Designing a Livestock Monitoring System and Evaluating the Performance of LoRa for a Farm

— Reforming agriculture by information and communications technology in Society 5.0 —

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Introduction of the presenter

• Jinshan Luo is a Master's Course student of a department of engineering, Utsunomiya University. His research interest is ad hoc network technology using LoRa and applying it to construct a sensor network to monitor livestock on a farm.
## Topics of this presentation

<table>
<thead>
<tr>
<th>GOAL</th>
<th>What we developed</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Clarify the relation between the quality of milk and grazing</td>
<td></td>
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<tr>
<td>(2) Monitor the behavior of cows during grazing, such as feeding glass, walking distance, active time, health condition.</td>
<td></td>
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<tr>
<td>(1) To monitor the behavior and health condition of a cow, we developed a sensor network by using LoRa. The communication distance of a large farm in Japan is 4km x 4km. We confirmed that our system can send cow’s data in a farm.</td>
<td></td>
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<td>(2) The LoRa network works by a solar battery.</td>
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</tr>
<tr>
<td>(3) We developed sensor with GNSS and solar panel for a cow to monitor the behavior. Also, we developed a pH sensor to measure rumen pH levels.</td>
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</tbody>
</table>
The part of the research results was obtained from the commissioned research by the National Institute of Information and Communications Technology (NICT), JAPAN. Also, this research is supported by JSPS KAKENHI Grant Number JP17H02249 and JP18K11849.
Situation of livestock business in Japan (1)

The American large-scale herd management method has been promoted. As a result, the traditional Japanese-style breeding management, which has been built based on a trustful relationship with livestock, is being lost.

Fine-grained, low-stress feeding management can reduce morbidity, increase reproductive efficiency, and improve raw milk quality. Breeding management that takes care of each animal and maximizes its individuality and ability leads to the production of high-value-added milk.
Situation of livestock business in Japan (2)

In this situation, grazing is attracting attention. Grazing can manage cows without stress since cows are originally living in the field. Production of high-value-added milk by grazing, feeding behavior of cows during grazing, and health status are not fully elucidated.

We want to clarify the relationship between grazing and quality of raw milk and develop a milk quality estimating system by using sensors, Information and Communication Technology (ICT) and Artificial Intelligence (AI).
Motivation of the research

(1) Clarify the relation between the quality of milk and grazing

(2) Monitor the behavior of cows during grazing, such as feeding glass, walking distance, active time, health condition.
Monitor amount of Activity and Feeding glass

Ph levels of cow’s rumen is normal, bacteria digest glasses.

If eat too much, the rumen becomes acidity and bacteria is dead

If the bacteria is dead, toxin causes liver damage.

Understand the relation among cow’s health, behavior and milk quality
Product from high quality milk, butter and cheese

Construct new business model and food chain

We would like to develop a relation between farmers and local residents and visitors to use and eat products in Tochigi Prefecture.
Society 5.0 for Agriculture

New Style Agriculture
Increase Productivity,
Resolving labor shortages,
Regional revitalization, etc.

New Life Style
Healthy longevity society,
Promoting Japanese food
to foreign countries

New Style Processing
and Distribution
Value Added Products,
Safety Food, Reduce Food
Loss, etc.

Smart Food Chain
Smart Production System

AI + Big Data, Robot

Problems in Japan
Aging of farmers,
Lower self-sufficiency rate,
Shrinking Market, etc.

Problems of Global
Environment
Increasing Population
Lack of food
Sixth sector industrialization of milk

High quality raw milk → High quality butter and cheese → High quality sweets → Gastronomy Tourism

High quality Restaurants → Health Tourism → Regional revitalization

Primary Industry → Secondary Industry → Tertiary Industry
Outline of the research

To support sixth sector industrialization of milk by ICT and AI

- Realtime tracking of cow’s feeding behavior
- Realtime measurement of Ph levels of cow’s rumen

Measure the quality of raw milk

Cloud

- Analysis between the quality of raw milk and behavior and Ph levels
- Development of Machine Learning Model

Feedback to

- Change of grazing area,
- Cattle treatment etc.
R&D Items of this project

- Realtime tracking of cow’s feeding behavior
- Realtime measurement of Ph levels of cow’s rumen (Under construction)
- Develop machine learning model to estimate the quality of milk (Under construction)
Realtime tracking of cow’s feeding behavior

Development:
Develop a sensor that has GPS and accelerometer.
From the accelerometer we can get the number of steps and chewing

Problem:
(1) Design of the sensor box
(2) Low power consumption (sensors and transmission)

For the transmission, we decided to use LoRa
Devices for experiment of LoRa

- BW: 62.5KHz
- SF: 12
- Tx power: 13dbm
- LoRa chip: ES920LR
- gain of the antenna: 0dbi

Transmitter

Receiver

The LoRa chip: ES920LR
# The Effect of SF and BW  
*(From the Data Sheet of ES920LR)*

Payload is 10 bytes

<table>
<thead>
<tr>
<th>Band Width (BW) (KHz)</th>
<th>Spreading Factor (SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7</td>
</tr>
<tr>
<td>62.5</td>
<td>144</td>
</tr>
<tr>
<td>125</td>
<td>72</td>
</tr>
<tr>
<td>250</td>
<td>36</td>
</tr>
<tr>
<td>500</td>
<td>18</td>
</tr>
</tbody>
</table>

Combination of BW x SF good for the long range communication (62.5KHz, SF=12)

Combination of BW x SF good to send large data (500KHz, SF=7)
### PAYLOAD IS 50 BYTES

<table>
<thead>
<tr>
<th>Band Width (KHz)</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>62.5</td>
<td>308</td>
<td>534</td>
<td>903</td>
<td>1642</td>
<td>2957</td>
<td>5587</td>
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<tr>
<td>125</td>
<td>154</td>
<td>267</td>
<td>452</td>
<td>821</td>
<td>1479</td>
<td>2793</td>
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<td>250</td>
<td>77</td>
<td>133</td>
<td>226</td>
<td>411</td>
<td>739</td>
<td>1397</td>
</tr>
<tr>
<td>500</td>
<td>38</td>
<td>67</td>
<td>113</td>
<td>205</td>
<td>370</td>
<td>698</td>
</tr>
</tbody>
</table>
Ozasa Farm

One of the largest farm in Japan. About 400 ha (4km x 4km)
Experiment at Ozasa farm

Trace of transmitter (sending GPS data)

Plot of received GPS data
Receiving rate of LoRa at Ozasa Farm

<table>
<thead>
<tr>
<th></th>
<th>Transmitter 1</th>
<th>Transmitter 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>The number of transmitted messages</td>
<td>2884</td>
<td>2507</td>
<td>5391</td>
</tr>
<tr>
<td>The number of received messages</td>
<td>2272</td>
<td>2113</td>
<td>4385</td>
</tr>
<tr>
<td>Message Receiving Rate</td>
<td>78.78%</td>
<td>84.28%</td>
<td>81.34%</td>
</tr>
</tbody>
</table>
Okumura-Hata Model

Okumura Hata Model was developed in Japan to design the mobile communication network.

\[
\text{Loss(dB)} = A + B \log(d) - \alpha + C
\]

where
\[
A = 69.55 + 26.16 \log[f(MHz)] - 13.82 \log[h_b(m)]
\]
\[
B = 44.9 - 6.55 \log[h_b(m)]
\]
\[
f(MHz): \text{Frequency,}
\]
\[
d(km): \text{Distance,}
\]
\[
h_b(m): \text{Base station height}
\]

\( \alpha \) and \( C \) depend on the location.
For example, the location is an open space, \( \alpha \) and \( C \) are defined as follows;
\[
\alpha = \{1.1 \log[f(MHz)] - 0.7\} h_m(m) - \{1.56 \log[f(MHz)] - 0.8\}
\]
\[
C = -4.78 \{\log[f(MHz)]\}^2 + 18.33 \log[f(MHz)] - 40.94
\]

\( h_m(m) \): Mobile station height
LoRa Receiver

Farm Area

Point A

Point B

1.5km
Okumura-Hata Curve

- Power (dbm)
- Distance (km)

- Point A
- Point B

Receiving Power Limit (-142)
The farm of Utsunomiya University

1km x 0.5km
Another trial in Utsunomiya

Trace of transmitter (sending GPS data)

Plot of received GPS data

4.2km
Okumura-Hata curve

- **Band**: 900MHz
- **TX Power**: 13dbm
- **Height TX**: 1.5m
- **Height RX**: 20m
- **Antenna Gain**: 0dbi
Devices

Cow’s sensor with solar panel

LoRa

LoRa Basestation with solar panel

Zigbee

3G/4G

Cloud
Conclusion

• The feasibility of using LoRa to monitor cows' behavior and health condition was proved because LoRa can send data such as location (GNSS) about 2km on the real farm in mountain area (Ozasa farm).

• As the next step, we would like to estimate a cow's health condition and find the effectiveness of grazing to increase the quality of milk by AI.

• As we briefly addressed the broader scope of a new food chain business model based on the Society 5.0 context, we would like to construct the “sixth sector industrialization” of milk by using these technologies.
• Thank you for reading this slide.
• If you have questions, please contact the following email addresses.
  • Atsushi Ito (at.ito@is.utsunomiya-u.ac.jp)
  • Jinshan Luo (kingsamlawsan@gmail.com)