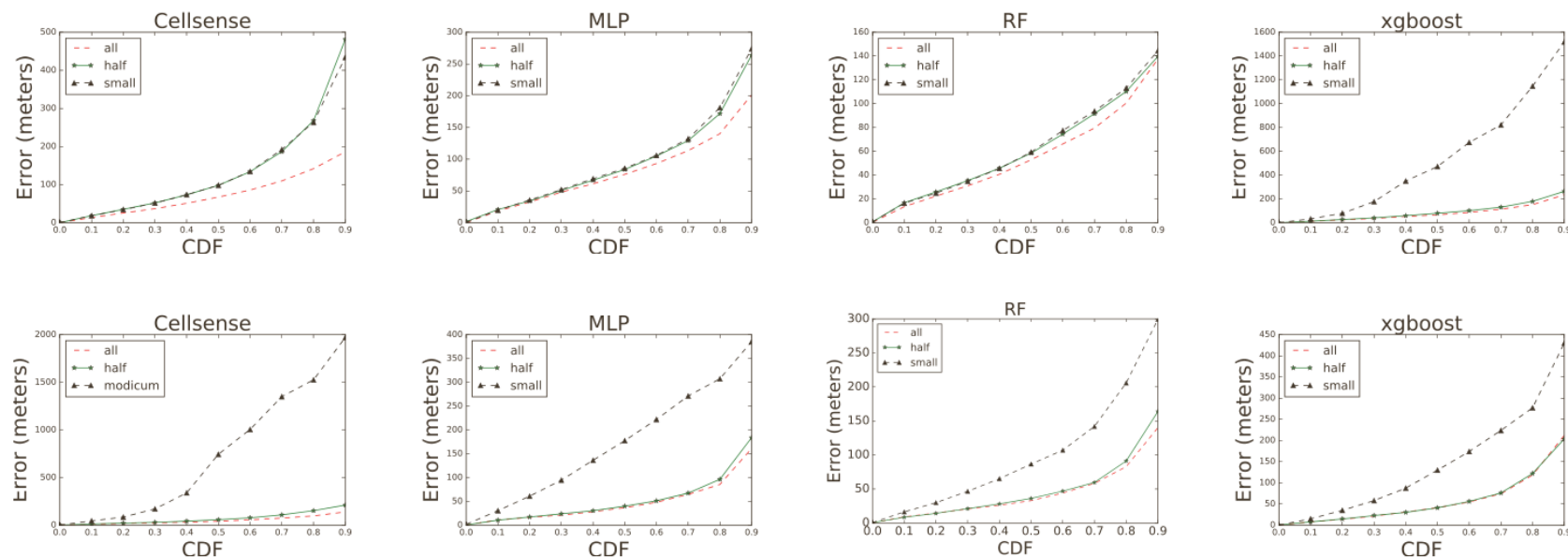


Fig. 6: Performance with different volumes of training data. 1<sup>st</sup> row: 2G; 2<sup>nd</sup> row: 4G

# Neighbors

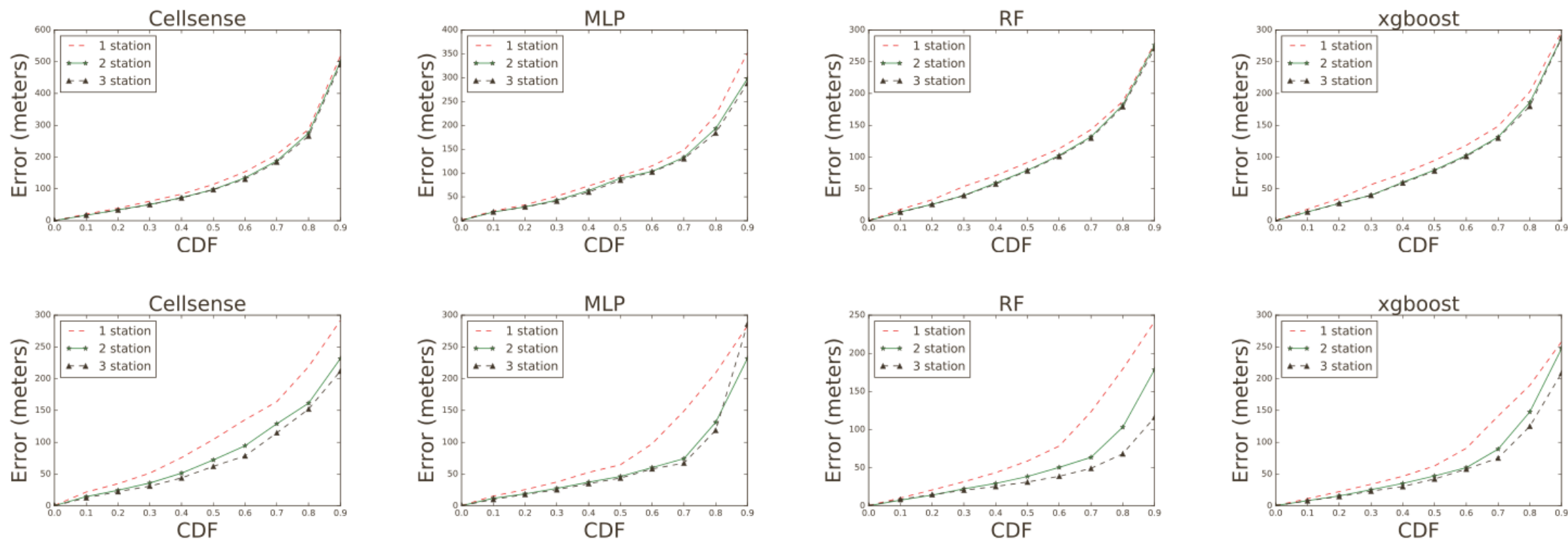


Fig. 7: Influence of neighbors. 1<sup>st</sup> row: 2G; 2<sup>nd</sup> row: 4G

# Gridding

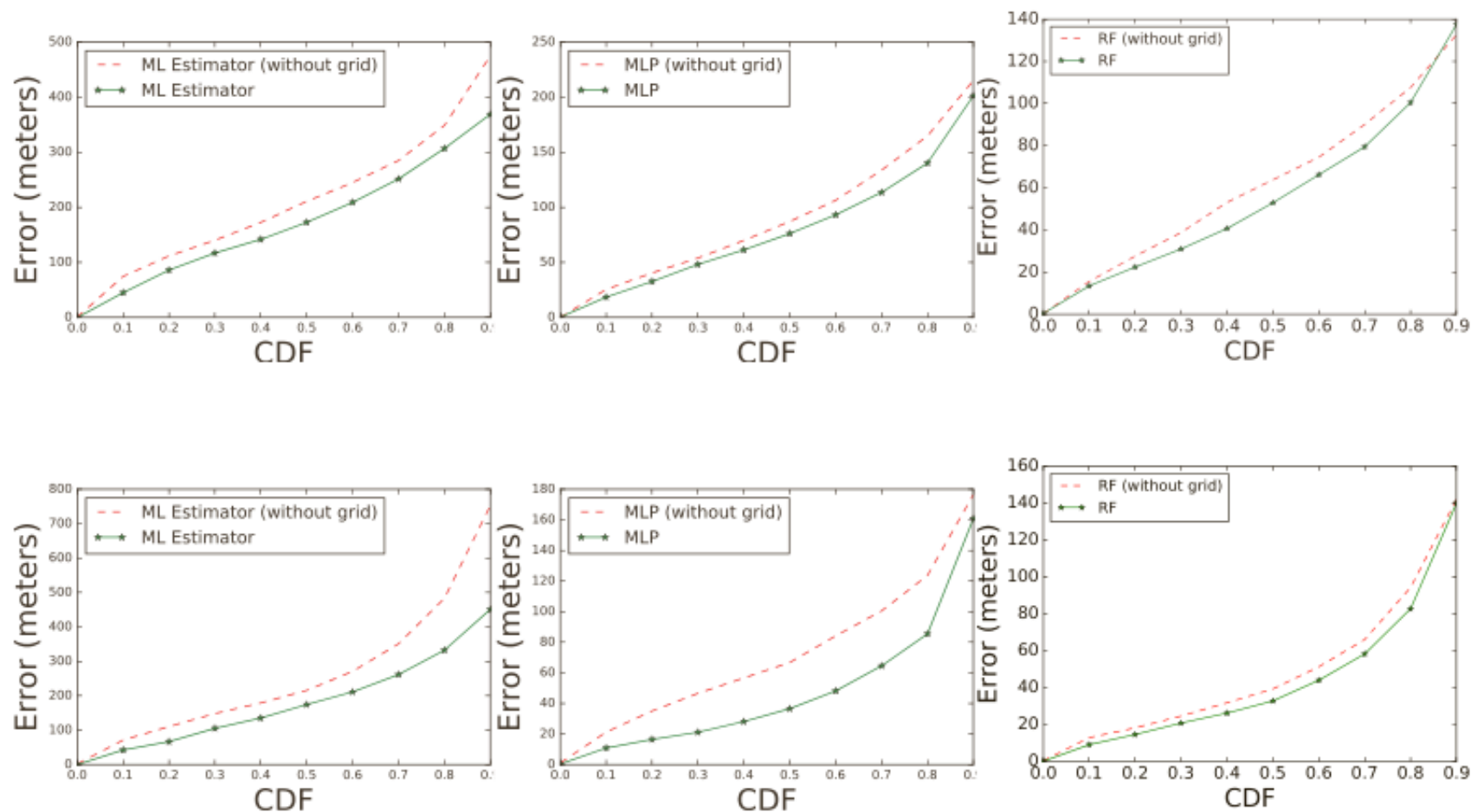


Fig. 8: Regression vs. Classification. 1<sup>st</sup> row:2G, 2<sup>nd</sup> row:4G



# Efficiency

Grid Size	50m		100m		150m		Regression	
	T	P	T	P	T	P	T	P
ML Estimator		619.6		279		160		204
Cellsense	17.34	11.35	17.27	5.94	17.33	4.3		
RF	10.26	1.35	4.81	0.54	3.29	0.36	1.56	0.15
MLP	891.62	0.07	710.9	0.04	647.71	0.02	501.76	0.02
XGBoost	9804	0.15	2717	0.07	1323	0.03		