

先端技術を活用した海辺・水辺の安全管理



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先端技術を活用した海辺・水辺の安全管理

海岸工学

海水浴場
リスク評価

水難事故
データ分析

海辺のみまも
りシステム

Pool 溺水事故
防止システム

VR
Eye-tracking



先端技術を活用した海辺の安全管理

水難事故の実態

水難事故の実態

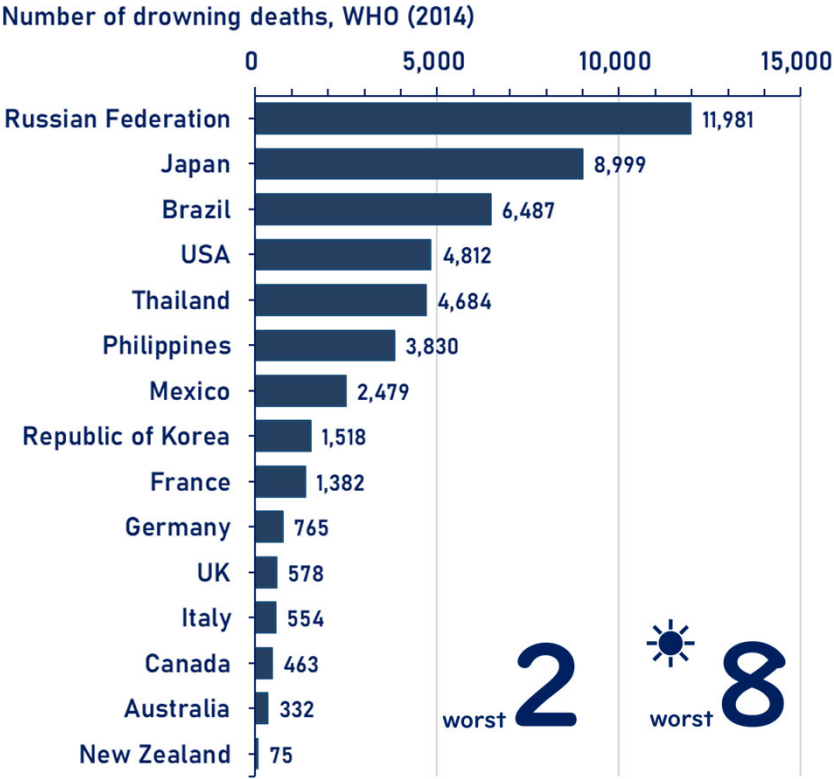


Fig. 1 国別の溺死総数,WHO

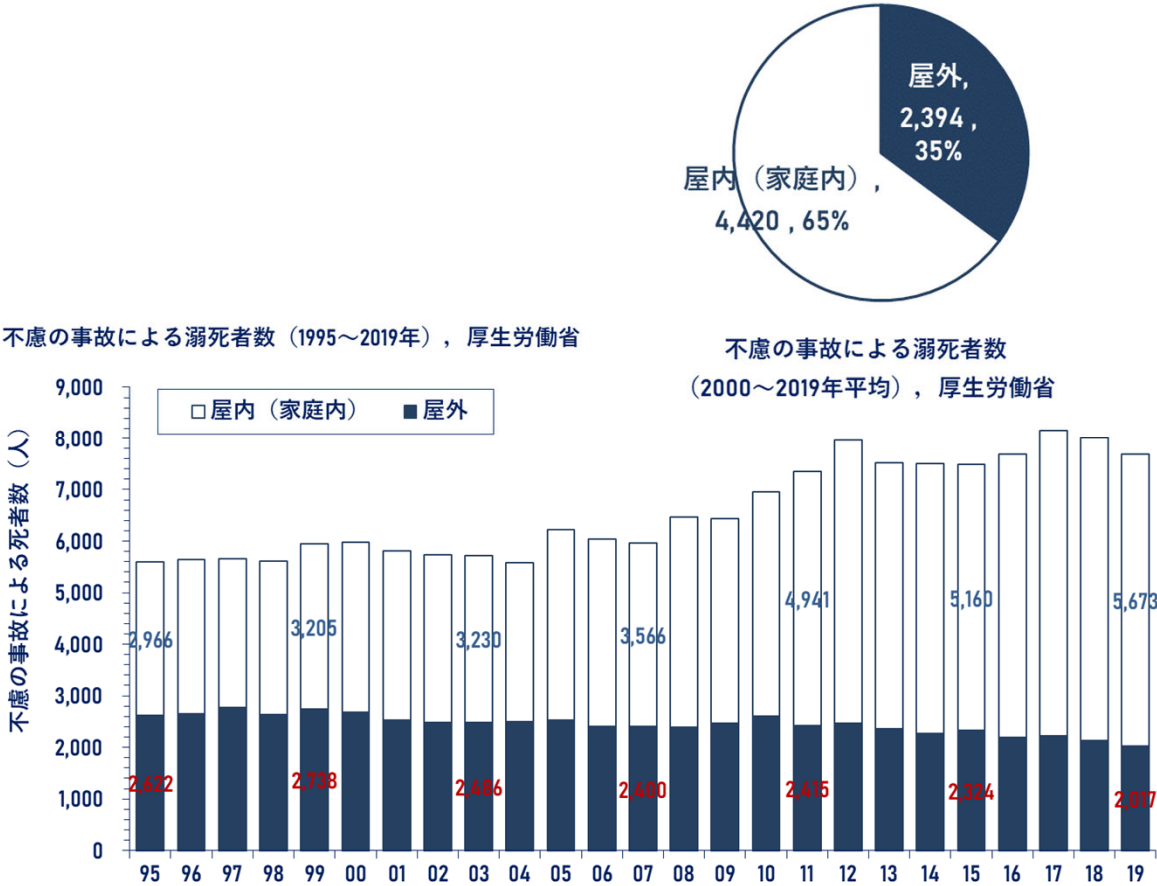


Fig. 2 不慮の溺水事故による死者数, 厚生労働省

水難事故の実態

1995

 × 0.4

2022

 × 2.5

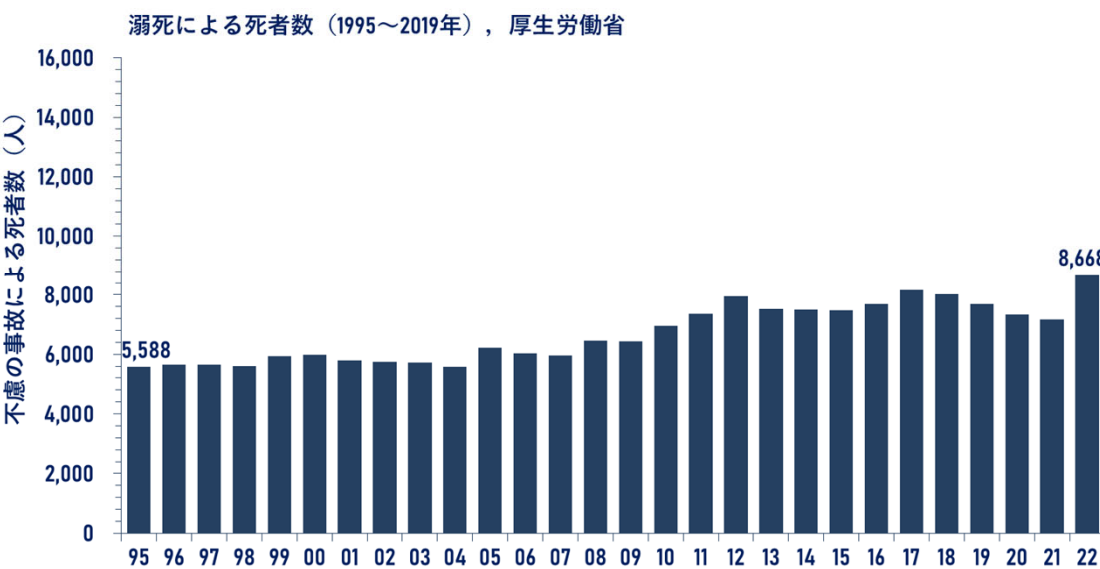
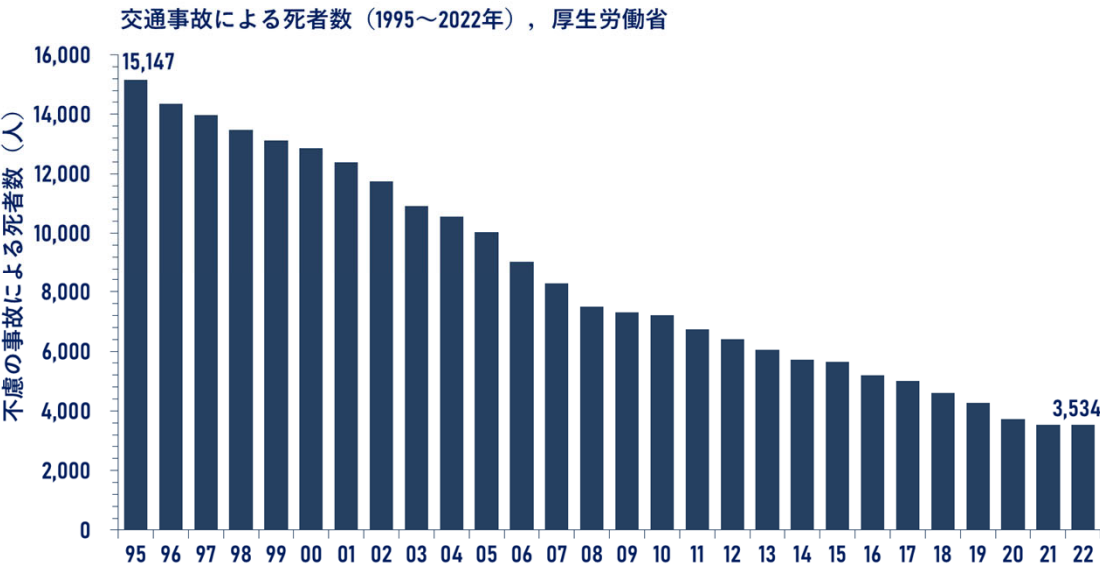


Fig. 3 不慮の事故による死者数の経年変化，厚生労働省

水難事故の実態

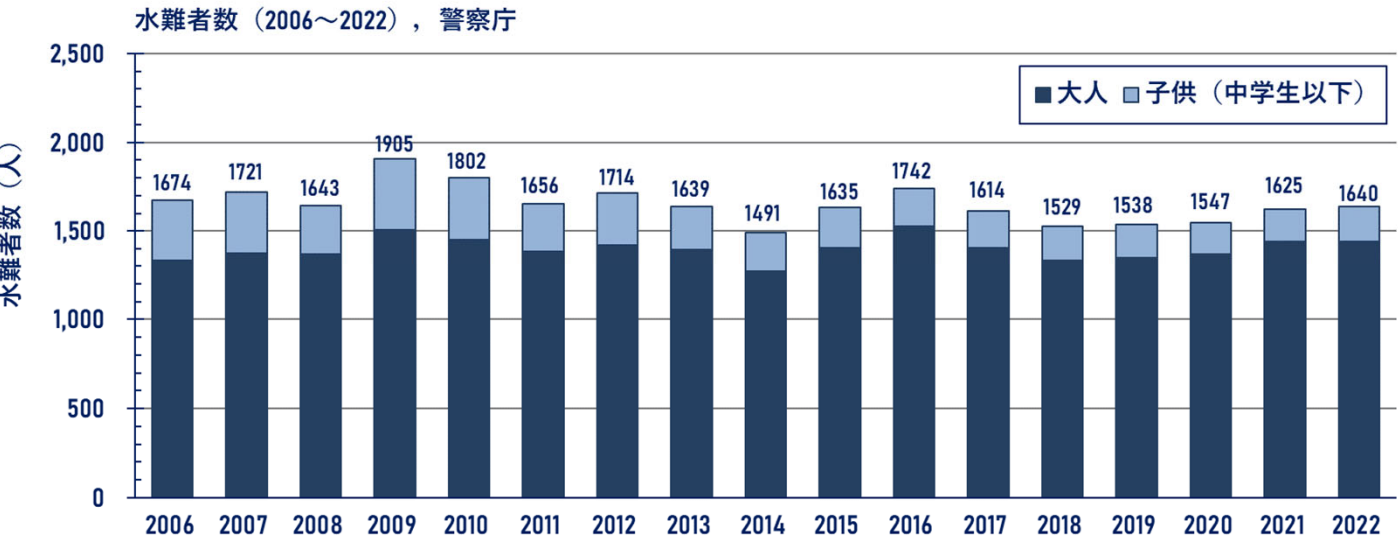


Fig. 4 水難者数（生存，死者・行方不明者）の経年変化，警察庁

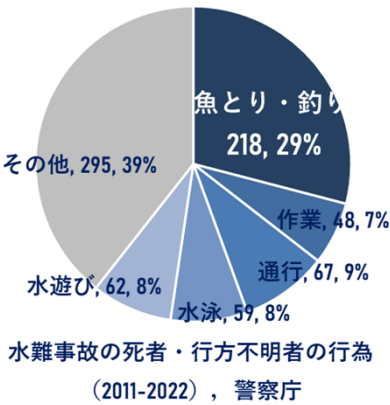
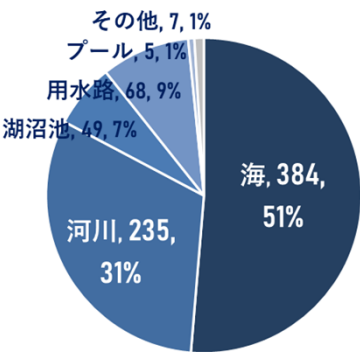


Fig. 5 水難事故（死者・行方不明者）の発生場所と行為 (2011-2022) , 警察庁

水難事故の実態

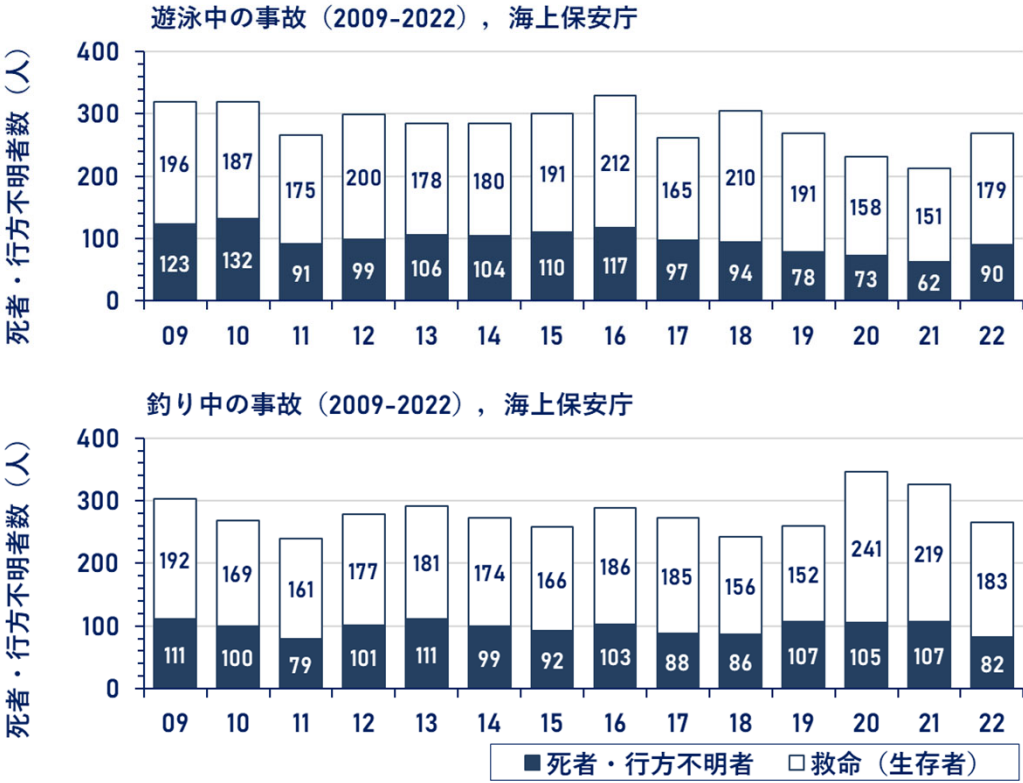


Fig. 6 遊泳中と釣り中の月別発生数（2009-2022年平均値），海上保安庁



Fig. 7 海浜事故等の事故内容別生存割合（2009-2019），海上保安庁

水難事故の実態



救急搬送に至らない救助。重大な事故に至る前に救助、安全移送したレスキュー活動。



意識なし、心肺停止など重症な要救助者の救助

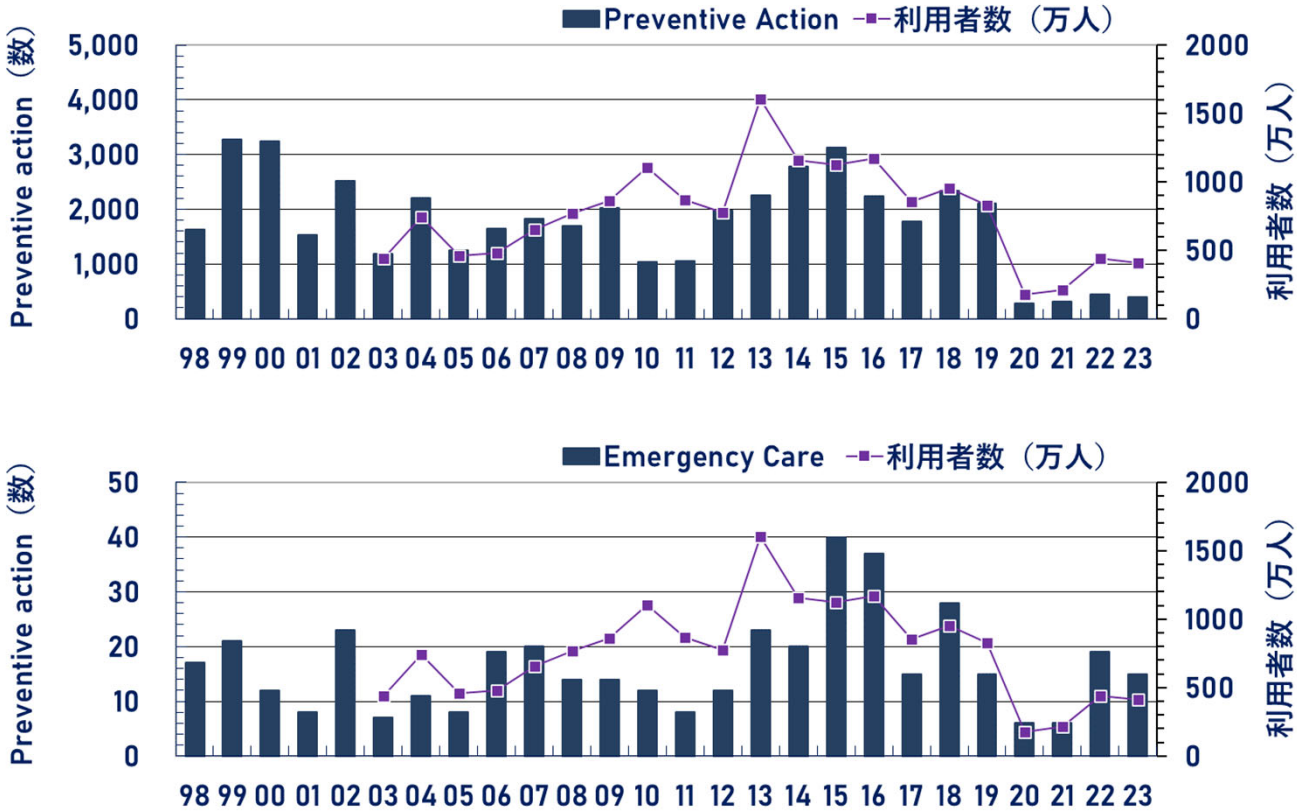


Fig. 8 ライフセーバーが活動する海水浴場での救助件数, JLA

水難事故の実態

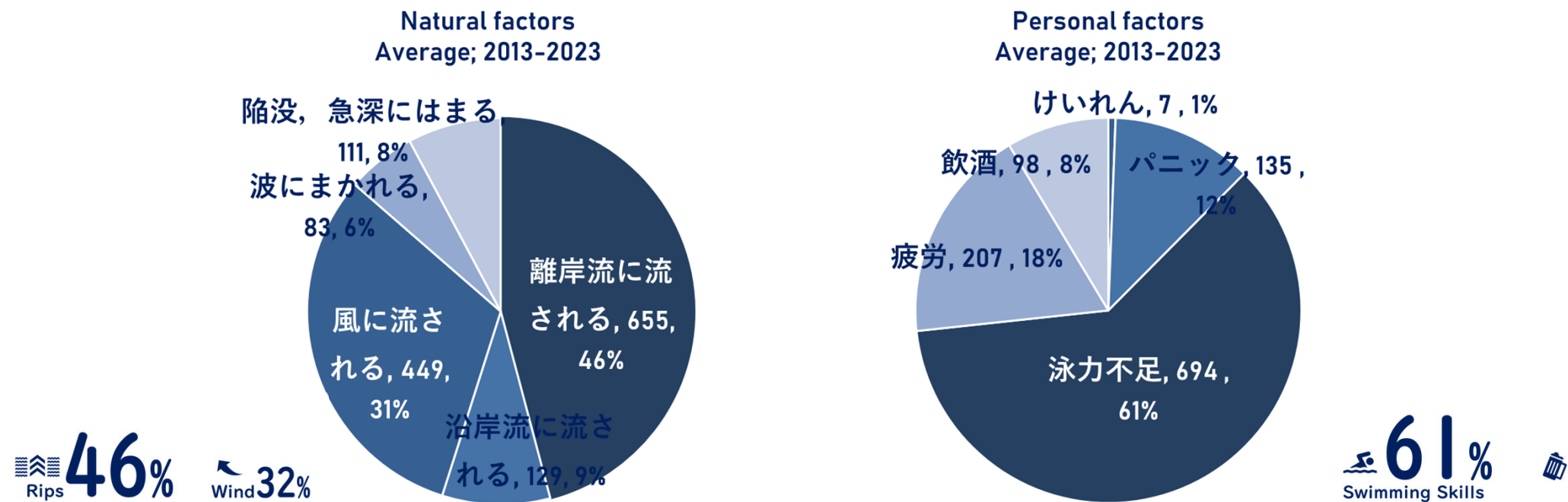


Fig. 9 レスキュー（溺れ）の自然要因, JLA

水難事故の実態



水難事故の実態



水難事故の実態



水難事故の実態

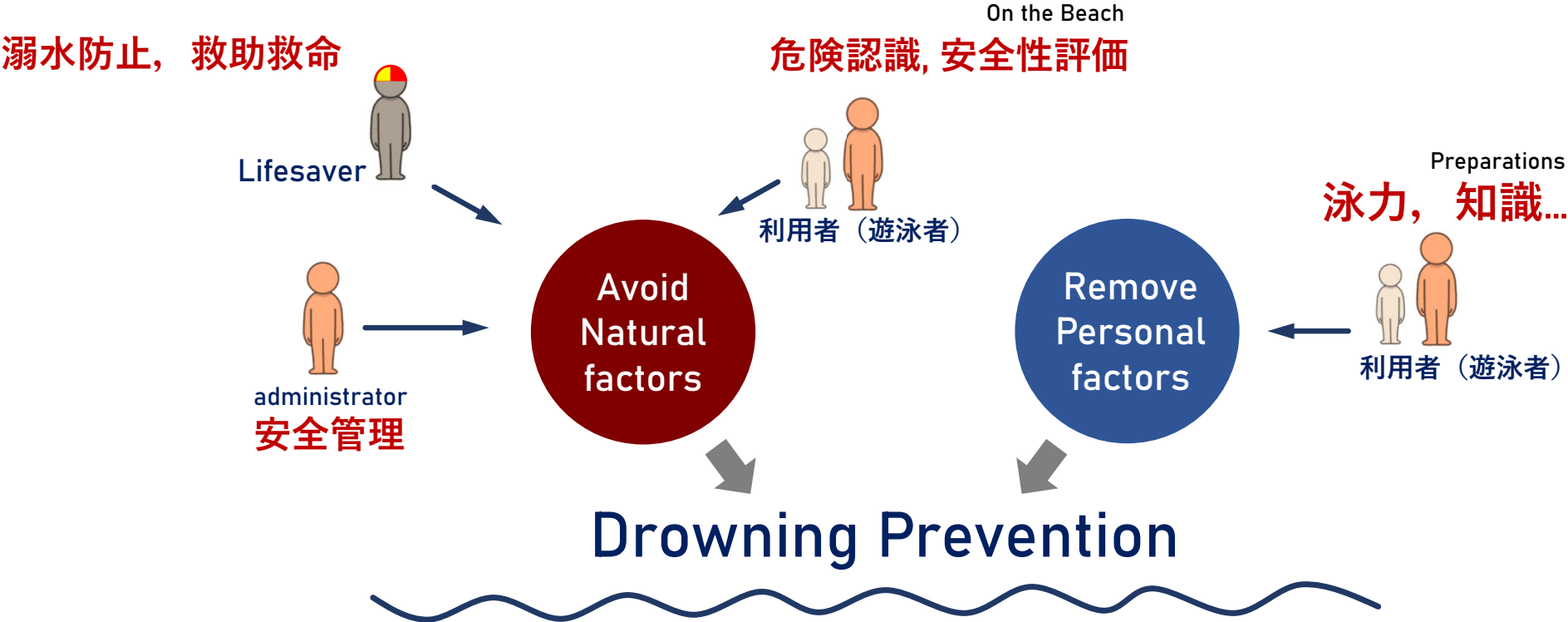
溺死の場合、溺れを目撃してから4分以内のCPR開始が要救助者の社会復帰につながる。 ➡ 迅速な救助救命。

Table. 1 海水浴場における溺死に対するライフセーバーのBLS効果
(2009～2014年, 86CPR症例のうちデータ分析が可能な44CPR症例に対する調査結果)

	溺死CPA症例 (n=44)		目撃あり (n=22)		目撃なし (n=22)	
溺者の特徴等						
平均年齢	36.2		32.9		39.4	
男性 (割合)	40	[91%]	20	[91%]	20	[91%]
ライフセーバーによるCPR	44	[100%]	22	[100%]	22	[100%]
処置の有無						
人工呼吸	44	[100%]	22	[100%]	22	[100%]
AEDの適用	41	[93%]	20	[91%]	21	[96%]
除細動	4	[9%]	3	[14%]	1	[5%]
結果						
心拍再開	15	[34%]	15	[68%]	0	[0%]
1ヶ月後生存率	13	[30%]	13	[59%]	0	[0%]
社会復帰率 (CPC1-2)	13	[30%]	13	[59%]	0	[0%]
救命に関する時間						
CPRを開始するまでの平均時間 (分)	6.7		4.2		9.3	
現場における心拍再開までの時間 (分)	8.1		8.1			



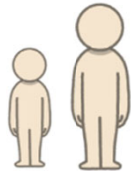
出典:T. Komine, H. Tanaka, H. Takyu, T. Kinoshi, S. Gotoh,E. Sone, R. Sagisaka, T. Ishikawa, S. Shimazaki; Effectiveness of surf lifesaver on OHCA occurred by drowning on the beaches in Japan. 8th Asian Conference for Emergency Medicine.



水難事故の実態

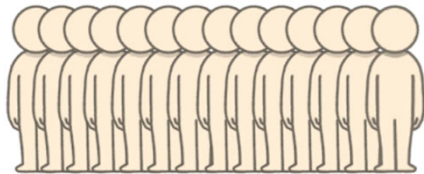
Avoid
Natural
factors

危険認識, 安全性評価



利用者 (遊泳者)

Difficulty of risk recognition and judgement under the momentary change in natural phenomena.
Especially understanding of Rip currents.



1 Lifesaver vs. over 1,000 beachgoers

The number of lifesavers is small at around 1 lifesaver compared to the thousands of beachgoers.



Swimming area

Beachgoers sometimes enter unpatrolled areas outside the swimming areas.

先端技術を活用した海辺の安全管理

AIとIoTを活用した“海辺のみまもりシステム”

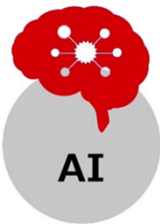
AIとIoTを活用した“海辺のみまもりシステム”

2018

システム開発



Take photos of the surface image



AI analyzes the image data in real time

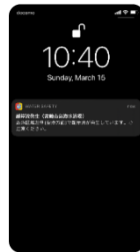
At time of
Rip current generation



Beachgoers and swimmers enter
into the Rip current area



System automatically informs it to the digital signage and beach-goer's smart phone.



System informs it to lifesaver's wearable device. Then, Lifesavers can take early action. A drone can fly automatically by linkage with the AI rip current detection.



Fig. 10 海辺のみまもりシステムの概要

AIとIoTを活用した“海辺のみまもりシステム”

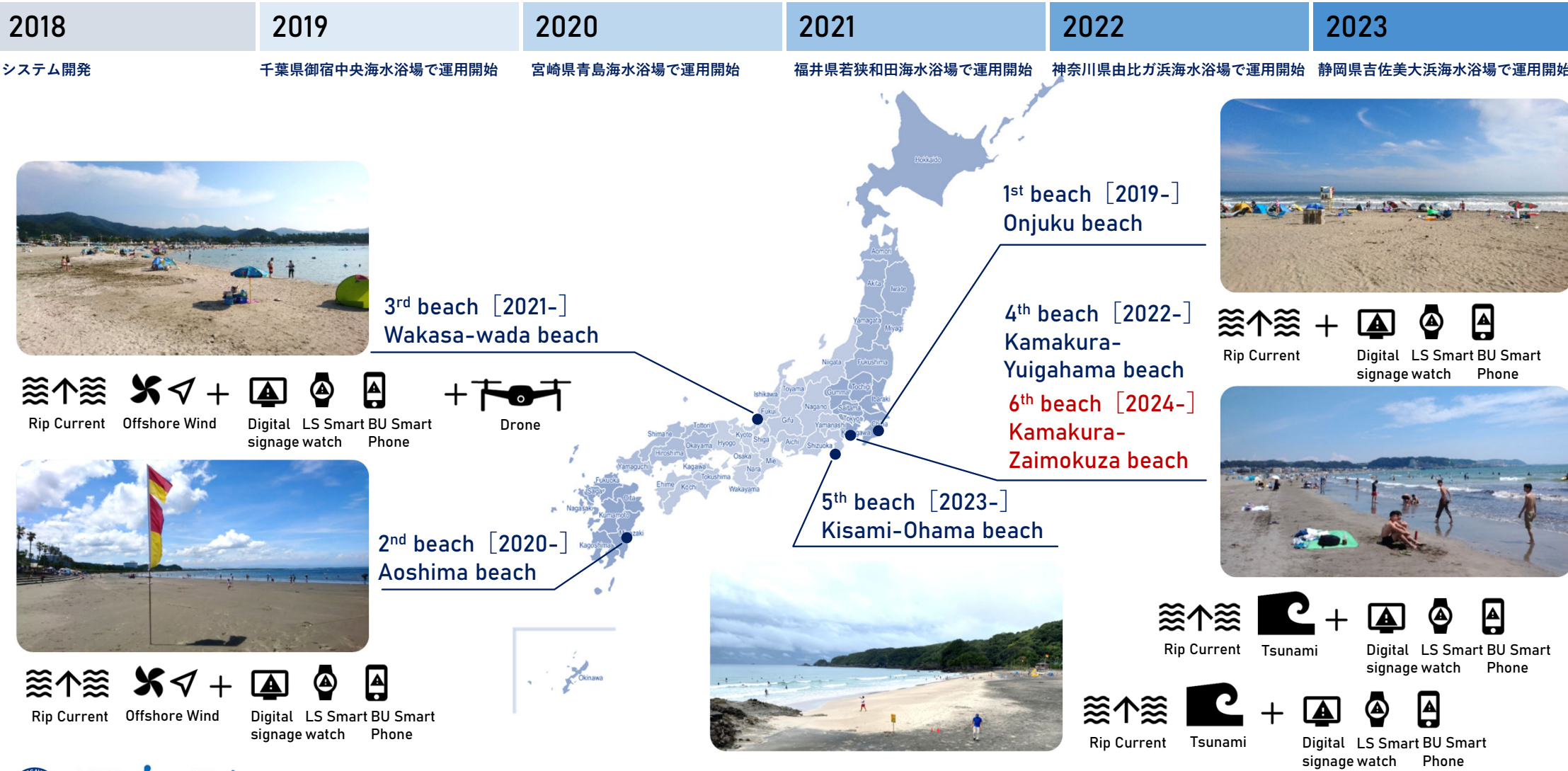
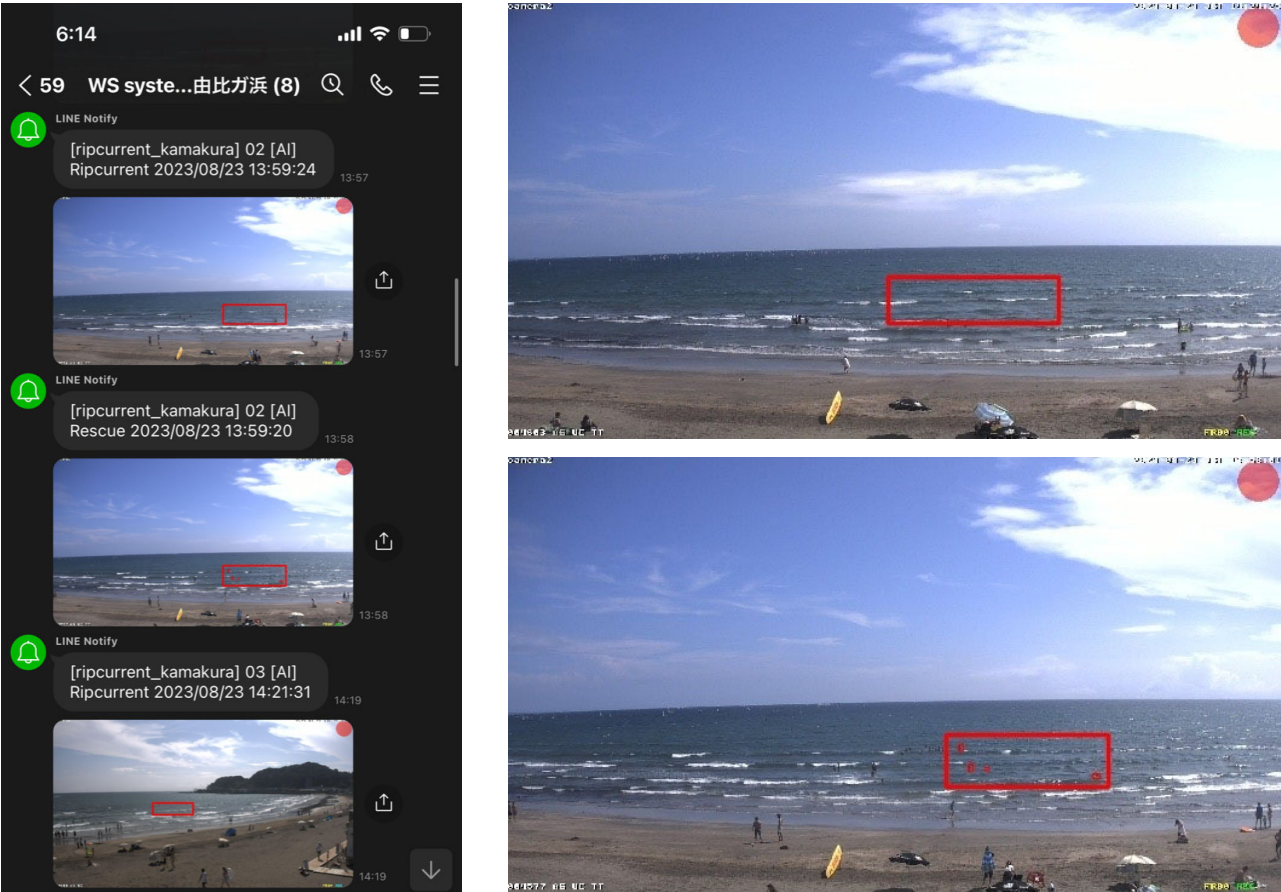


Fig. 11 海辺のみまもりシステム運用海岸（2024年9月時点）

AIとIoTを活用した“海辺のみまもりシステム”



離岸流と離岸流エリア内の人の検知例，2023年8月23日

Fig. 12 海辺のみまもりシステムによるライフガード，ライフセーバーへの通知結果の例

AIとIoTを活用した“海辺のみまもりシステム”



DL 8,807人 (2024.3.31)



Fig. 13 Water Safetyアプリの概要

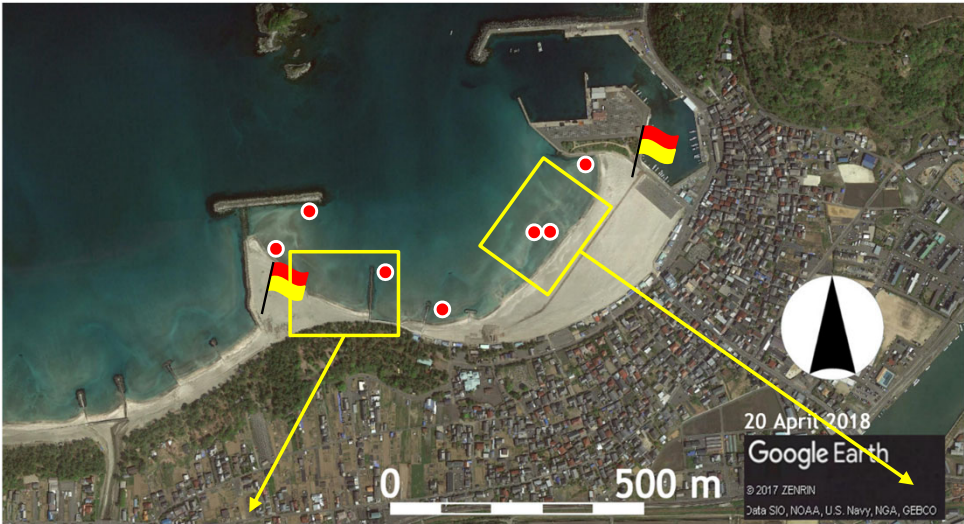
AIとIoTを活用した“海辺のみまもりシステム”



Fig. 14 海辺のみまもりシステムによる実際のレスキューの例（千葉県御宿中央海水浴場 Cam 1の撮影範囲）

動画； <https://ls.jla-lifesaving.or.jp/accident-prevention/mimamori-system/>

AIとIoTを活用した“海辺のみまもりシステム”



[Rip current survey]

February 24, 2021 13:00-15:00

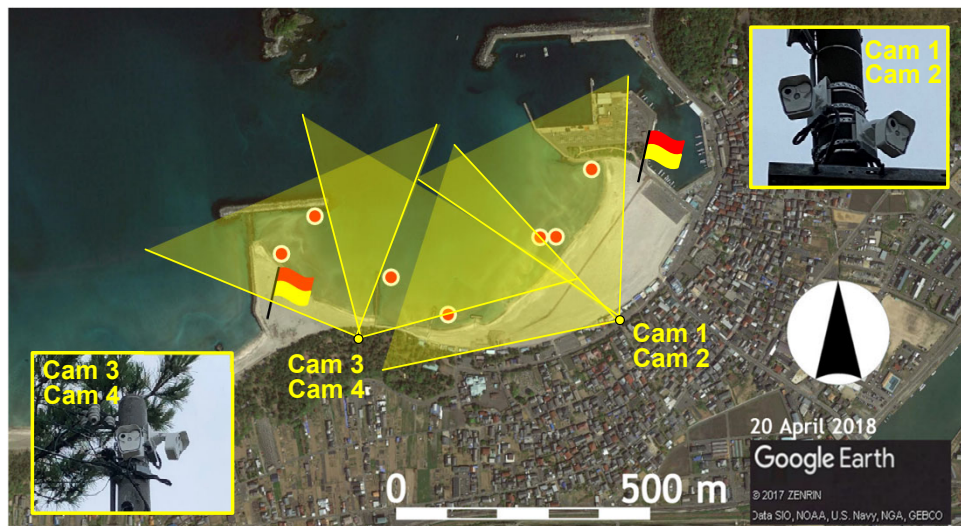
Breaking wave height; about 0.5 m, tide level DL+0.05 m

Observed waves at NOWPHAS wave observation point (53 km northeast of the target coast); $H_{1/3} = 1.15$ m, $T_{1/3} = 7.8$ s



Fig. 15 Results of color dye survey

AIとIoTを活用した“海辺のみまもりシステム”



4 web cameras were installed on the beach so that these locations would be within the shooting range of the fixed-point camera.



Fig. 16 Images of shooting areas by 4 web cameras

AIとIoTを活用した“海辺のみまもりシステム”

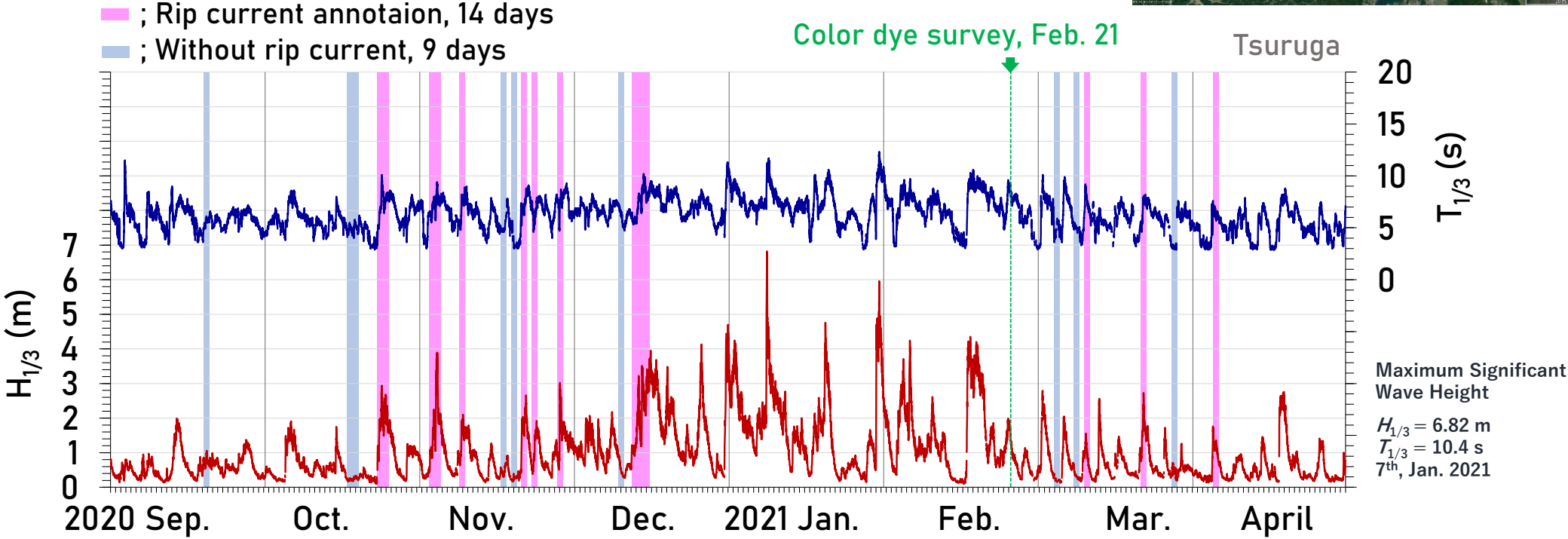


Fig. 17 Wave conditions during image data acquisition period used for AI learning. (1st Sep. 2020 – 30th April 2021)

AIとIoTを活用した“海辺のみまもりシステム”

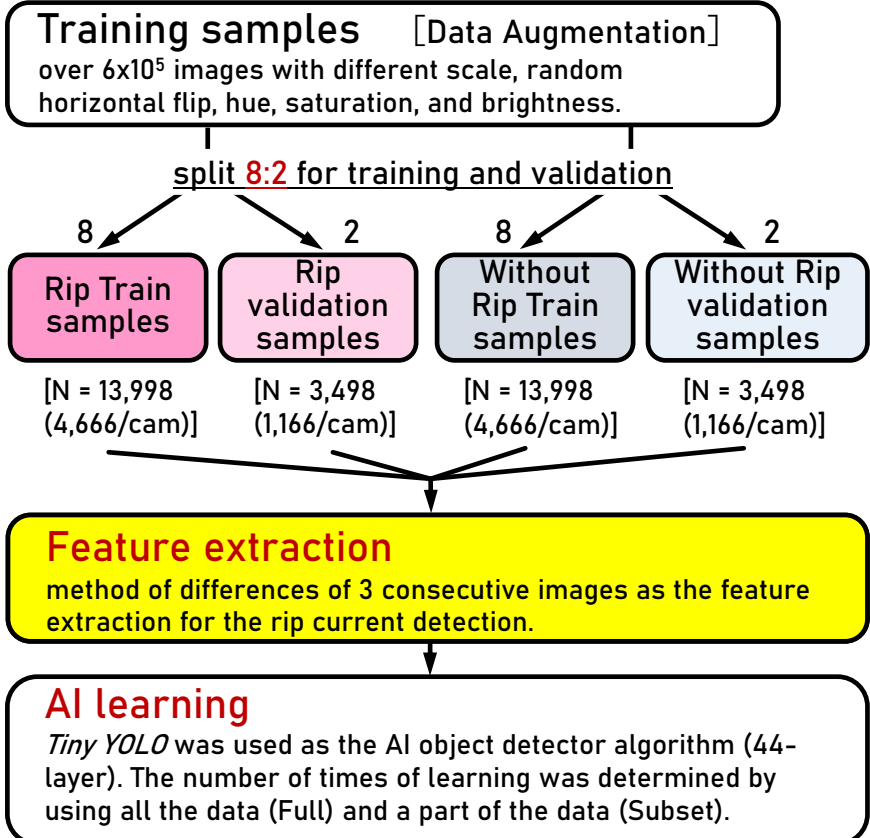
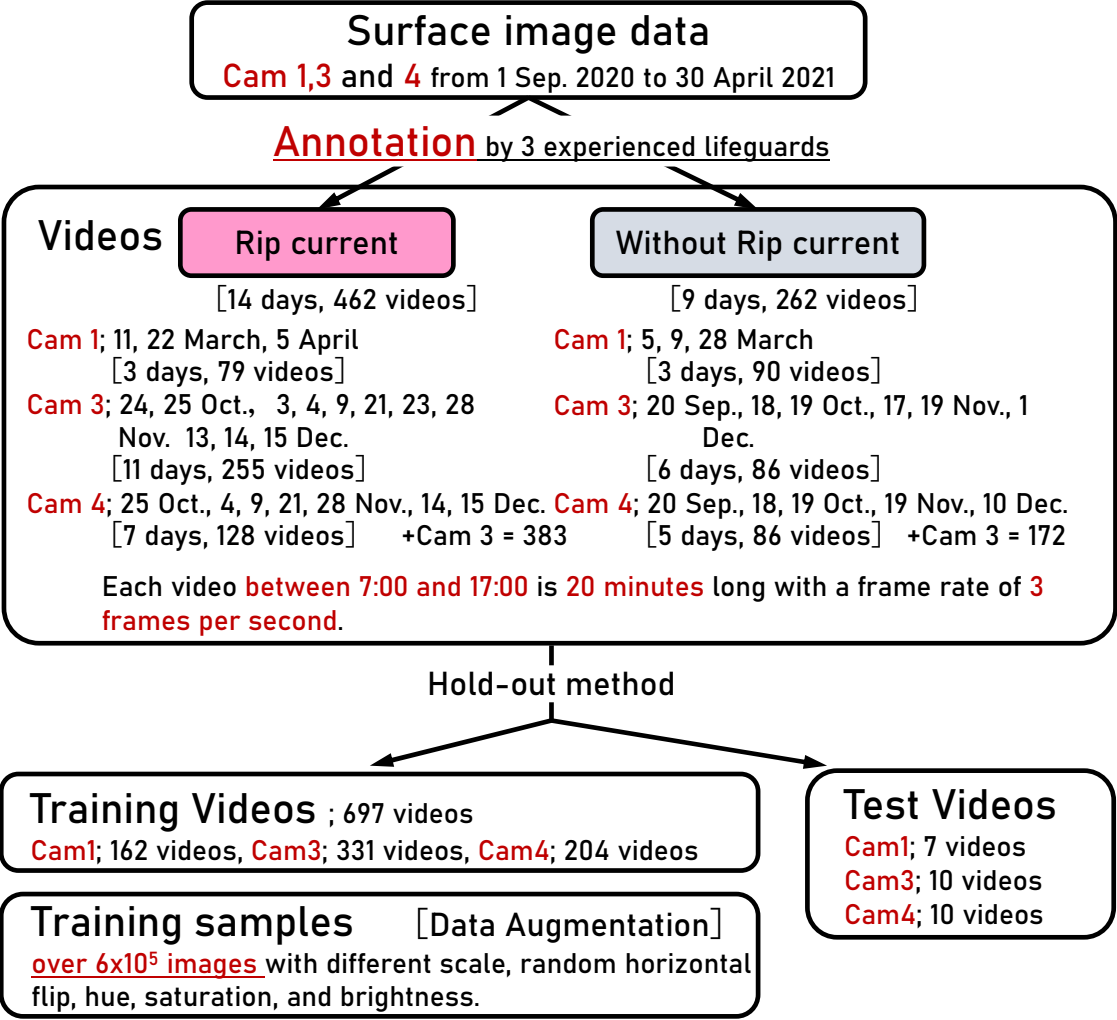


Fig. 18 AI learning method and composition of data

AIとIoTを活用した“海辺のみまもりシステム”

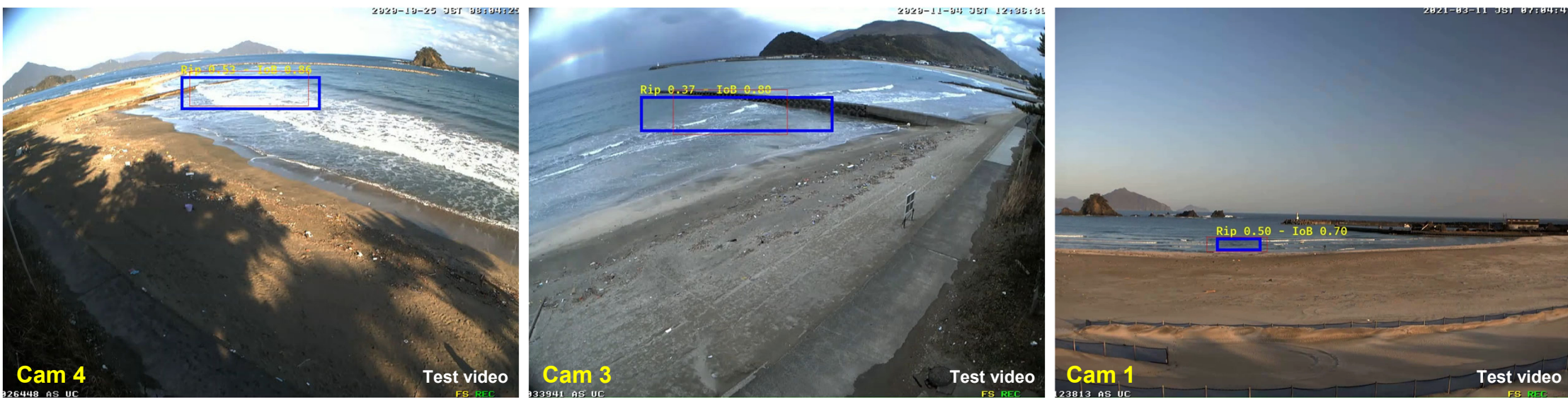


Fig. 19 Comparison of the rip current detection by AI and the annotation area.

Table 1 AI model evaluation method

Accuracy	Percentage of correctly detected rip currents and without rip currents $(TP+TN)/(TP+FP+FN+TN)$
Precision	Percentage of correctly detected rip currents. $TP/(TP+FP)$
Recall	Percentage of correct detections for all test rip current data. $TP/(TP+FN)$
F measure	Harmonic Mean of Precision and Recall. $(2 \times \text{Precision} \times \text{Recall}) / (\text{Precision} + \text{Recall})$

Table 2 Verification results of created AI model.

data	Accuracy	Precision	Recall	F-Measure
All	0.87	0.48	1.00	0.65
Cam 1	0.84	0.71	1.00	0.83
Cam 3	0.86	0.19	1.00	0.32
Cam 4	0.89	0.23	1.00	0.37

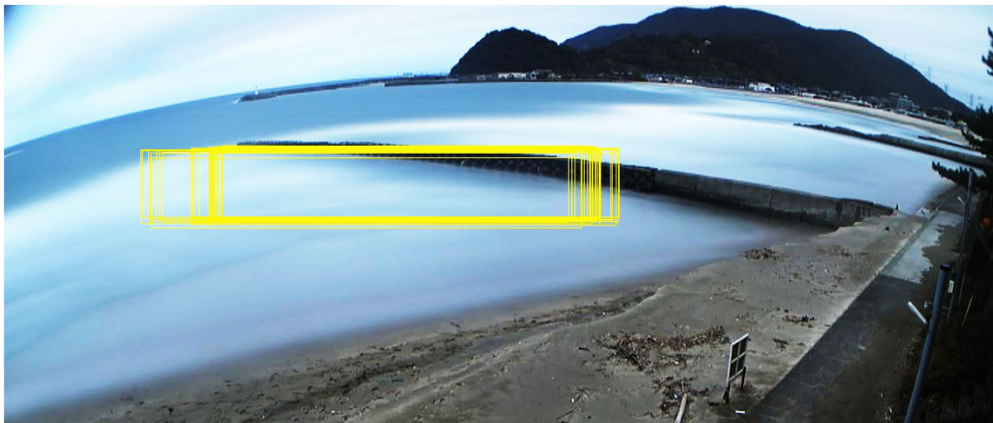
Confidence 0.3, Intersection over Unit 0.3, Skip 3 frames(/s)

TP: True Positive, The result of AI judged as a rip current is correct.
FP: False Positive, The result of AI judged as a rip current is false.
FN: False Negative, The result of AI judged as a without rip current is false.
TN: True Negative, The result of AI judged as a without rip current is correct.

AIとIoTを活用した“海辺のみまもりシステム”



(a) Shooting image 12:00, October 23, 2021



(b) Detection areas overlaid an averaged image from 12:00 to 13:00

Fig.21 Example of rip current detection results by AI of Cam 3.



(a) Shooting image 12:00, October 23, 2021



(b) Detection areas overlaid an averaged image from 12:00 to 13:00

Fig.20 Example of rip current detection results by AI of Cam 1.

Numerical simulation

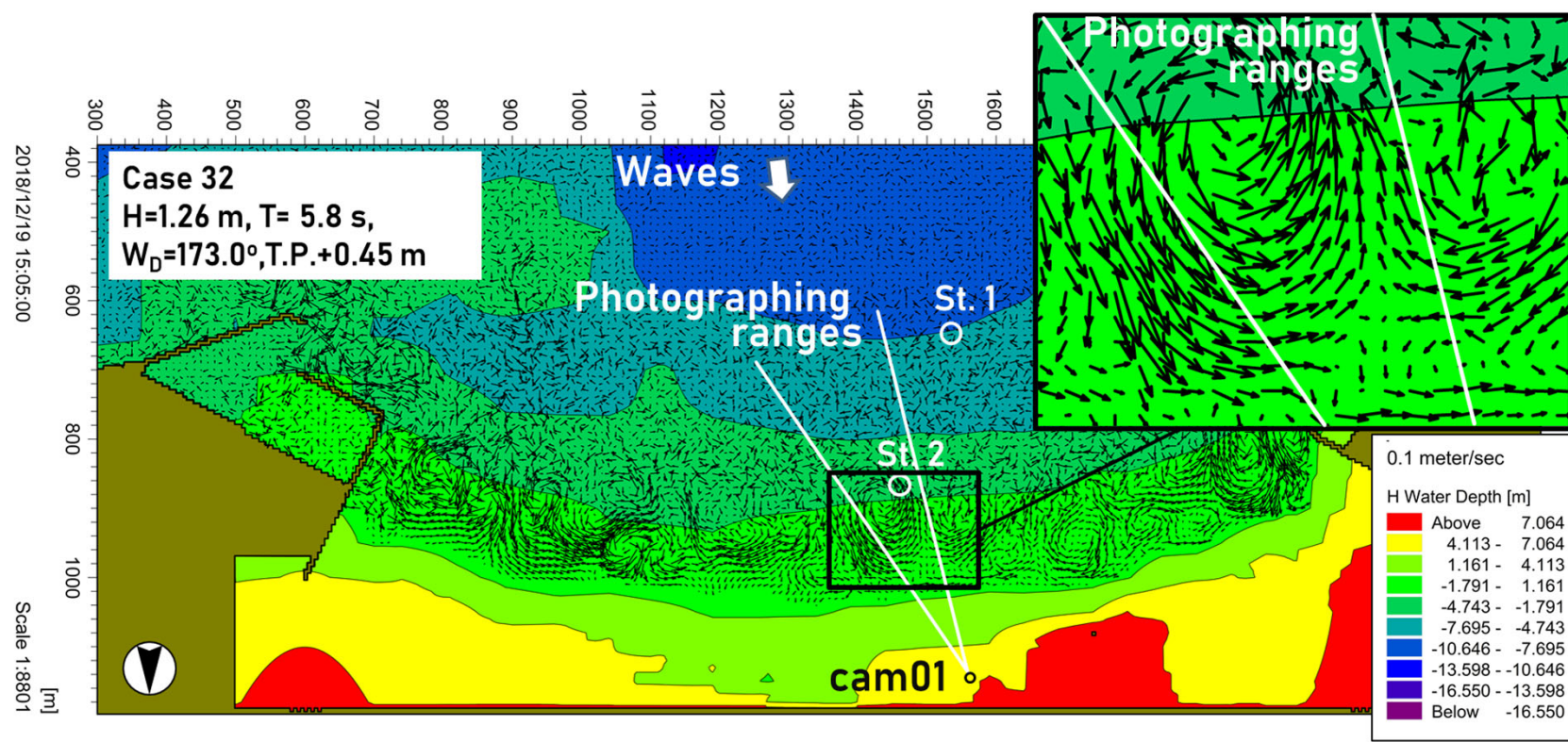


Fig.22 An example of the calculation result in case of rip current detection by AI.

Verification of Rip Current Detection by AI

Numerical simulation

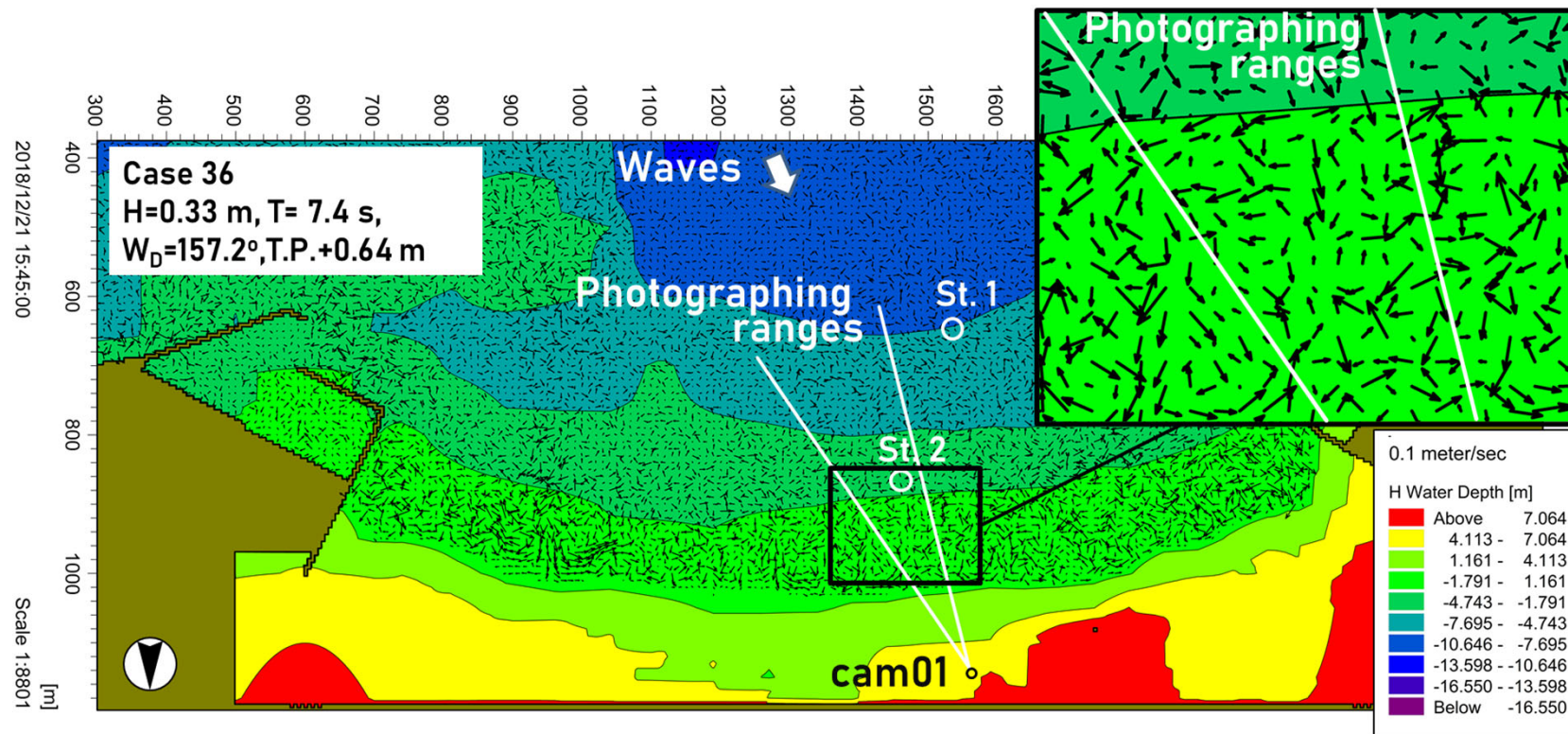


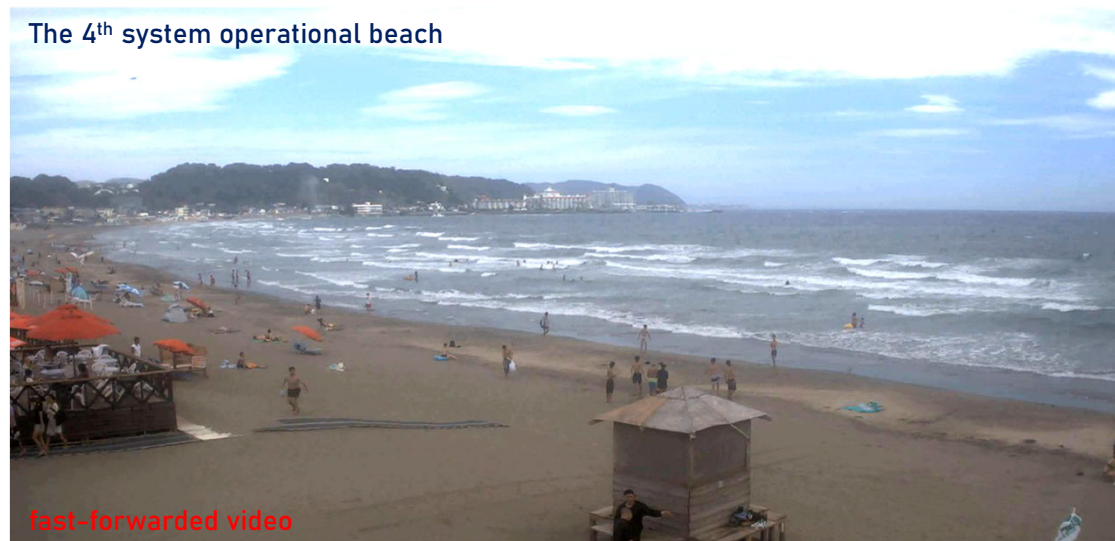
Fig.23 An example of the calculation result in case of no rip current detection by AI.

AIとIoTを活用した“海辺のみまもりシステム”

The 1st system operational beach



The 4th system operational beach



The 3rd system operational beach



The 2nd system operational beach



Fig. 24 Examples of rip current detections and human entry detections.

AIとIoTを活用した“海辺のみまもりシステム”

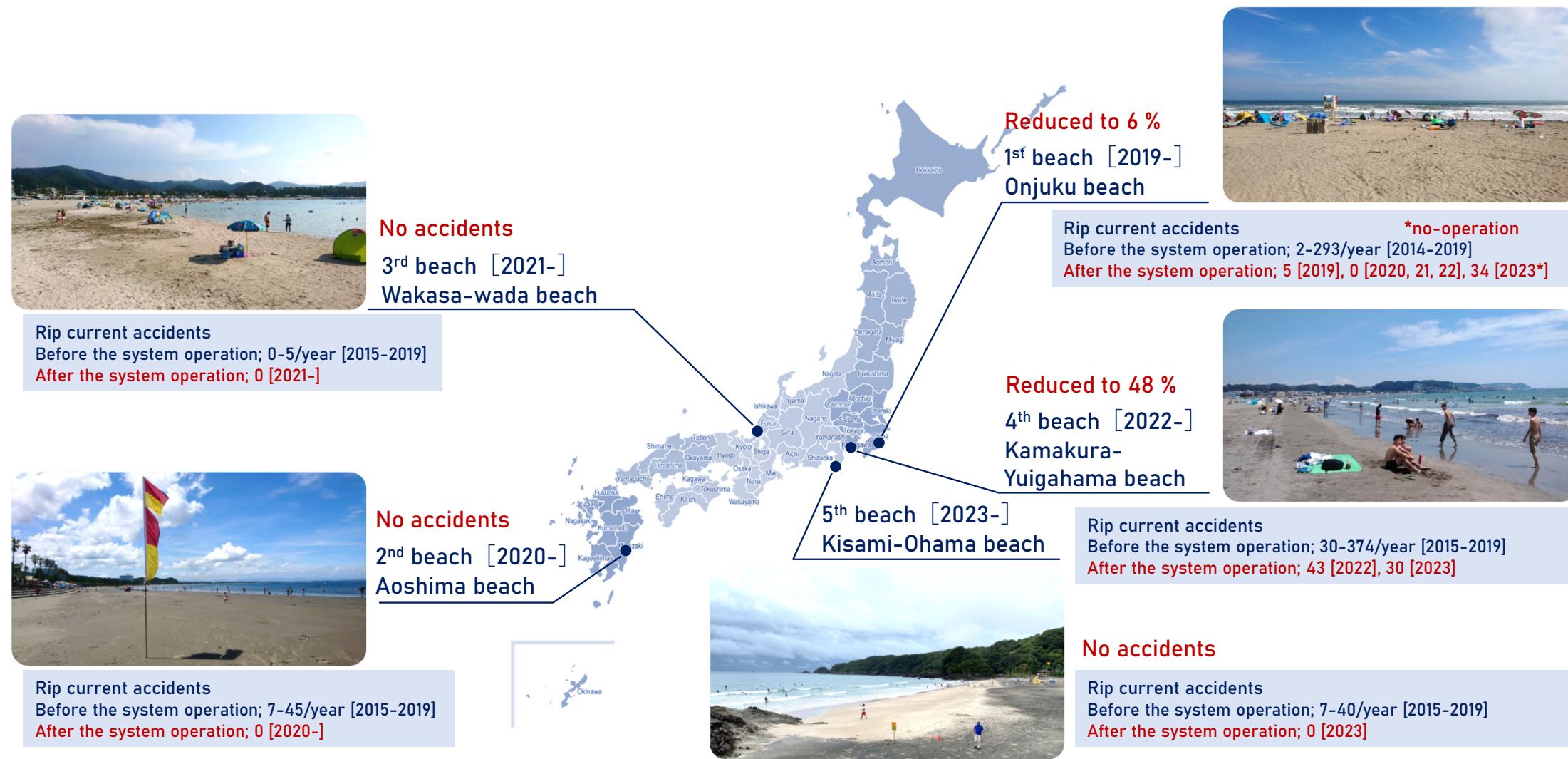
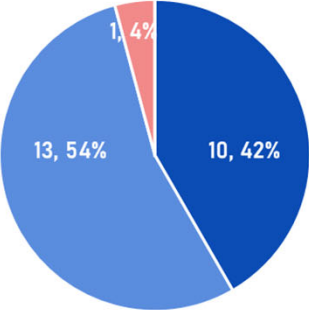


Fig. 33 システム運用後の離岸流に起因する救助の実態（2023年3月時点）

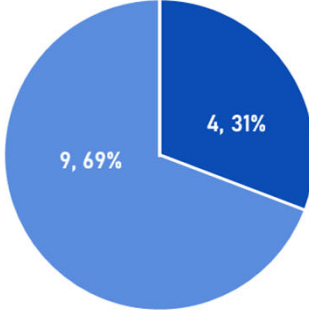
AIとIoTを活用した“海辺のみまもりシステム”

Q1：海辺のみまもりシステムは海水浴場利用者の事故防止に有効か？
(n=24)



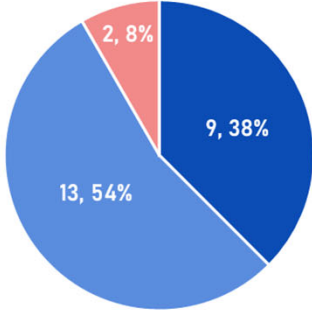
■ とてもそう思う ■ そう思う
■ そう思わない ■ 全くそう思わない

Q2：ライフセーバー用スマートウォッチは、迅速な人命救助に有効か？
(n=13)



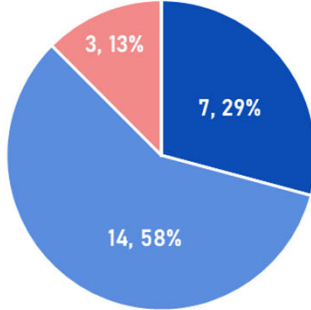
■ とてもそう思う ■ そう思う
■ そう思わない ■ 全くそう思わない

Q3：システムによる離岸流の検知は溺水事故防止に有効か？検知は正しかったか？ (n=24)



■ とてもそう思う ■ そう思う
■ そう思わない ■ 全くそう思わない

Q4：システムによる離岸流エリアへの人の検知は溺水事故防止に有効か？検知は正しかったか？ (n=24)



■ とてもそう思う ■ そう思う
■ そう思わない ■ 全くそう思わない

Fig. 34 2023年にシステムを運用した3海岸（高浜町，鎌倉市，下田市）の自治体，ライフセーバーを対象にしたアンケート調査結果

AIとIoTを活用した“海辺のみまもりシステム”



津波防災機能 [鎌倉市由比ガ浜2022-, 下田市吉佐美大浜2023-]

Tsunami



Fig. 35 津波アラート機能の概要

AIとIoTを活用した“海辺のみまもりシステム”

【現状】

ライフセーバーによる監視, パトロール



【高度化】

ライフセーバーによる監視, パトロール

海辺のみまもりシステムによる監視



- ①離岸流発生の確認
- ②離岸流エリアなど危険個所への利用者の立入りの確認



- ①ライフセーバーによる注意喚起（放送）
- ②ライフセーバーによる現地での誘導（声掛け）
- ③ライフセーバーによる救助（安全移送）



- ①離岸流発生の確認
- ②離岸流エリアなど危険個所への利用者の立入りの確認

- ③離岸流の検知
- ④離岸流エリアなど危険個所への利用者の立入りの検知
- ⑤ライフセーバーに通知



- ①ライフセーバーによる注意喚起（放送）
- ②ライフセーバーによる現地での誘導（声掛け）
- ③ライフセーバーによる救助（安全移送）

- ④システムによる利用者の注意喚起（携帯）



- ⑤ドローンによる利用者の誘導（監視・放送）

- 課題；
- 目的地まで飛行させるドローン操縦の難しさ。
 - 操縦者が限定される。
 - ドローンパイロットに依頼（コスト大）。

システム連動によるドローン飛行自動化

- 誰でも簡単なアクションで飛行可能。
- 目的地到達にかかる時間短縮（迅速な対応）

AIとIoTを活用した“海辺のみまもりシステム”



Drone Patrol

システム・ドローン連動機能：離岸流エリアに立ち入った利用者に対して自動でドローンを誘導。

音声発信機能を付けたドローンの試験運用実施（2023年8月 若狭和田海水浴場にて）。

試験運用により、システムが要救助者を検知すると、ドローンは485 m離れた要救助者付近に1分以内（ $V=8.8\text{m/s}$ ）で自動飛行できることを確認。注意喚起のためにLSが現地に到着する時間を約半分に短縮することが可能。



音声発信機能付ドローン



離岸流に流された人に対するドローンの自動飛行・注意喚起の例



Fig. 36 自動飛行のドローンのルート

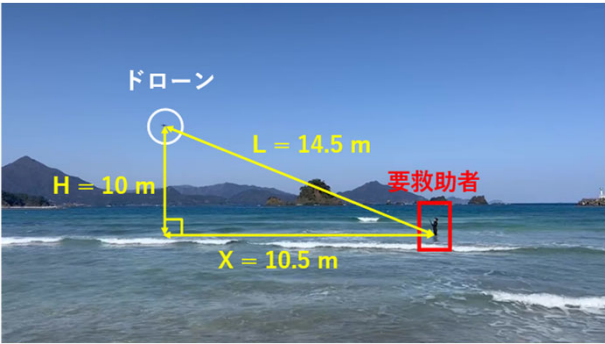


Fig. 37 ドローンと要救助者の位置の例

AIとIoTを活用した“海辺のみまもりシステム”



Help signal
助けてサイン



映像；日本ライフセービング協会

AIとIoTを活用した“海辺のみまもりシステム”



Help signal
助けてサイン

AUSTRALIA

I Need Help!

Wave your arm above your head and attract attention if you need help!

Lifeguards watch for this signal, so if you need help, they will be on their way.

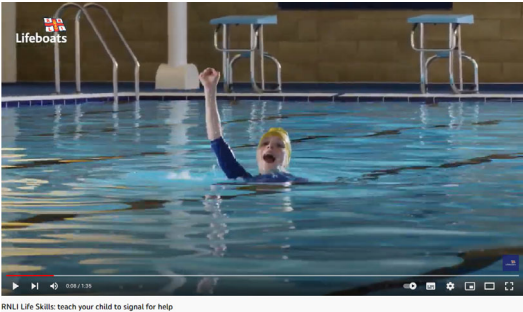
Activity: Lifeguards have lots of equipment to help them get to people who need help. Can you name anything they use?

Link: But remember, if we can't see you, we can't save you!

Australian for Life



UK



The Royal National Lifeboat Institution

[RNLI Life Skills: teach your child to signal for help - YouTube](#)

CANADA

11. Learn the emergency signal.

Emergencies: raise one hand and call your surf coach

In case of any emergency, you should be able to get your surf coach's or friend's attention quickly and easily. You should discuss this with your surf coach or experienced surf friend about this signal, so it is clearly understood between both of you. One of the most efficient signals is to call your coach while waving one arm completely straight, to and fro above the head.

[11 Security Aspects of Surfing - Beginner Surf Tips \(barefootsurftravel.com\)](#)

USA

Be Water Competent?

How to Make Water Safety a Priority

Know What To Do In An Emergency

Resource Center

Chain of Drowning Survival

A person who is drowning has the greatest chance of survival if these steps are followed:

1. Recognize the signs of someone in trouble and shout for help.
2. Rescue and remove the person from the water (without putting yourself in danger).
3. Ask someone to call emergency medical services (EMS). If alone, give 2 minutes of care, then call EMS.
4. Begin rescue breathing and CPR.

[Water Safety | American Red Cross](#)

[Hand Signals for Ocean Swimmers - VladSwim](#)

AIとIoTを活用した“海辺のみまもりシステム”



ヘルプシグナル検知機能 [試験運用中]

Help signal
助けてサイン



AIモデルによるヘルプシグナルの検知例

AIとIoTを活用した“海辺のみまもりシステム”

海辺のみまもりシステム



Rip Current



Offshore Wind



Tsunami



Help signal
助けてサイン



Drone Patrol



Drowning
detection



Lightning



UV



Robot Rescue



+



Digital
signage



LS Smart
watch



Bg Smart
Phone



海辺のみまもりシステムlite版



Rip Current



Offshore Wind



Tsunami



Help signal
助けてサイン



Drone Patrol



Drowning
detection



Lightning



UV



Robot Rescue



+



Digital
signage

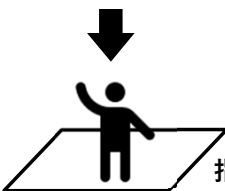


LS Smart
watch



Bg Smart
Phone





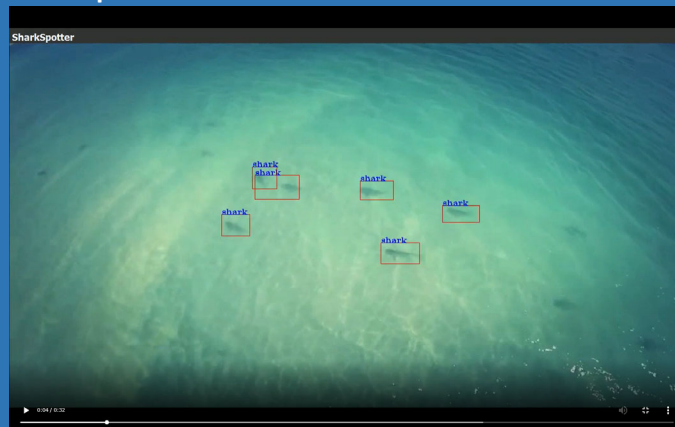
指定したエリア内に人が立ち入るとライフセーバーにアラートを発報

New technologies under Development or Available

- **Shark detection [AI]**

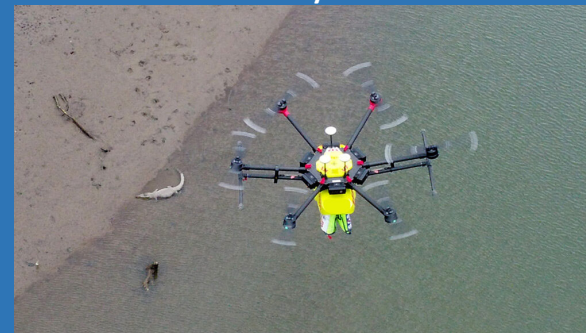
- The system developed by UTS is being used by industry partner Westpac Little Ripper to identify sharks, raise alarms and provide greater protection for swimmers and surfers..

Sharkspotter



Ripper Corp., <https://rippercorp.com/divisions/little-ripper-lifesaver/>

AI Crocodile detection system for drones



Ripper Corp., <https://rippercorp.com/divisions/little-ripper-lifesaver/>

Nabin Sharma, Muhammed Saqib, Paul Scully-Power & Michael Blumenstein; SharkSpotter: Shark Detection with Drones for Human Safety and Environmental Protection, Humanity Driven AI pp 223–237, 2021. https://link.springer.com/chapter/10.1007/978-3-030-72188-6_11.

先端技術を活用した海辺の安全管理

プールにおける溺水事故防止システム “AQUAGUARD”

Introduction

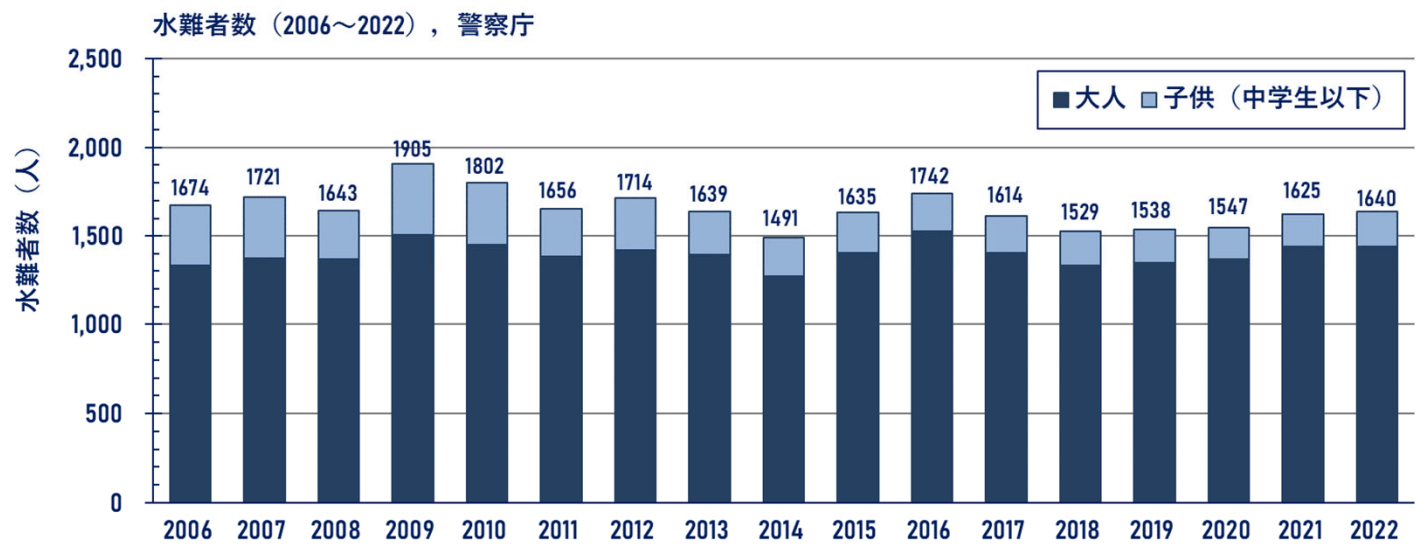


Fig. 38 水難者数（生存，死者・行方不明者）の経年変化，警察庁

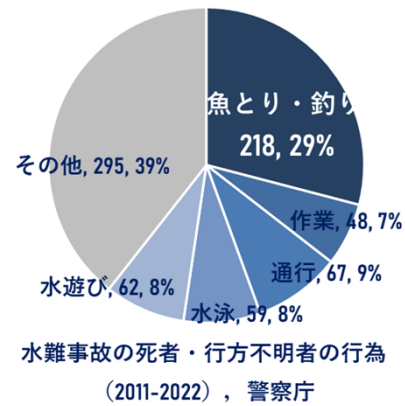
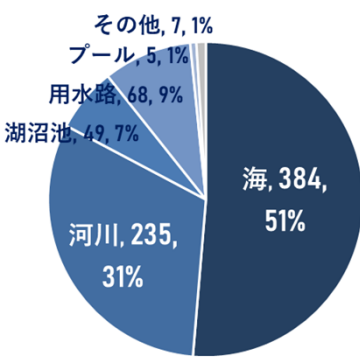
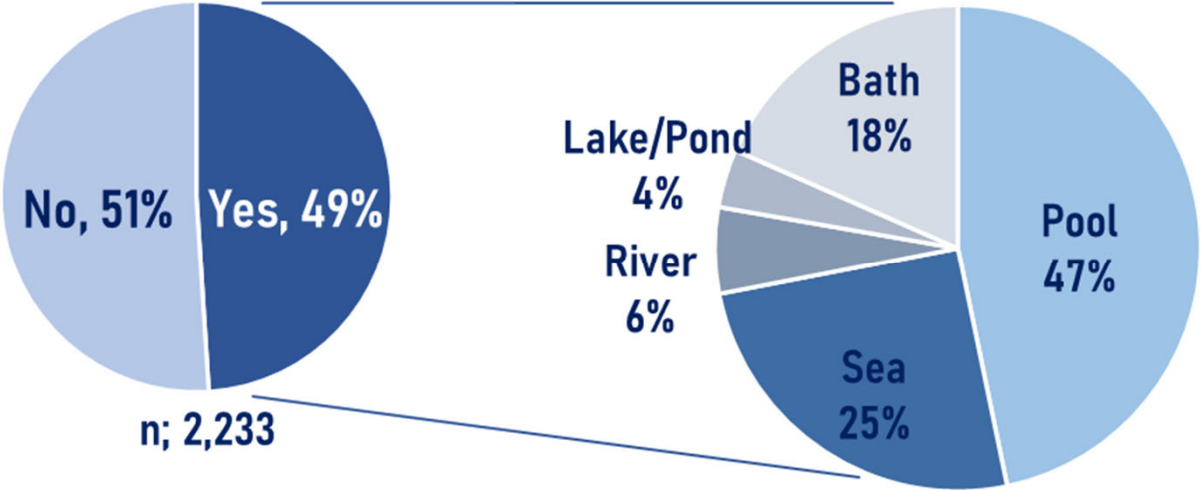


Fig. 39 水難事故（死者・行方不明者）の発生場所と行為（2011-2022）, 警察庁

Introduction

Actual situations of water-related accidents in Japan

Near drowning experience



Why...?
When swimming pools are opened in schools in summer vacation, guardians without monitoring experience are in charge of safety management in many cases.

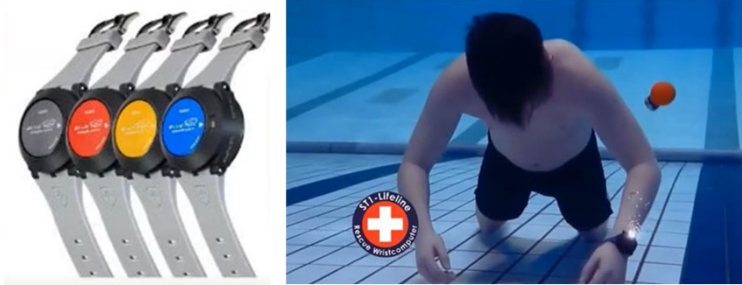
Data; Japan Lifesaving association,
National sports agency commissioned project. 2022.

Fig. 40 Results of a survey of elementary and junior high school students regarding a near-drowning experience.

Introduction

Existing technologies to assist the monitoring and rescue; Personal device for drowning prevention

BlueFox ST1



Bluefox [Switzerland] <https://www.bluefox-swiss.com/en/systems-for-private/>

Sentag Pool Safety System



Sentag [Sweden] <https://www.sentag.com/how-it-works/>

WAVE



Wavedds [New Zealand] <https://www.wavedds.com/explore>

Seenwater

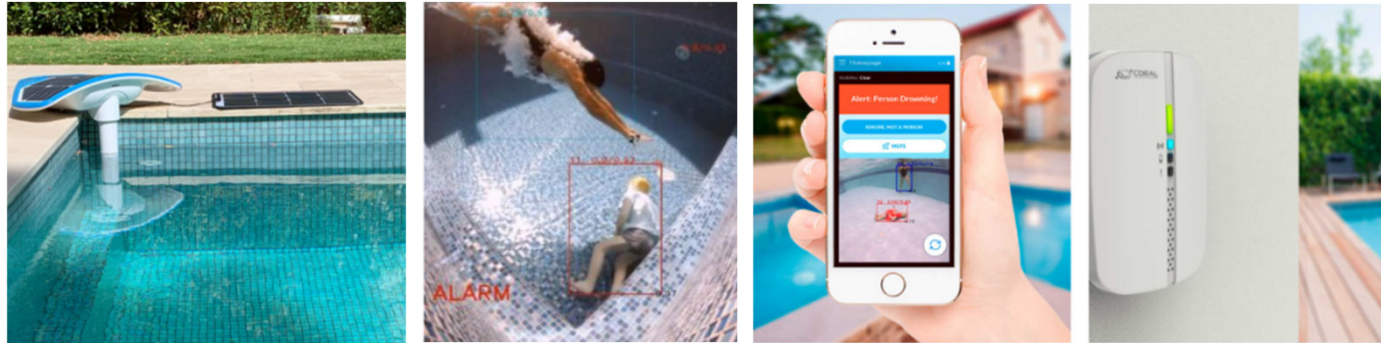


Seenwater [China] <http://www.seenwater.com/>

Introduction

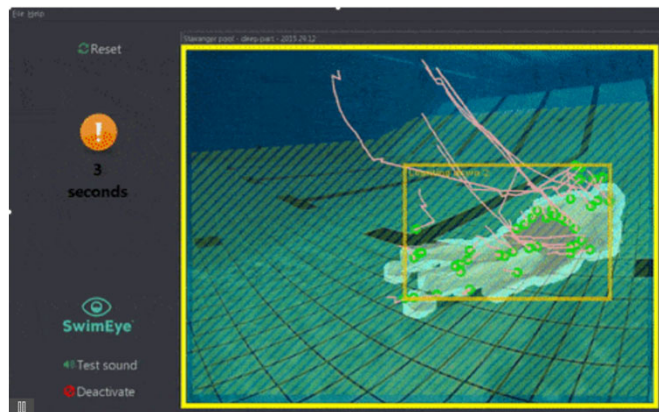
Existing technologies to assist the monitoring and rescue; Computer vision drowning detection

Coral Detection Systems



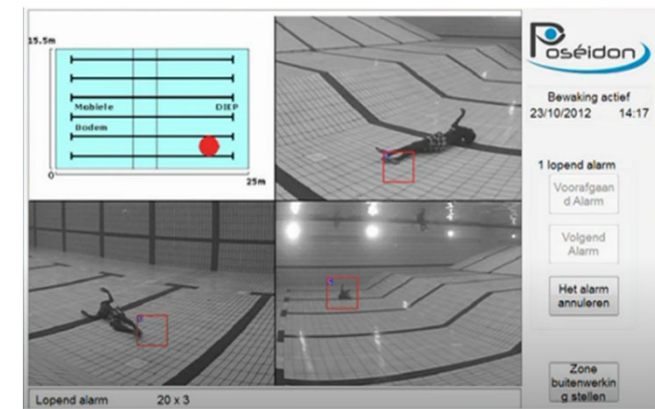
Shtik Media [Israel] <https://coraldrowningdetection.com/>

SwimEye



SwimEye [Norway] <https://swimeye.com/>

Poseidon



Maytronics <https://drowningprevention.com.au/>

Introduction



Uimahallin valvontakamera Helsinki, 30.1.2016

Introduction

It is important that before near-drowning which means that a suspected drowning or dangerous situation, the technology should detect and enhance “**Keep Watch**”.

Swimming



Dangerous situation



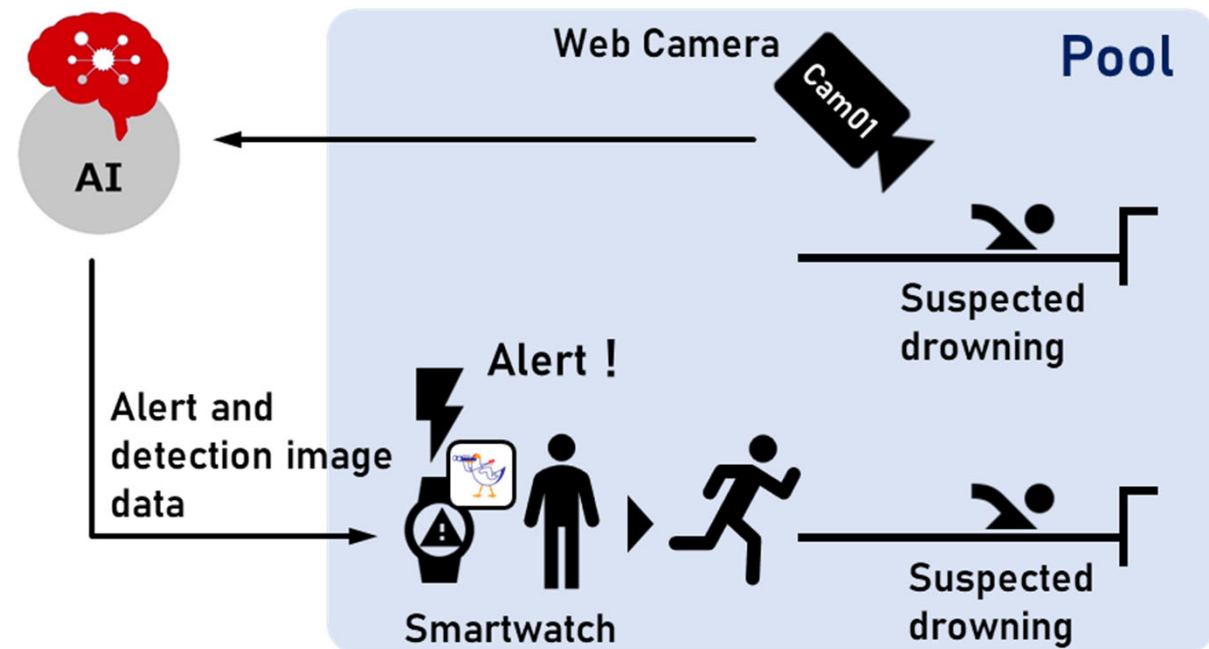
Near-drowning



Drowning

In the developed system, AI analyzes image data which is taken by web cameras at the poolside in real time.

At the time of detection of suspected near-drowning, drowning and dangerous situations leading to drowning accidents, the system informs it to the lifeguard's or pool staff's smartwatch.



Creation of AI model



Suspected near-drowning, drowning [4 cases]

a1



Beating the water surface

a2



Head bobbing up and down

a3



Climbing the ladder movement

a4



Flow or submerge without moving limbs



Dangerous situations leading to drowning accidents [5 cases]

b1



Moving underwater while jumping up and down

b2



Collision of swimmers

b3



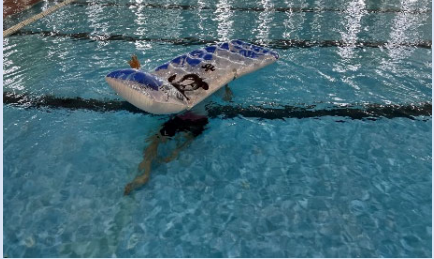
Diving under a platform on the bottom of the pool

fb1



Capsizing of pool float

fb2



Person hiding under the pool float

Creation of AI model

Determination of
detection objects

Collection of
image data

AI learning

Verification of
AI model

Experimental test

1st AI model

Small swimming pool
20m × 10 m, h= 0.8-1.1 m

32,867 image data



Fig. 41 Examples of image data of near-drowning and dangerous situations by subjects.

Creation of AI model

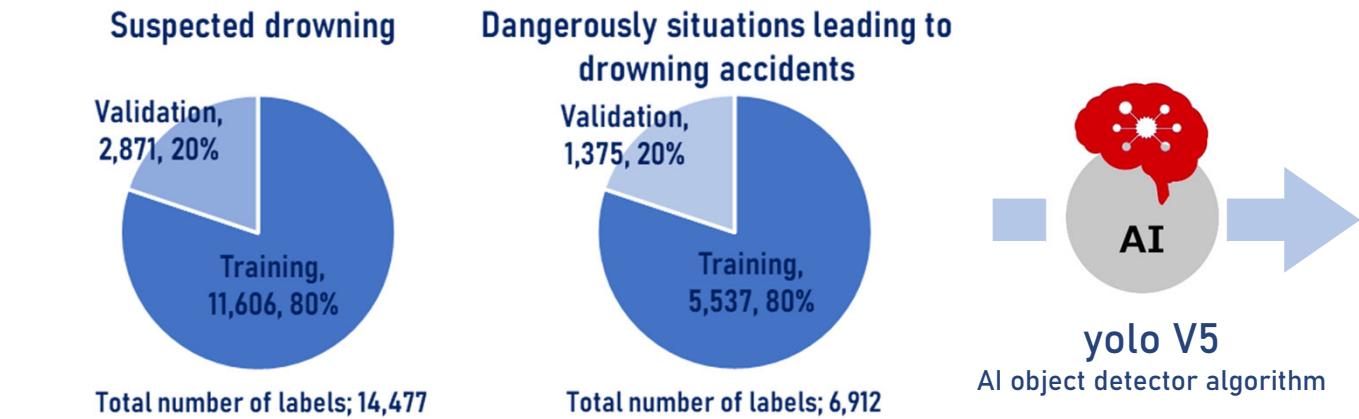
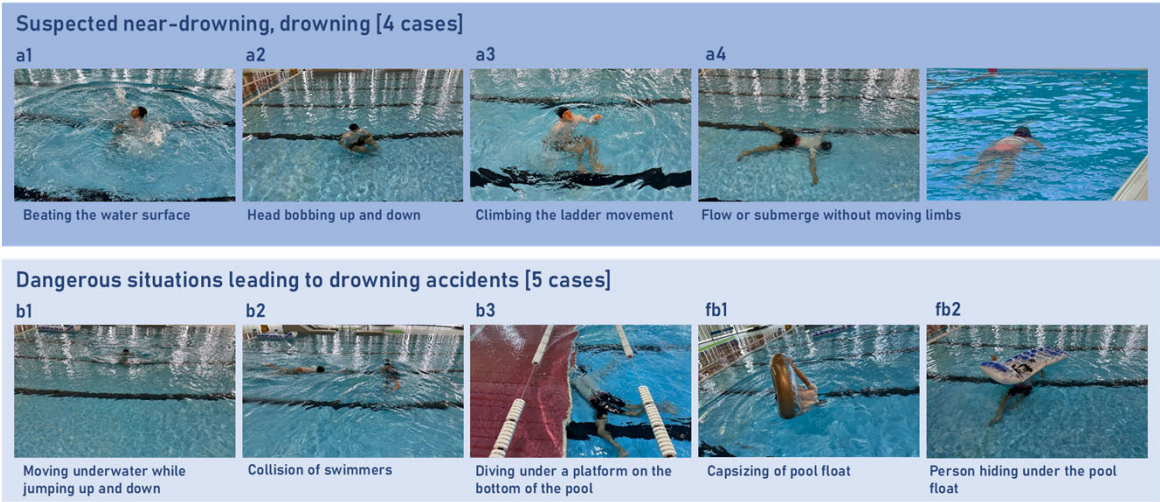


Fig. 42 Number of labels in Images for AI deep learning.

PACIFIC NETWORK

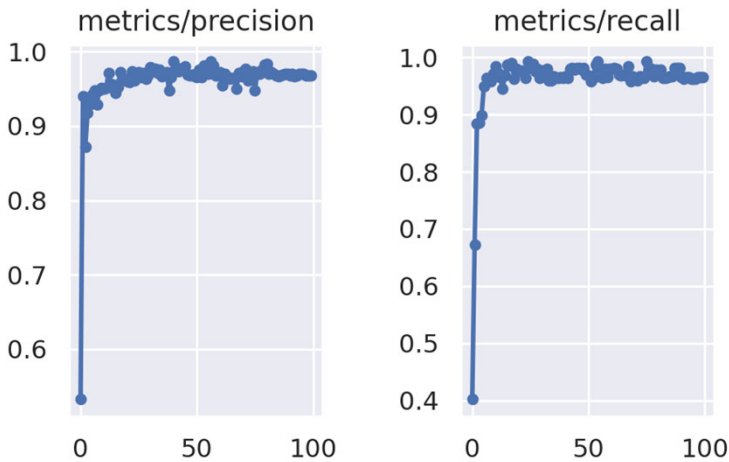
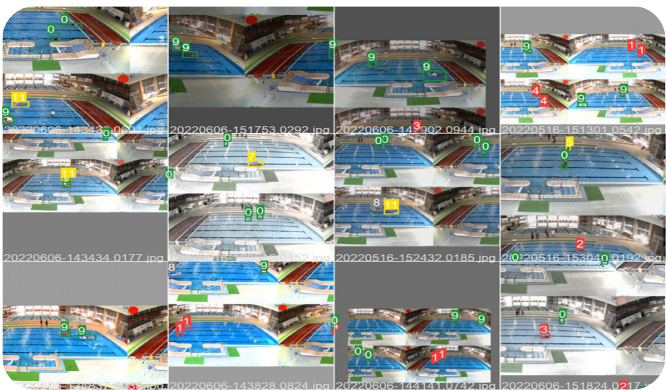
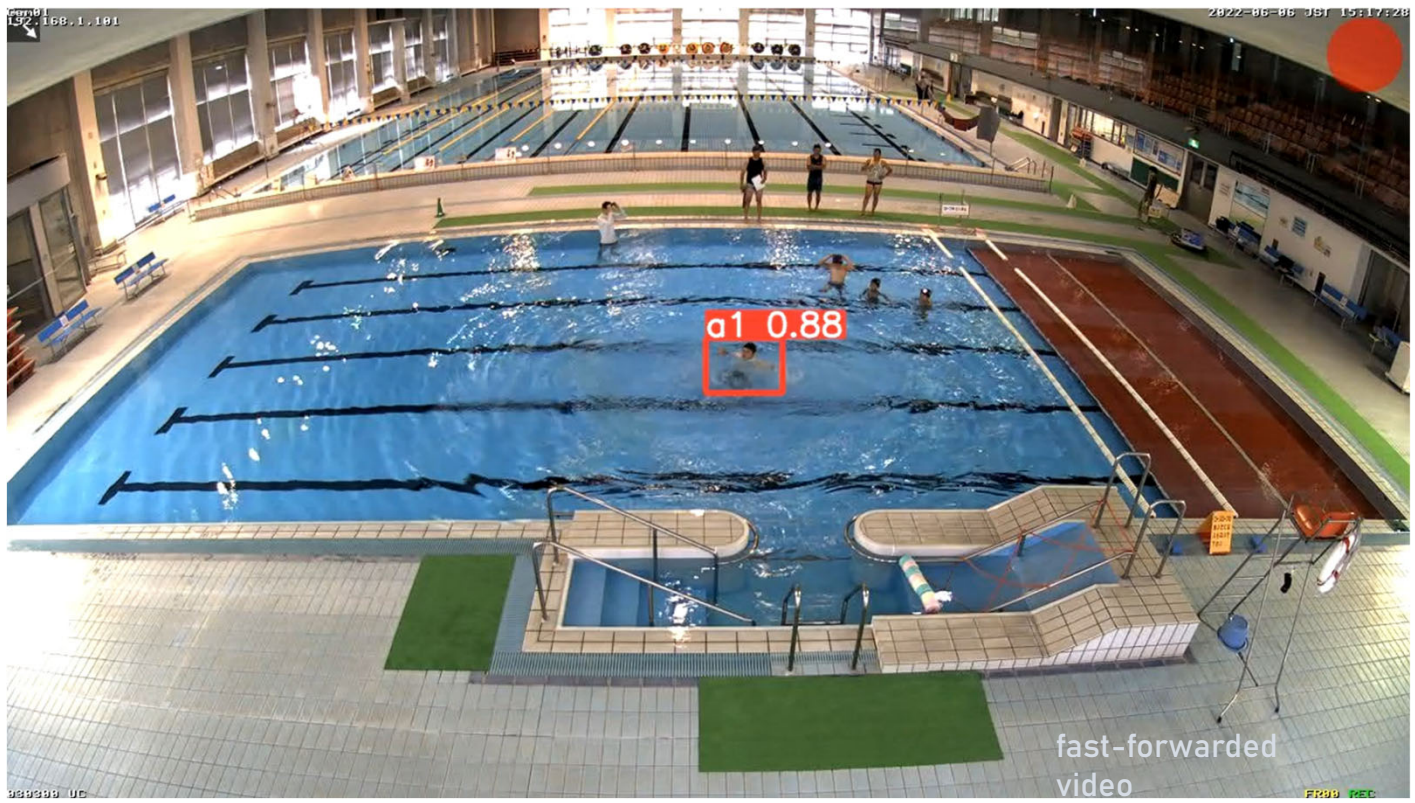


Fig. 43 Changes in precision and recall depending on the number of epochs. [Model 2-2]

Creation of AI model



Precision	96.0 %	Percentage of correctly detected near-drowning and high-risk situations. TP / (TP+FP)
Recall	95.7 %	Percentage of correct detections for all test near-drowning and high-risk situations. TP / (TP+FN)
F measure	0.96	Harmonic Mean of Precision and Recall. (2 × Precision × Recall) / (Precision+ Recall)

TP: True Positive, The result of AI judged as a rip current is correct.
FP: False Positive, The result of AI judged as a rip current is false.
FN: False Negative, The result of AI judged as a without rip current is false.
TN: True Negative, The result of AI judged as a without rip current is correct.

Creation of AI model

Determination of
detection objects

Collection of
image data

AI learning

Verification of
AI model

Experimental test

The developed system was tested in the swimming pool for 79 days from 26 July to 20 Oct. 2022.

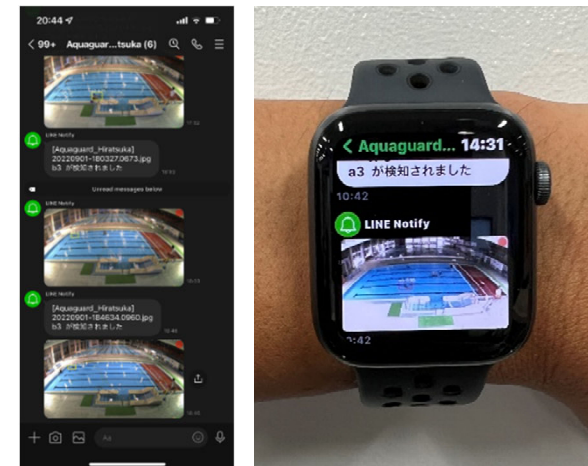
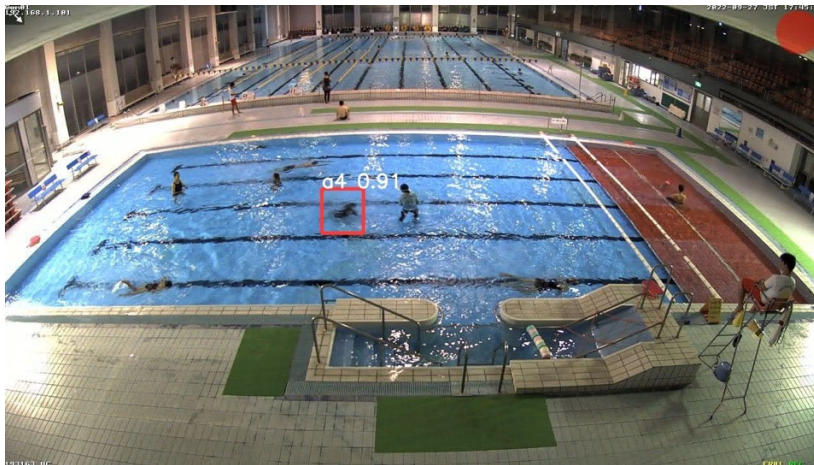
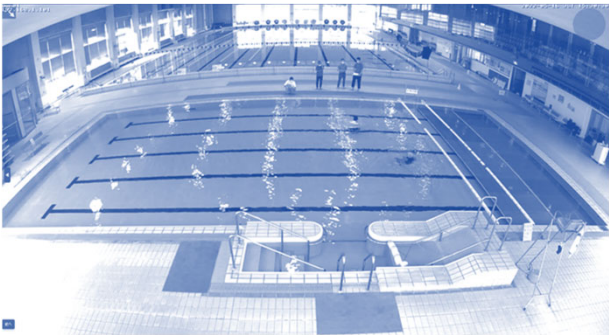


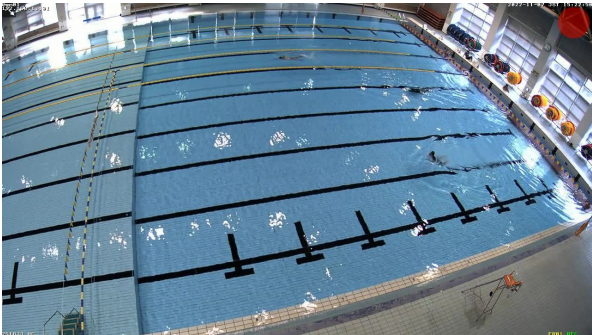
Fig. 44 Examples of notifications to smartphones and smartwatches by the system.

The results of detection of suspected near-drownings and dangerous situations were generally reasonable. Inexperienced pool staff can determine the high-risk situation that requires attention by using the system information.

Application



1st AI model
Small pool 20m × 10 m, h = 0.8-1.1 m



2nd AI model
Main pool 50 m × 25 m, h = 1.7-2.0 m

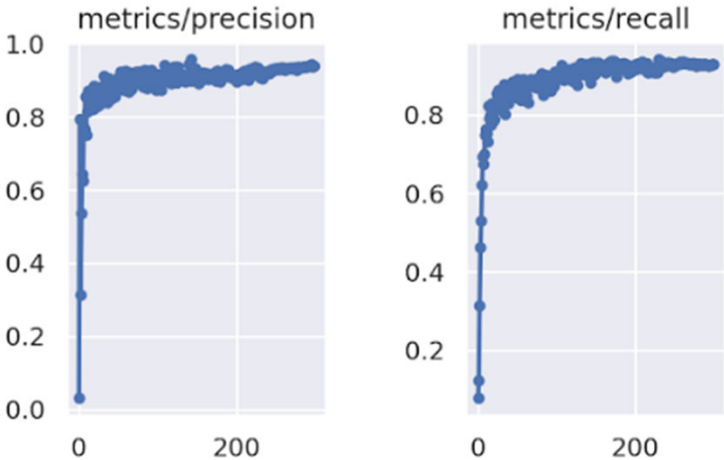
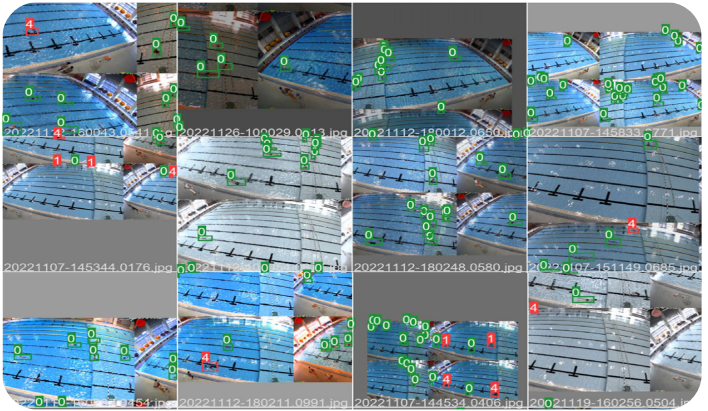
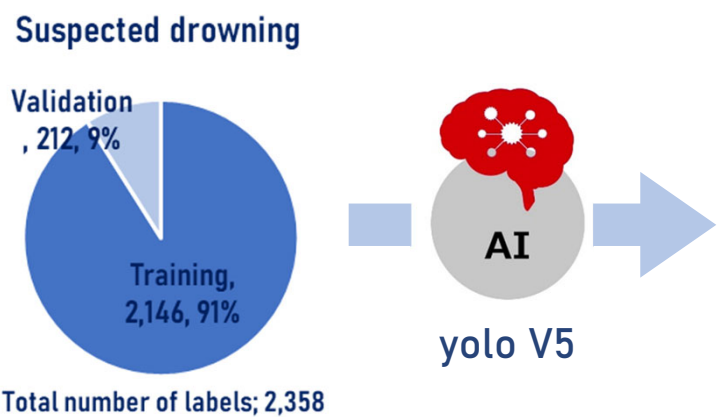
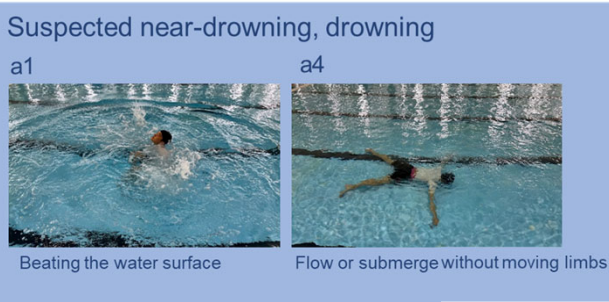
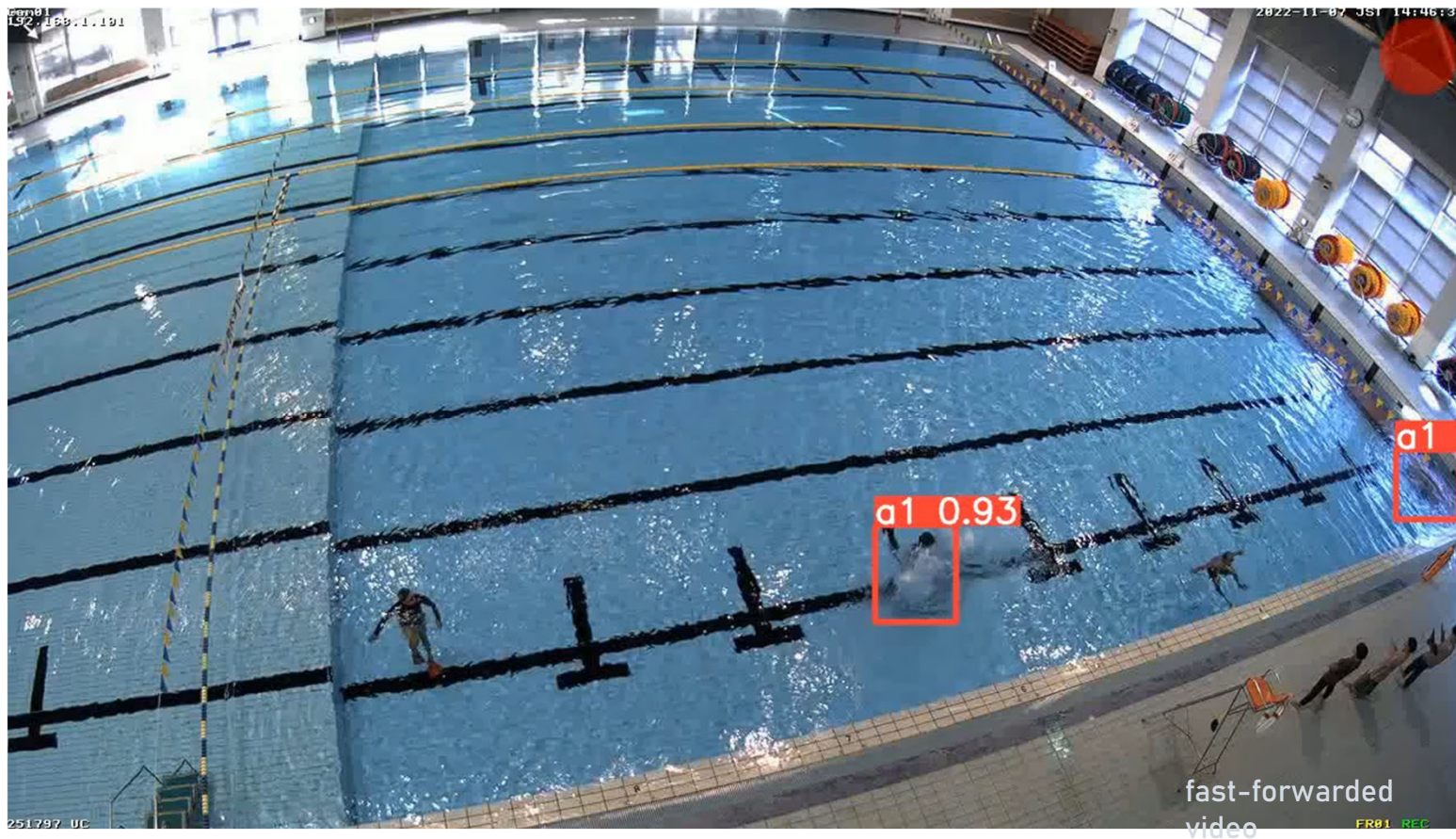


Fig. 46 Changes in precision and recall depending on the number of epochs. [Model 3-2-7]

Application

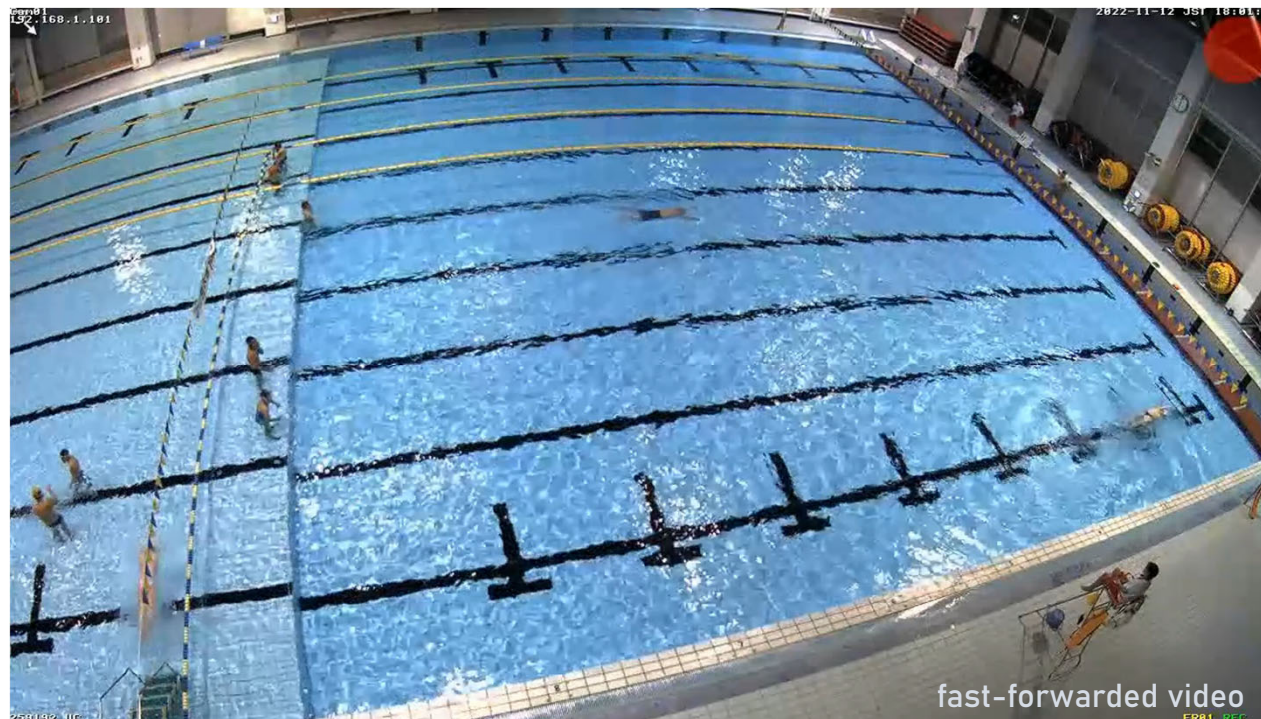


Precision	94.1 %	Percentage of correctly detected near-drowning and high-risk situations. $TP / (TP + FP)$
Recall	92.7 %	Percentage of correct detections for all test near-drowning and high-risk situations. $TP / (TP + FN)$
F measure	0.93	Harmonic Mean of Precision and Recall. $(2 \times Precision \times Recall) / (Precision + Recall)$

TP: True Positive, The result of AI judged as a rip current is correct.
 FP: False Positive, The result of AI judged as a rip current is false.
 FN: False Negative, The result of AI judged as a without rip current is false.
 TN: True Negative, The result of AI judged as a without rip current is correct.

Conclusion

The developed system would strengthen “Keep Watch” in pools and create a safer swimming environment.



先端技術を活用した海辺の安全管理

まとめ

先端技術を活用した海辺・水辺の安全管理

海岸工学

海水浴場
リスク評価

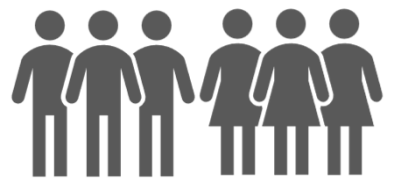
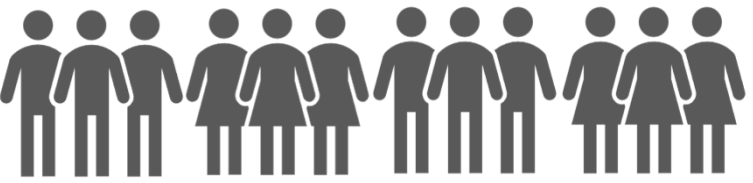
水難事故
データ分析

海辺のみまも
りシステム

Pool 溺水事故
防止システム

VR
Eye-tracking





Technologies

Water Safety



Technologies



海辺，水辺に関わるすべての人が支え合あう，
事故ゼロの安心，安全で楽しい海辺・水辺空間の創出を目指して

