

Secure and Efficient Image Recognition Applications on the 5G Network

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Outline

- Who we are
- DOCOMO's AI business and GPU
- Advantages and disadvantages of mobile network
- What is 5G?
- Image recognition use cases on 5G network
- Secure image recognition on mobile network

Do you know NTT DOCOMO?

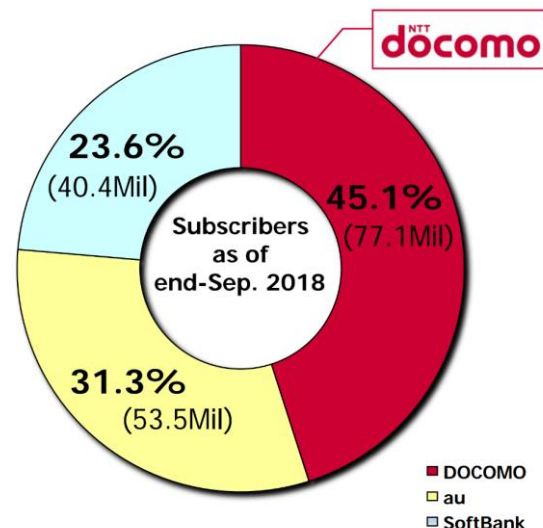
Who We Are

NTT DOCOMO is the largest mobile-phone operator in Japan!

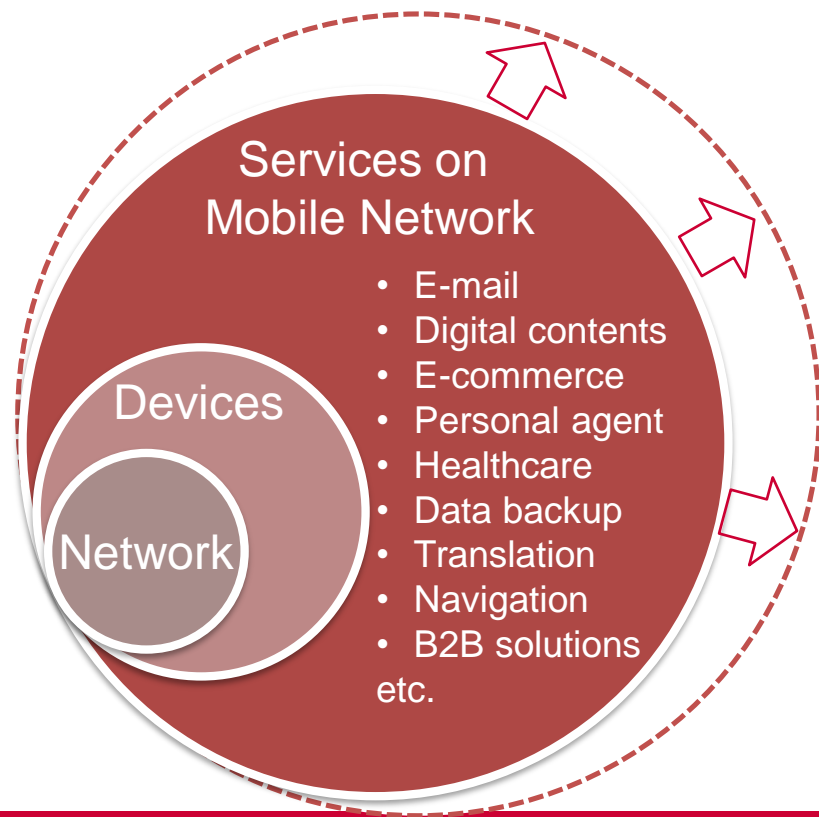
History

- 1992: Established
- 1993: Launched its first digital cellular phone service
- 1999: Launched World's first mobile Internet-services platform
- 2001: Launched the first 3G service
- 2010: Launched one of the earliest commercial LTE services

Subscriber share snap shot in Japan

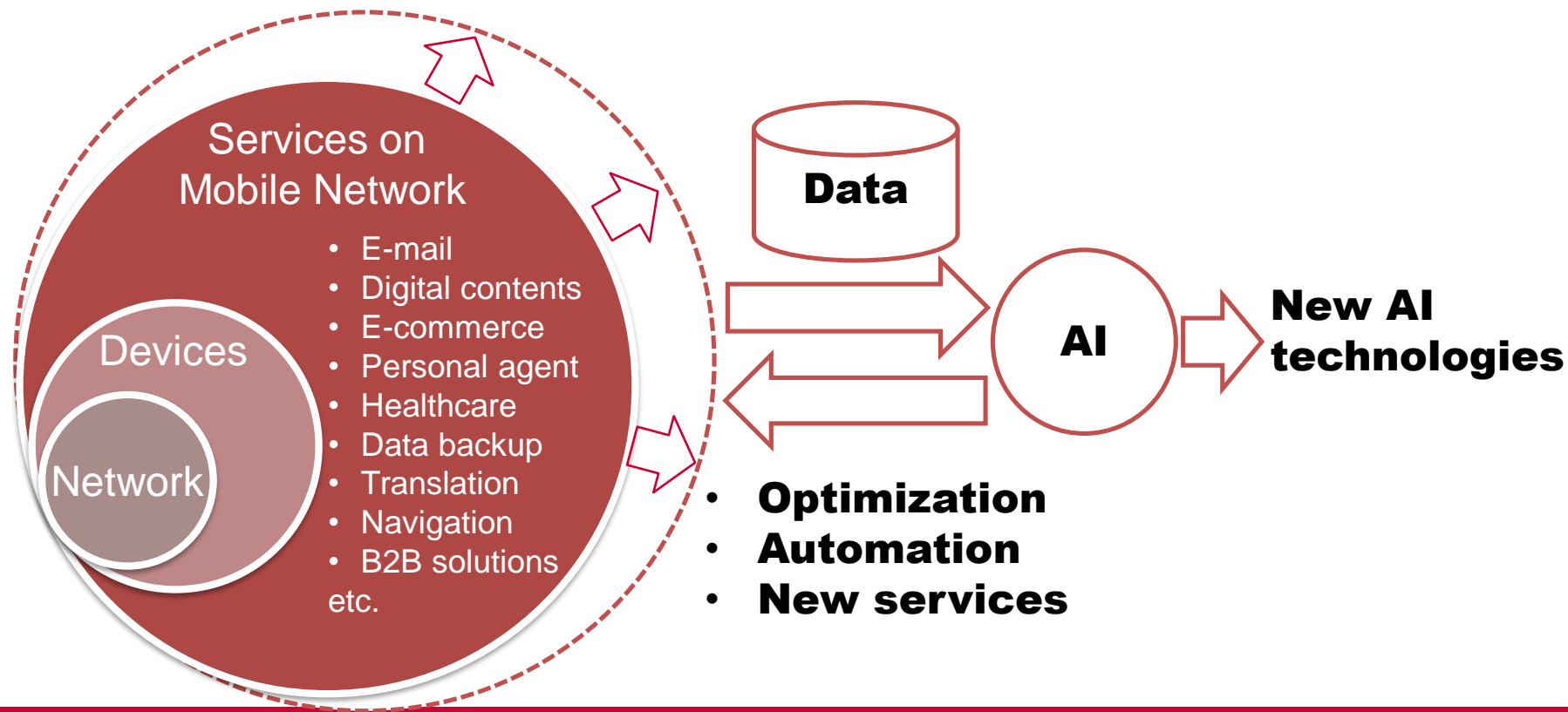


NTT DOCOMO Provides Various Services



We are extending our services & business beyond the mobile network

Our AI Applications



Our Image Recognition Technologies

- Traditional feature matching
 - Product recognition
- Deep Learning
 - Category classification
 - Object detection
 - Feature based searching & clustering
 - Action/scene recognition for video
 - Character recognition
 - Face attribute recognition

DOCOMO's Image Recognition Solution 1

MERCHANDISE SHELF RECOGNITION

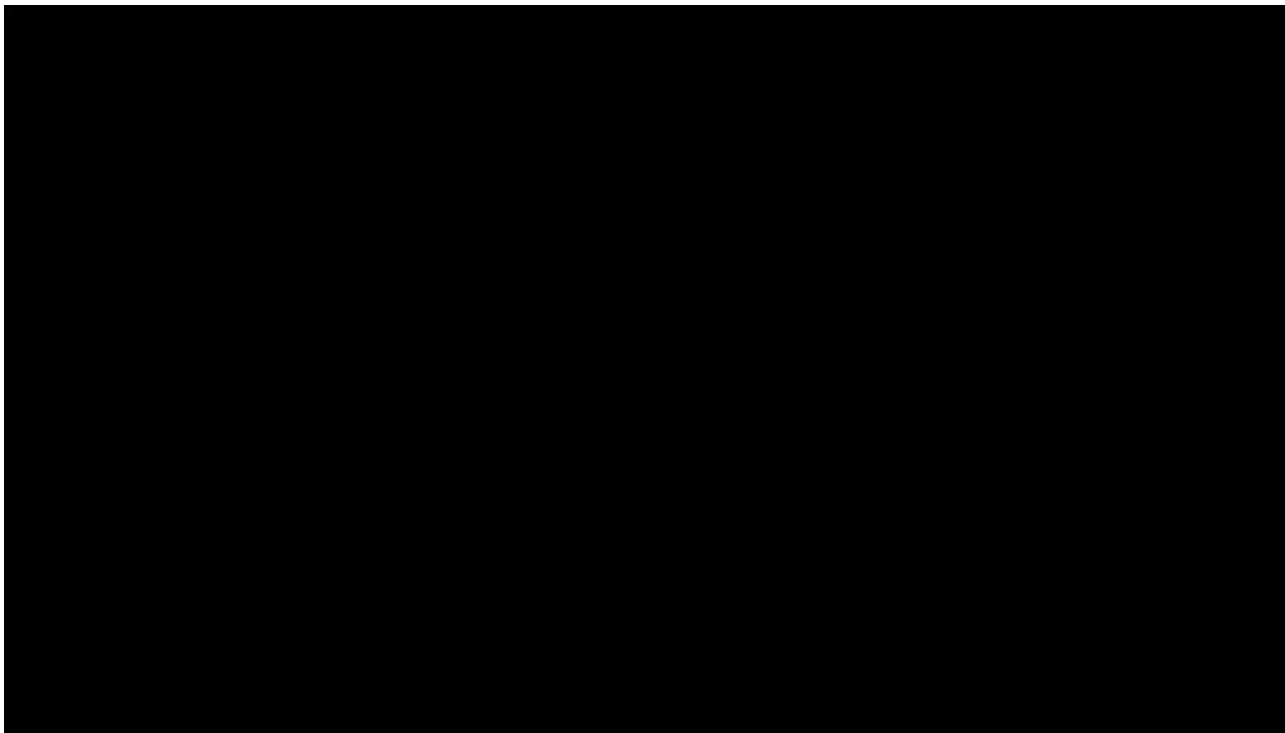
Merchandise Shelf Recognition

- Automatically capture shelf data only by taking pictures
 - Product IDs or Names
 - Number of items & Share
 - Placement
 - Facings
- The captured data can be used to analyze shelf allocation.



Product	Num.	Share
XXXX	2	3%
YYYY	5	5%
...		

Merchandise Display Recognition



Who Needs Shelf Data?

Shelf data(shelf allocation) is gathered manually by

- **Consumer packaged goods (CPG) companies**
 - To increase in-store exposure
- **Retail companies**
 - To investigate better shelf condition & increase sales



Make In-store Shelf Allocation Analysis Shorter

- The current shelf allocation can be obtained by only taking pictures of shelves.
 - For less measurement cost in terms of operation time
 - More frequent and accurate shelf allocation for marketing.
- Several major CPG companies are using our system in Japan

Working hours to collect data

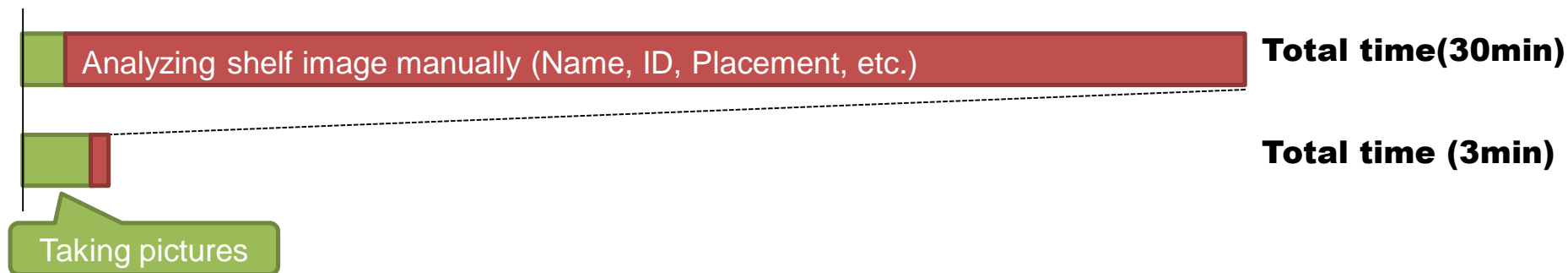
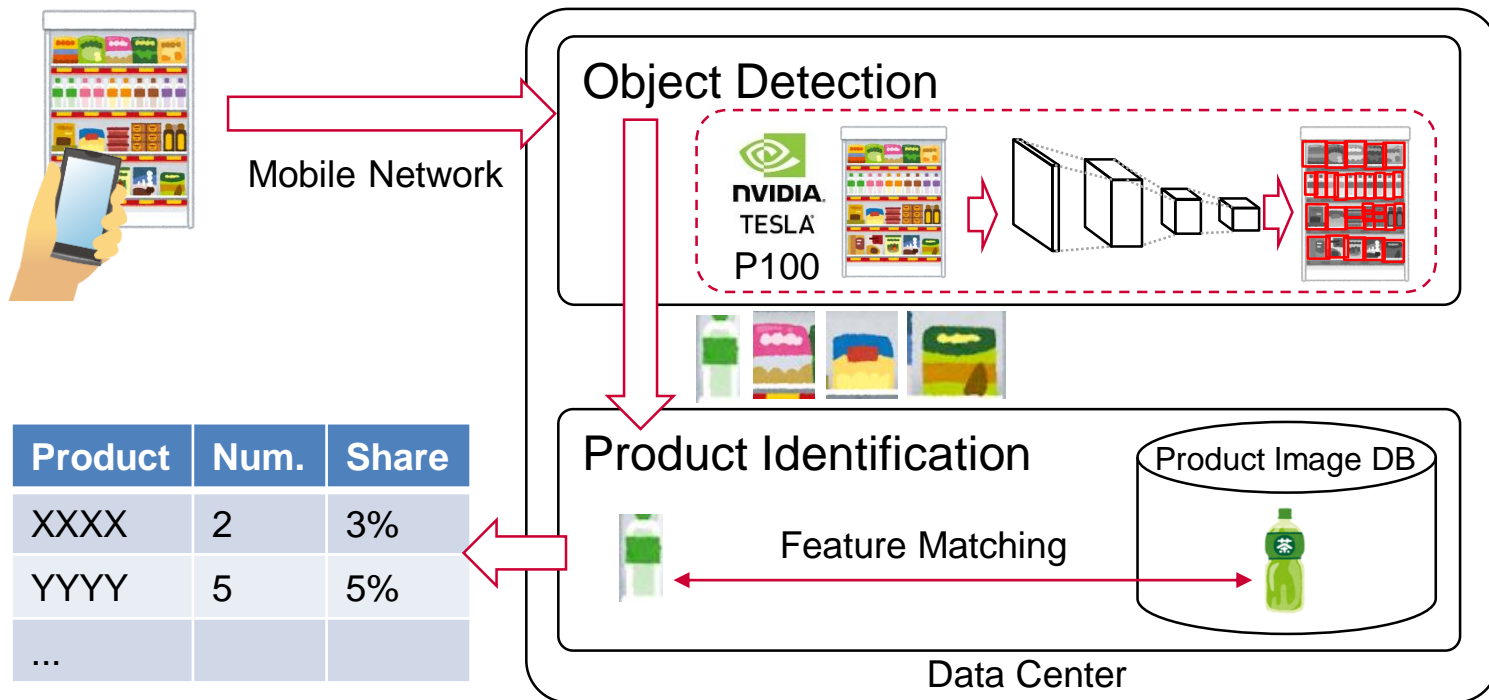


Image Recognition for Shelf

- Using both deep learning & traditional feature matching



Advantages of Our Technology

- Fast & robust product identification: 7M-image DB in 1sec
 - Robust search using local feature matching
 - Proprietary implementation on approximate nearest neighbor search

1. Detect keypoints
2. Calculate their feature vector



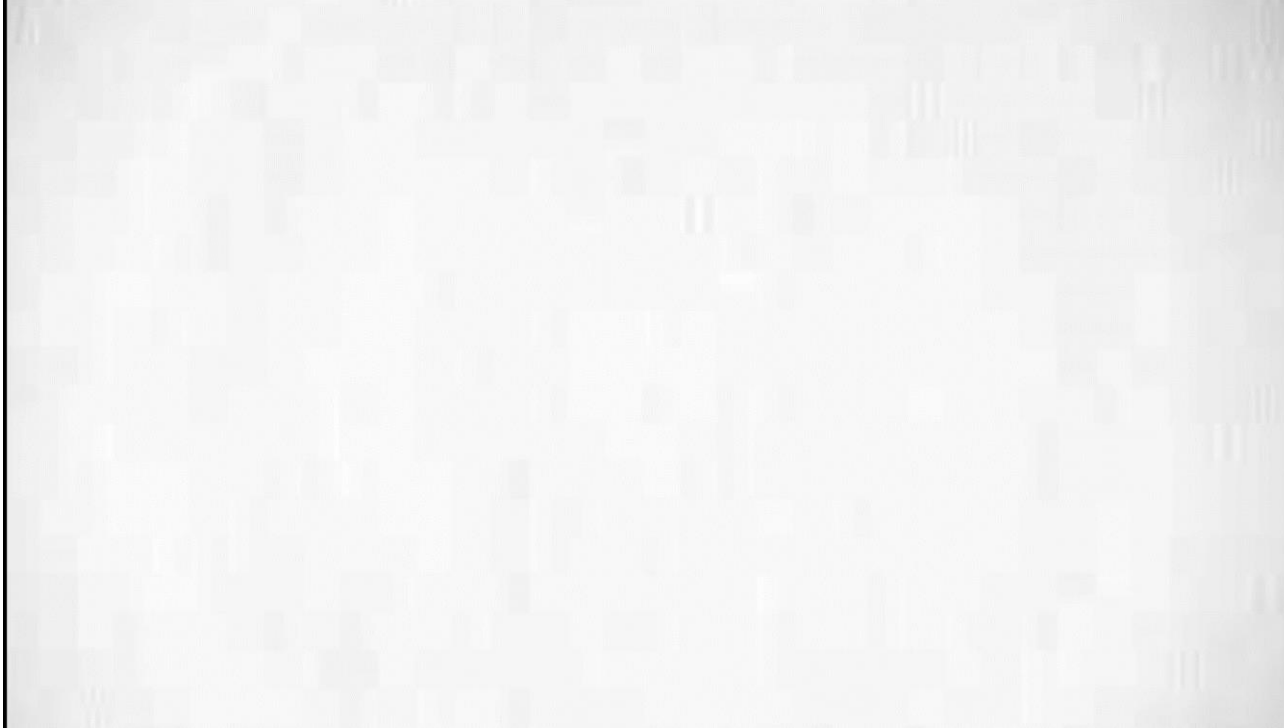
3. Keypoint matching



Product-recognition App for Visitors to Japan

- Determining detailed contents of Japanese-labeled food products to meet specific dietary requirements for health or religious reasons
 1. Detecting product using deep learning
 2. Identifying product by matching with image feature DB
 3. Retrieving detail contents from product content DB
- Conducting trial with FOOD DIVERSITY Inc. on their application, HALAL GOURMET JAPAN.

Product-recognition App for Visitors to Japan

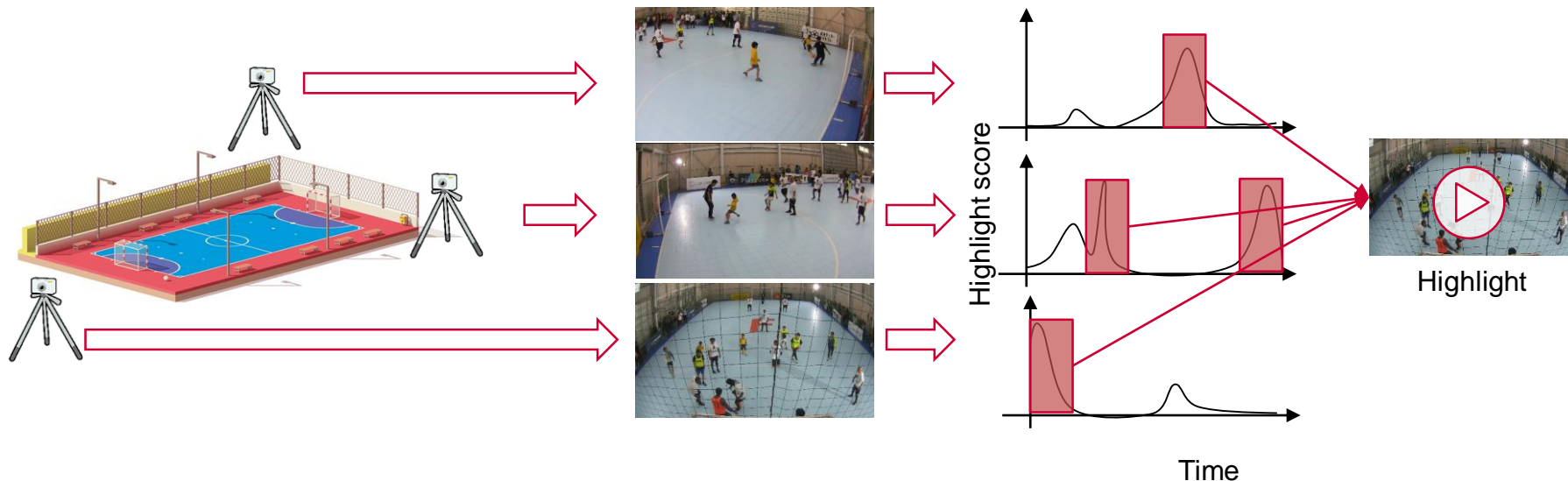


DOCOMO's Image Recognition Solution 2

AUTO HIGHLIGHT GENERATION FOR FUTSAL

Auto Highlight Generation for Futsal

- Automatically generating highlight from futsal videos
 - Recording videos from multi cameras
 - Extracting goal and shoot scenes



Highlight for Armature Futsal Players

- Help armature futsal players to get “likes”
 - Sharing their futsal game highlight on SNS after futsal game
- Provide this service with rental court servicer
 - Conducting trial with SOCCER.COM, Inc.



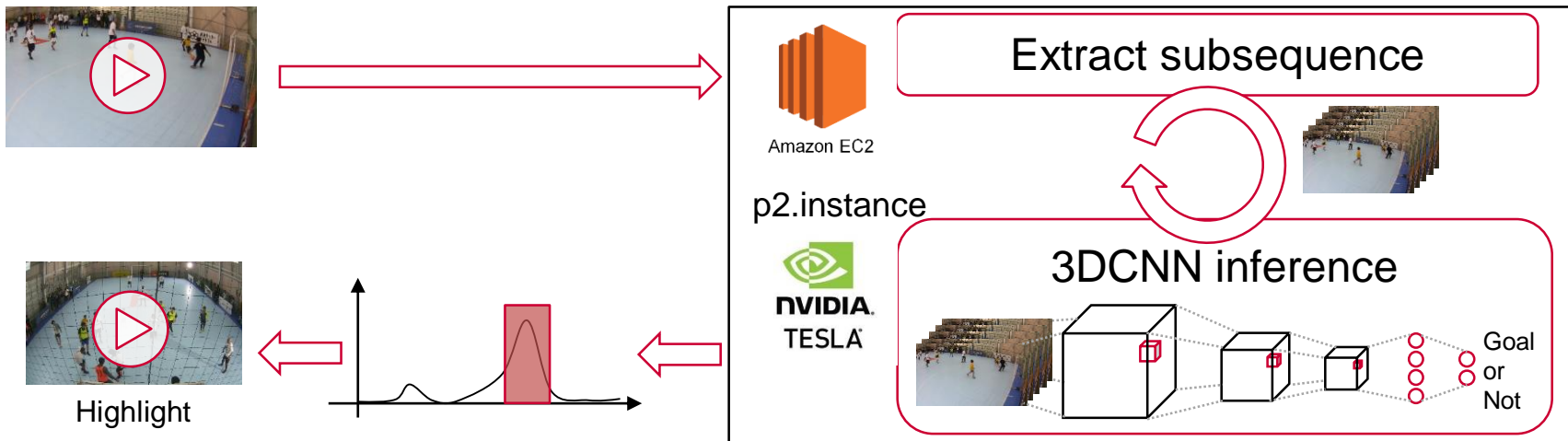
Auto Highlight Generation for Futsal

Auto Highlight Generation
for Futsal

NTT DOCOMO, INC.

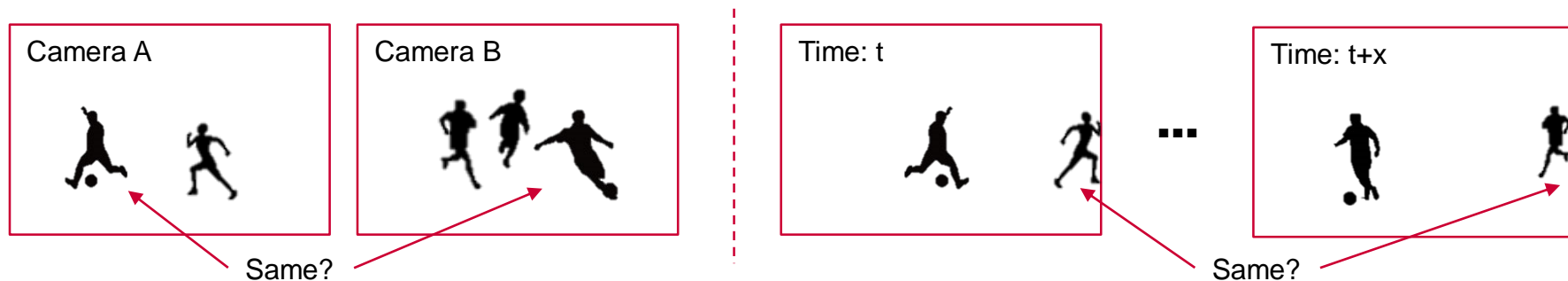
How to extract Highlight?

- 3DCNN based neural network
 - Convolve 3-dimensional tensor: width x height x time (or depth)
 - Learn Spatiotemporal Features: motion
- Infer goal or not to each subsequence

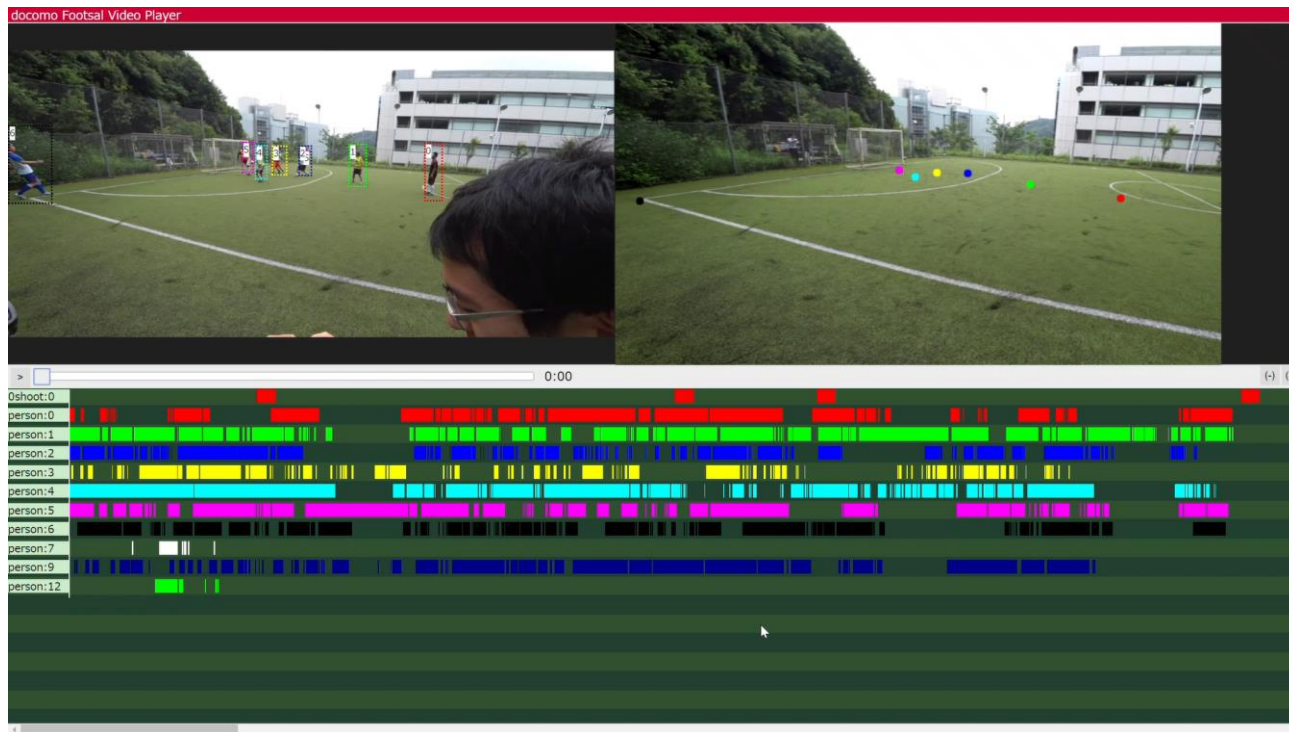


Next Step: Personalized Highlight

- Generate highlight for each player by tracking them
- Need re-identification based on bib number & whole body feature
 - Players go out and came back to camera many times
 - Players are caught by multi cameras



Current Result of Tracking

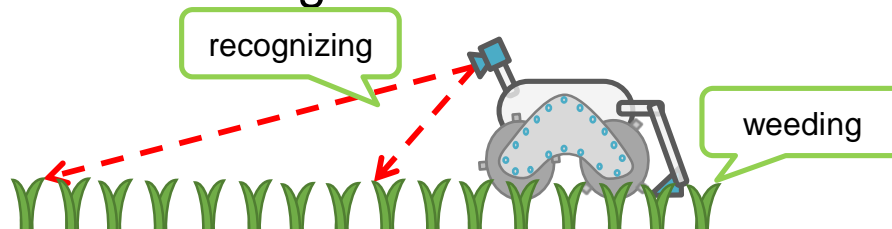


DOCOMO's Image Recognition Solution 3

FIELD WEEDING ROBOT

Field Weeding Robot

- In Japan, Many farmers weed the farm land manually
 - To have better vegetable for organic farming
 - To cope with narrow farm land
- Robot for weeding
 - Runs autonomously on the field by recognizing vegetables
 - Prevents weeds between vegetables
 - Reduces weeding burden of farmers

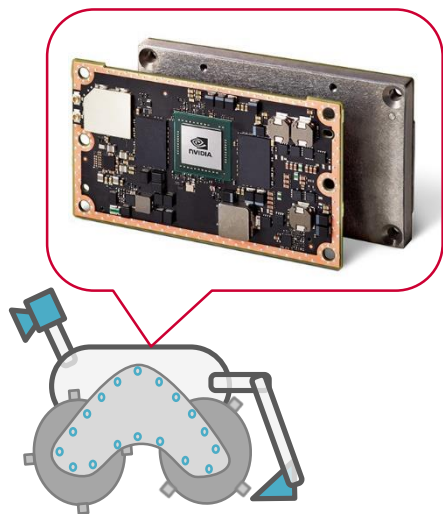


Field Weeding Robot Demo

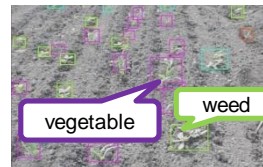
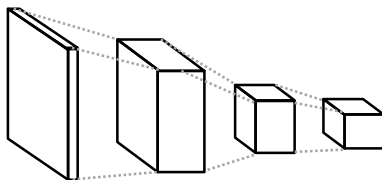


How to Recognize Weeds?

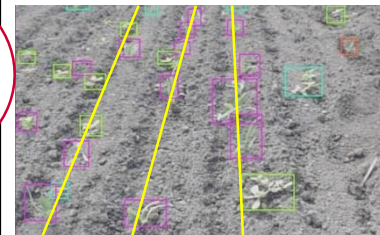
- Recognizing vegetables using AI technologies including computer vision, robotics, and deep learning.
- Inferencing in real time on **Jetson TX2**



Weed and Vegetable Detection (Deep Learning)

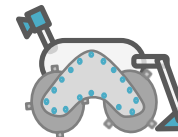


Line Detection



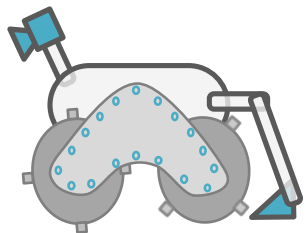
Summary of Image Recognition Solution

- Traditional feature matching
 - Product recognition
- Deep Learning
 - Category classification
 - Object detection
 - Feature based search & clustering
 - Event recognition for video
 - Character recognition
 - Face attribute recognition



GPU for Image Recognition

Edge GPU



Jetson

Cloud GPU

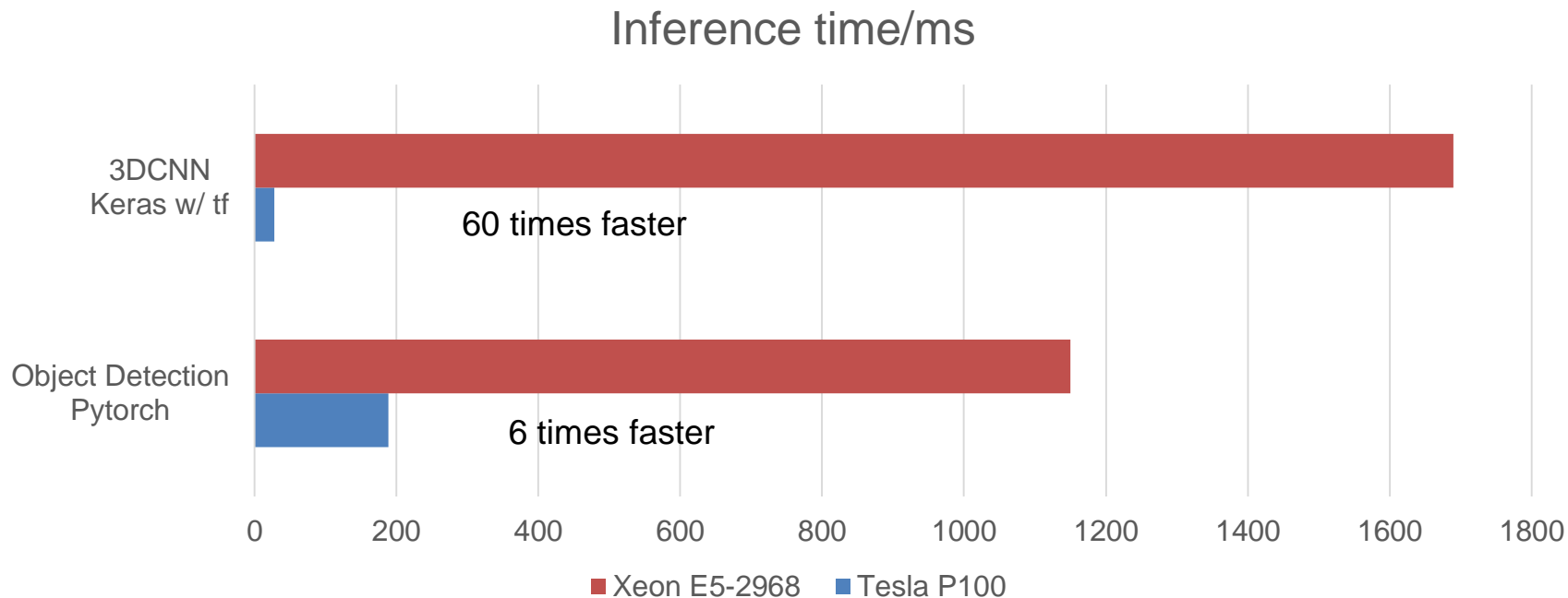


P100 & K80



GPU is Essential for Image Recognition

- GPU makes deep learning inference faster



Mobile Network to Use Cloud GPU

- Benefit of using mobile network on image recognition system
 - You can send image data to cloud from mobile devices
 - Mobile network allow us to utilize rich cloud resource anywhere
 - Fast deep learning inference on GPU
- Mobile network is underutilized for image recognition services

Solution	Where	How to access
Display recognition	Data Center	Mobile network
Highlight movie generation	Cloud	Optical line
Field Weeding Robot	Edge	-

Challenges to Use Mobile Network

Challenges		
Latency	Real time recognition	<ul style="list-style-type: none">- Autonomous driving- Anomaly detection
Upload speed	Fast uploading of input data	<ul style="list-style-type: none">- Recognizing movies- Recognizing many large images
Download speed	Fast downloading of recognition results	<ul style="list-style-type: none">- Highlight movies- Contents delivery based on recognition result
Security	Upload/download sensitive images securely	<ul style="list-style-type: none">- Surveillance camera- AI camera in the house

Solution

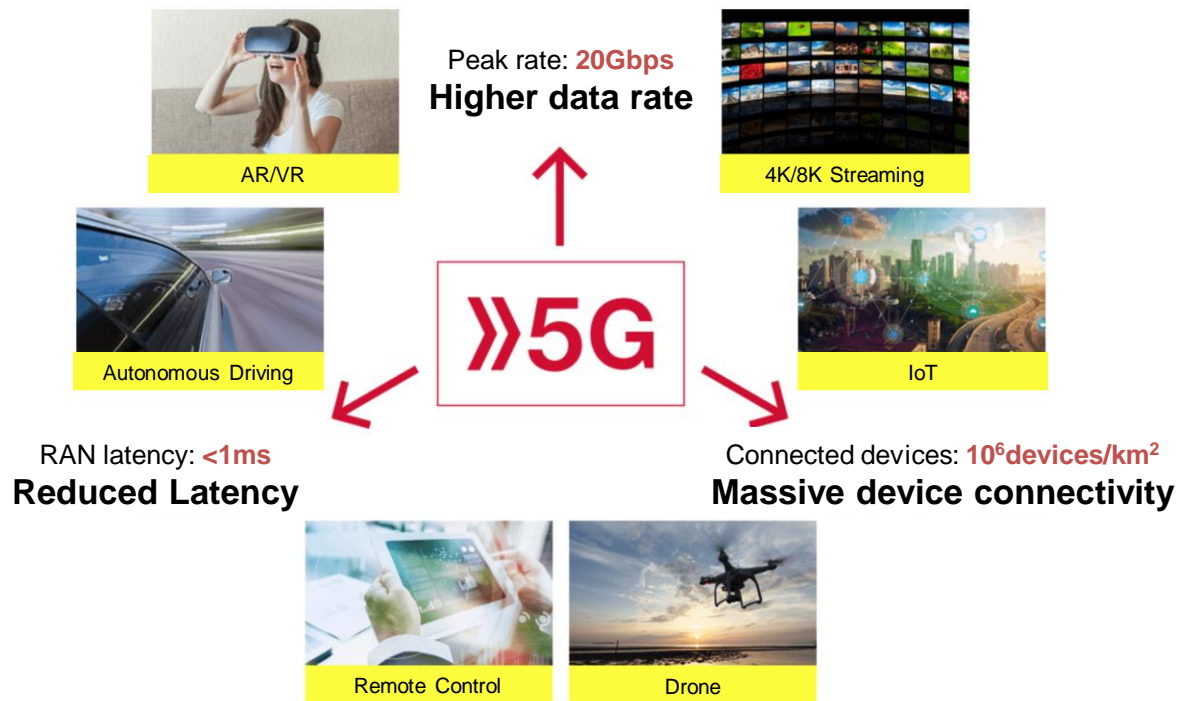
5G + α

What is 5G?

- 5G :The next, fifth generation, mobile communication system
- DOCOMO'S 5G Network Rollout



5G Target



5G accelerate image recognition via mobile network

Challenges		
Latency	Real time recognition	<ul style="list-style-type: none">- Autonomous driving- Anomaly detection
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Image Recognition Experiments with 5G

- Our image recognition experiments with 5G
 1. Bib number recognition in marathon
 2. 5G adaptive signage cart to increase advertising effect

Challenges		
Upload speed	Fast uploading of input data	<ul style="list-style-type: none">- Recognizing movies- Recognizing many large images
Download speed	Fast downloading of recognition results	<ul style="list-style-type: none">- Highlight movies- Contents delivery based on recognition result

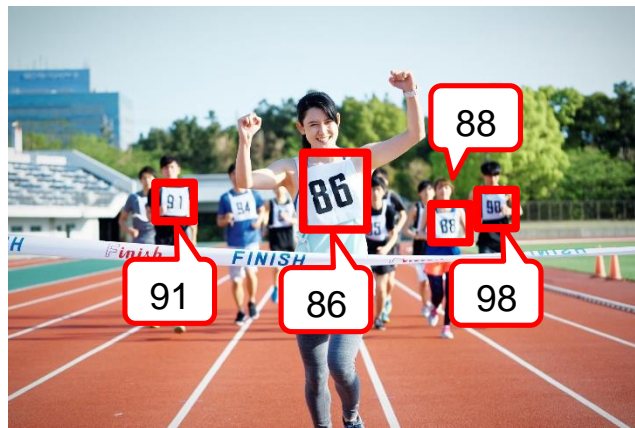
Image Recognition on 5G Network

NUMBER RECOGNITION IN MARATHON

Bib Number Recognition in Marathon

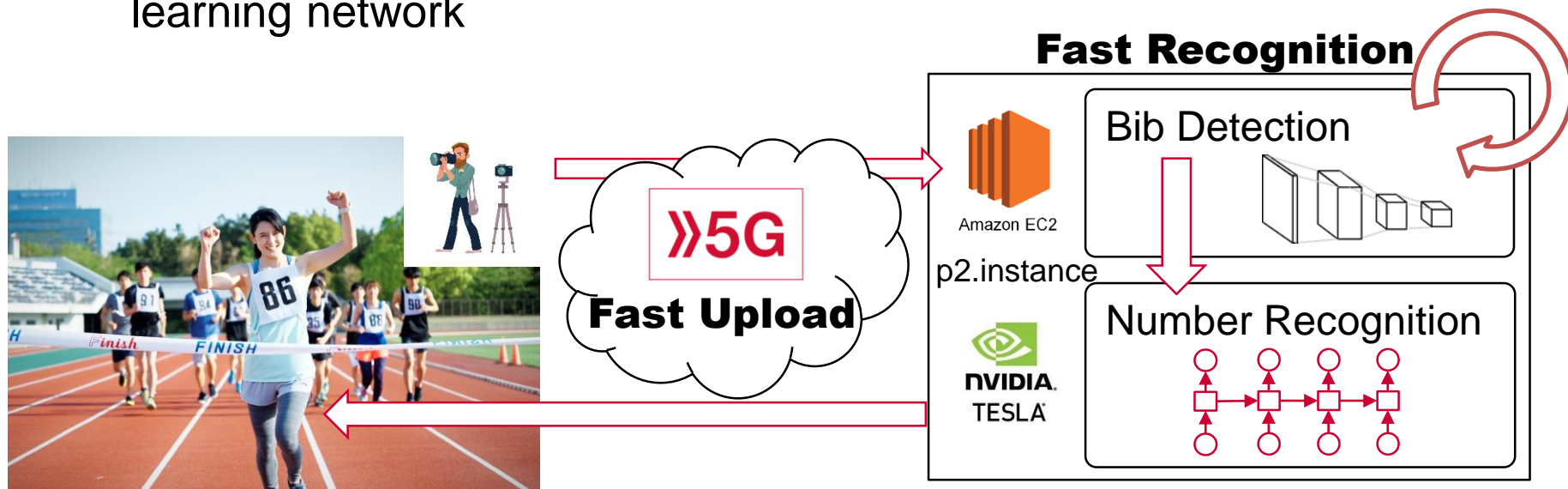
Provide goal scene photo immediately after runners finished

1. Photographers take pictures of marathon runner
2. Our system recognizes bib number from runner photos
3. We provide each picture to runner who is in it



5G for Image Uploading

- Uploading marathon images to cloud via 5G network
- Detecting bib and recognize number on GPU resources using deep learning network



Experiments in Ehime Marathon

- We conducted trial in Ehime Marathon
 - Date: 2/10/2019 10:00-16:00
 - Place: Ehime prefecture in Japan
 - Num. of participants: about 10,000

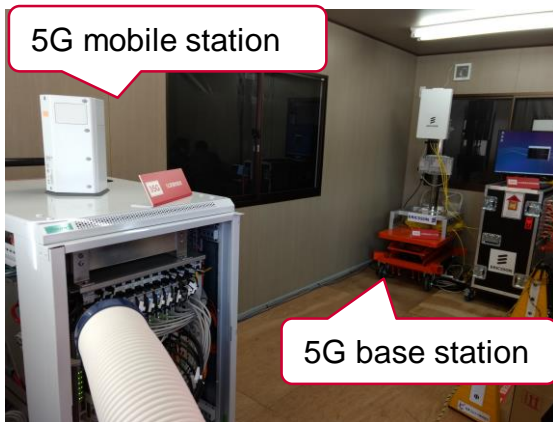


Image Recognition on 5G Network

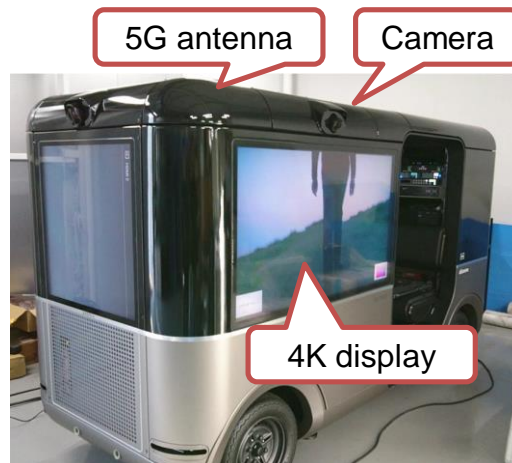
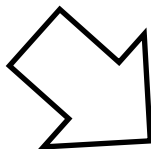
5G ADAPTIVE SIGNAGE CART

Joint trial with Sony

- For real-time transmission of high-definition video via 5G network on 5G concept cart

NTT
docomo

5G



SONY



High-tech vehicle
Camera
Display

Adaptive Signage Cart

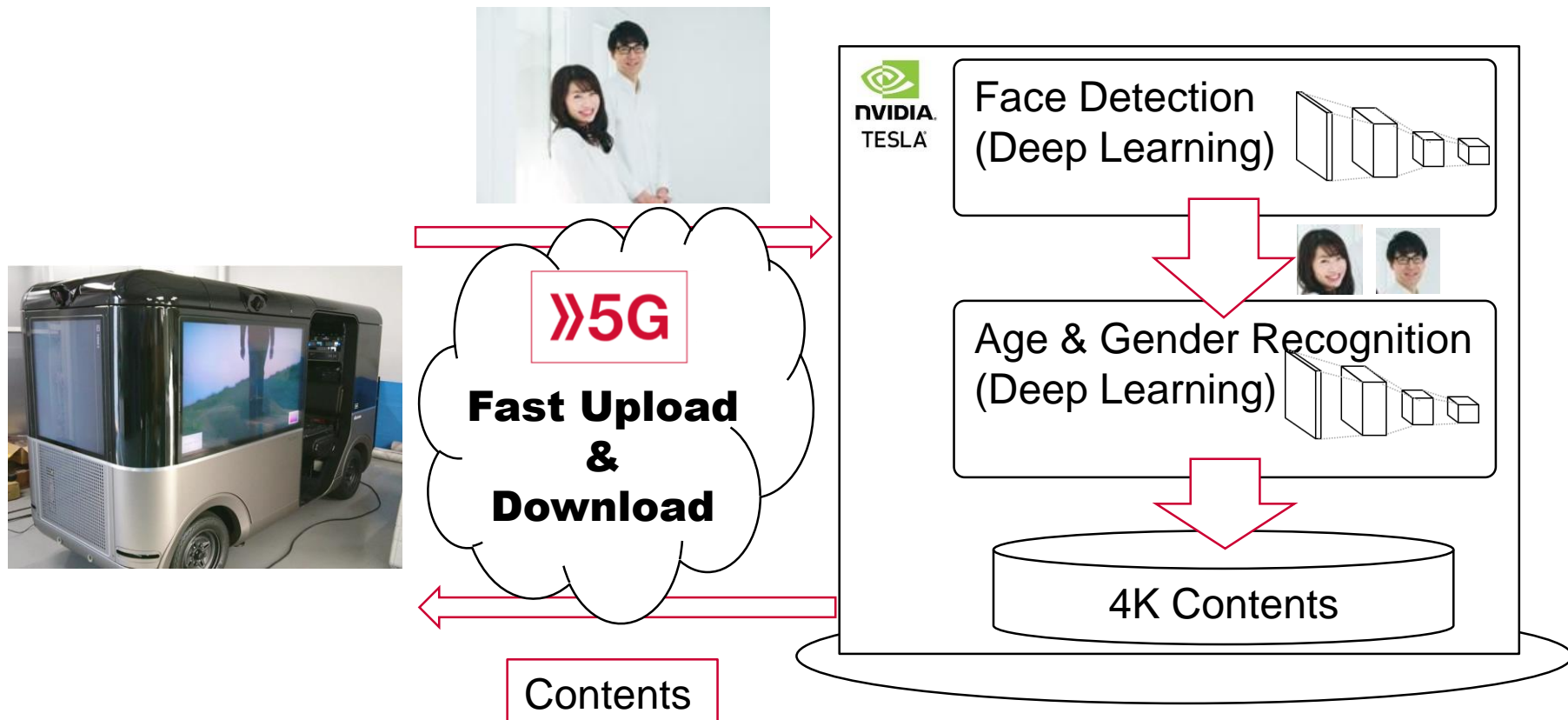
- Adaptive contents delivery to increase advertising effect
 1. Taking photos around cart
 2. Recognizing age & gender
 3. Changing & streaming 4K signage contents according to recognition results



Adaptive Signage Cart Demo

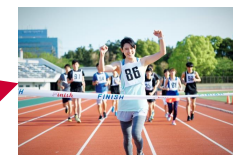
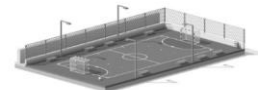
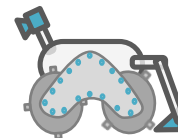


5G for 4K video streaming



Summary of 5G Experiment

- Traditional feature matching
 - Product recognition
- Deep Learning
 - Category classification
 - Object detection
 - Feature based search & clustering
 - Event recognition for video
 - Character recognition+ 5G's higher data rate
 - Face attribute recognition+ 5G's higher data rate



Security

Additional approach to solve security concerns

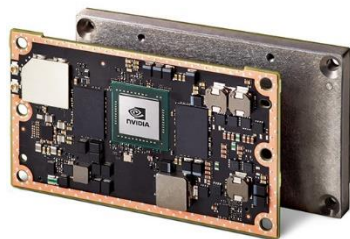
1. Image recognition on edge and cloud
2. DOCOMO Open Innovation Cloud
 - Private cloud connected with dedicated line

Challenges		
Security	Upload/download sensitive images securely	<ul style="list-style-type: none">- Surveillance camera- AI camera in the house

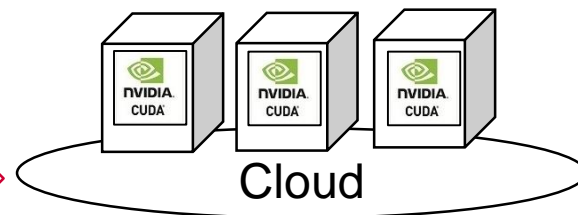
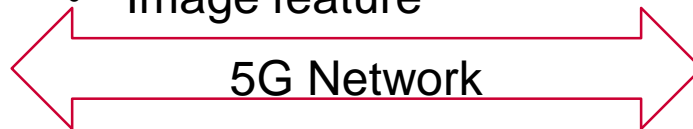
IMAGE RECOGNITION ON BOTH EDGE & CLOUD

Image Recognition on Edge and Cloud

- Convert sensitive image data to no-sensitive one on the edge
- Perform complex image recognition inference on the cloud



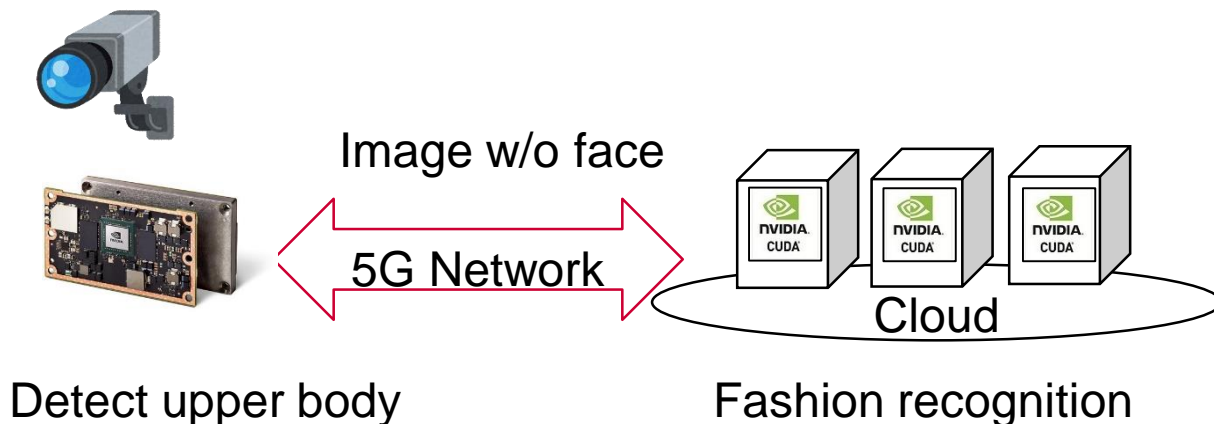
- Non-sensitive image clip
- Image feature



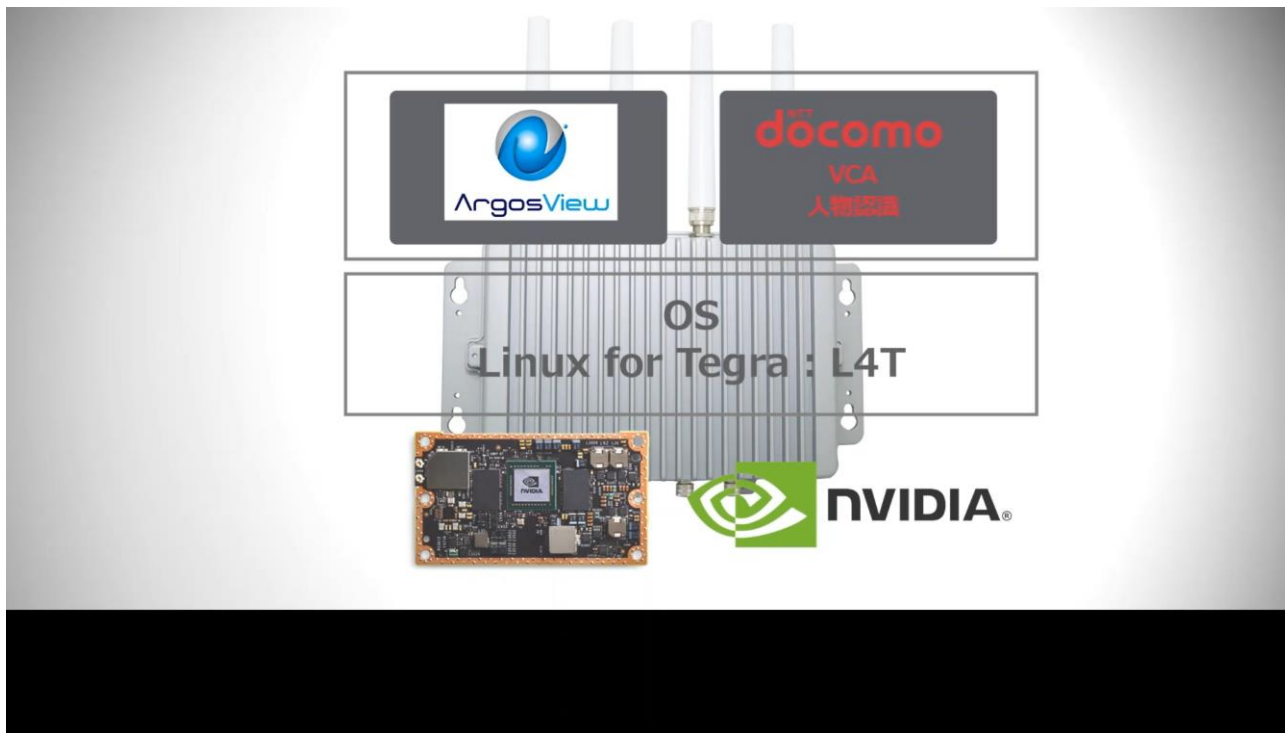
- Convert image to no-sensitive data
 - Object detection and clipping
 - Feature extraction
- Complex deep learning
- Feature matching with large database

Experiment

- Fashion item recognition for surveillance camera
 - Recording movie using surveillance camera
 - Detecting body parts (upper/lower/face) on the edge
 - Uploading upper body image to cloud & inferring item category



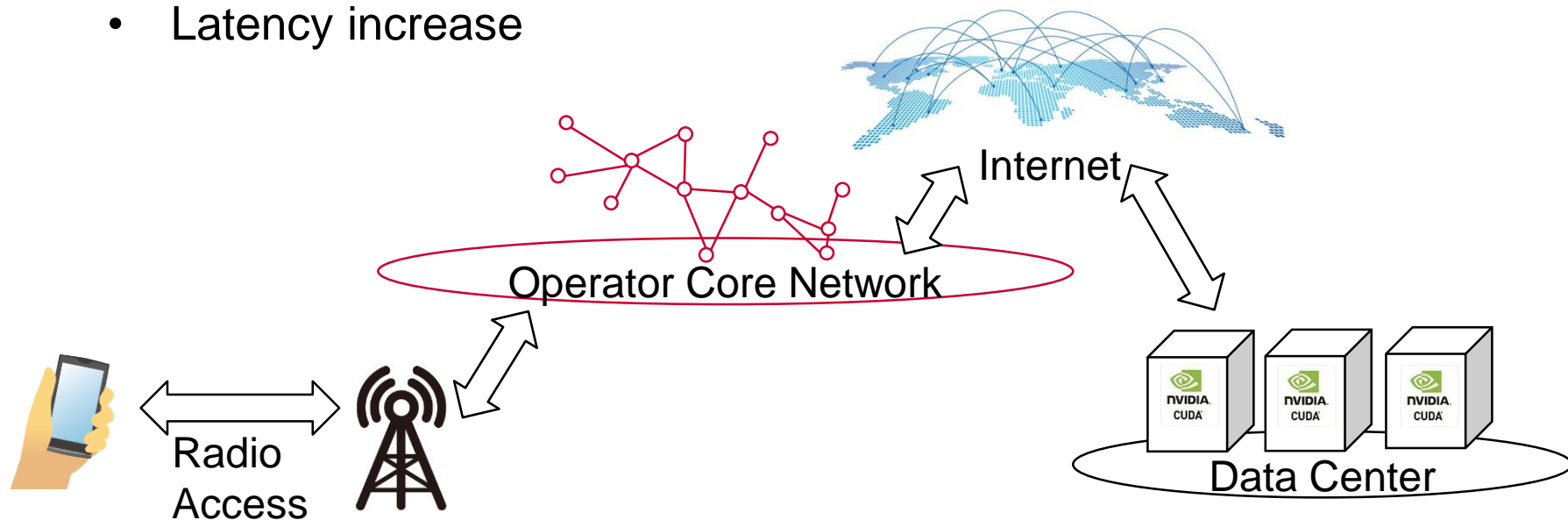
Fashion Item Recognition From Surveillance Camera



DOCOMO OPEN INNOVATION CLOUD

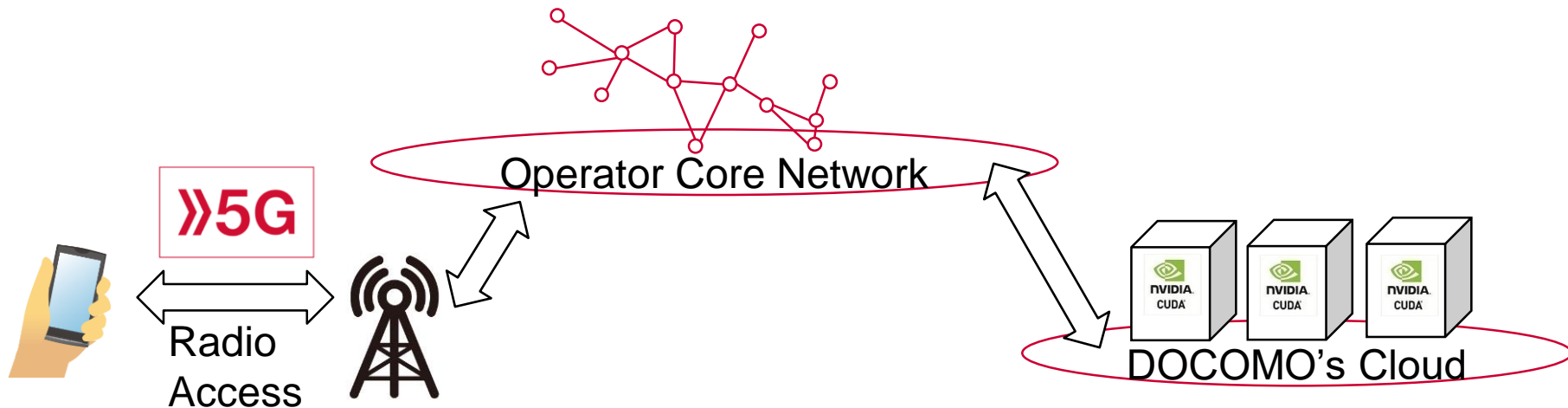
Access Cloud Resource via Mobile Network

- Usually pass through internet when you want to use cloud resource
 - Risk of information leak
 - Latency increase



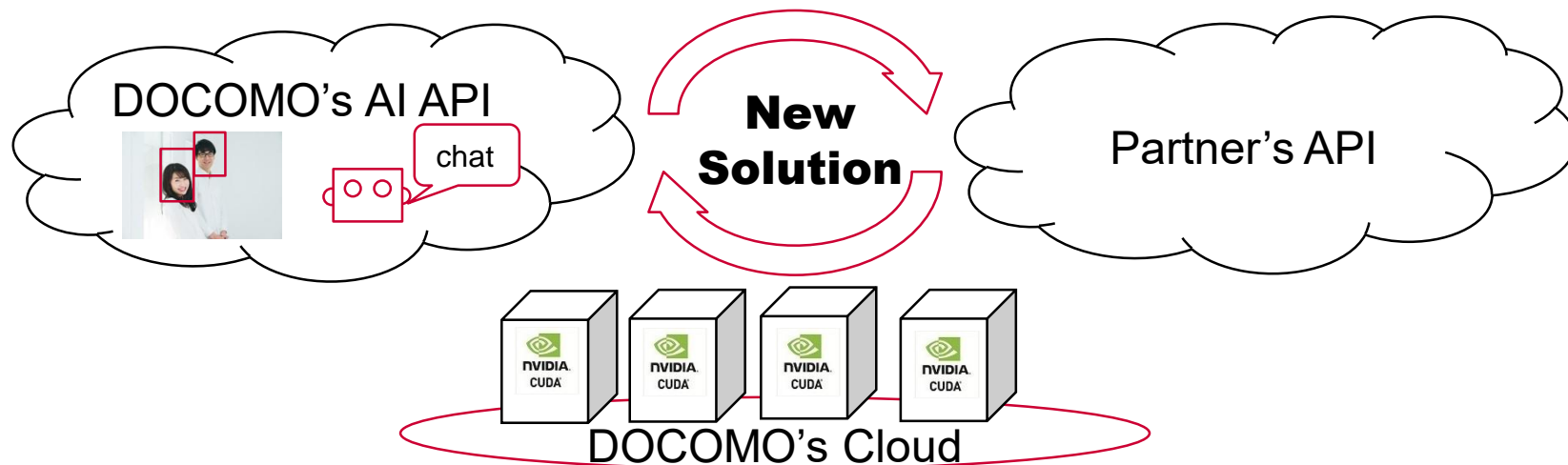
Private Cloud with Dedicated Line

- DOCOMO Open Innovation Cloud is directly connected to cloud resource via DOCOMO's core network
 - Reduce security risk of information leak
 - Reduce latency between mobile devices and cloud resource



For Open Innovation

- Open Innovation Cloud provides useful APIs for your services
 - DOCOMO's AI APIs
 - Partner's API
- You can provide your API & solutions on this cloud



Summary

- NTT DOCOMO is developing image recognition solutions both on the edge and cloud computing
- By connecting devices with cloud resource via mobile network, you can use rich GPUs for image recognition
- 5G network helps us use cloud resource for image recognition because of its characteristic, low latency and higher data rate
- NTT DOCOMO also provides additional solution to enhance the security when using mobile network