g-RIPS 2022 Mitsubishi Project B Final Presentation

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Multi-Objective Optimization for Best Early Prediction of Extreme Weather Events

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Water vapor and wind) Cumulonimbus clouds

) Heavy rain) Extreme weather event

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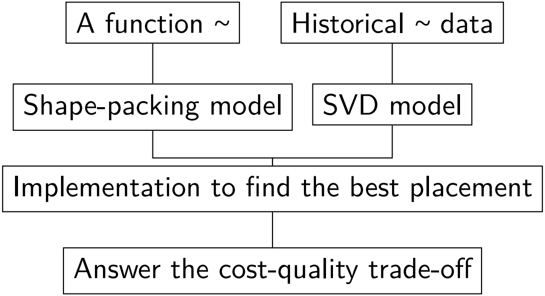
The ability to sense the distribution of water vapor and wind provides larger lead time in detection.

For this project, we will consider the best placement of high-grade and low-grade LiDAR instruments in Japan to help sense extreme weather.

Figure: Cumulonimbus Clouds and LiDAR Instruments

GOAL: To solve a multi-objective optimization problem regarding the performance of placement and cost of the instruments.
Strategy: Depending on the type of data for significance function $\sim$, to accomplish this we will:



Definition

The **prediction area** $_0$ is a bounded finite, real, 2 dimensional manifold (the topography of a city). The **prediction space** $= {}_0 \; (0; \;)$ where > 0 can be infinite. This is understood to be the surface of a city and the air space of interest above the surface of the ground.

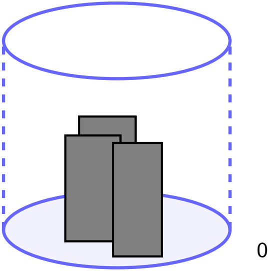


Figure: The prediction space and the prediction area.

Definition (Water and Wind Significance)

The functions $\sim_\circ ; \sim_{®}$: $[§_0; §_1]$! R^+, where $[§_0; §_1]$ is an interval of time where an extreme weather event would occur.

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$$\sim(\mathbf{x}; ¶; §) = \sim_{\circ}(\mathbf{x}; ¶; §) + \sim_{®}(\mathbf{x}; ¶; §) \tag{1}$$

The sum is simply **significance function**.

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There are two types of LiDAR instruments: low-grade and high-grade.

Low-grade) Cost & Viewing set &

High-grade) Cost & Viewing set %

Assuming uniform continuity of the significance function, let the cheaper instrument be a thin vertical cylinder where the reading is constant for each height section with controllable error.

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We will let the viewing set of the expensive instrument to be a wider conical set with viewing angle .

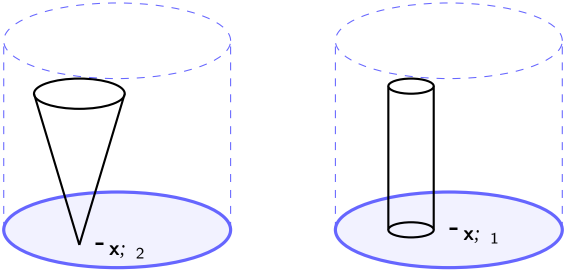

Figure: Viewing sets for high and low quality instruments.

Definition

A **configuration** $_j$ of j instruments is a set of j pairs, $(\mathbf{x}_1;\ _1);\ldots;(\mathbf{x}_j;\ _j)$ that represent the placements and types of instruments. The viewing set of $_j$ is the union of the viewing sets of each of the instruments.

$$-\ _j = \bigcup_{\_=1}^{j} -_{\mathbf{x}_\_;\ \_} \tag{2}$$

$$w(\ _j) = \int_{\S_0}^{\S_1} \int_{-\ _j} \sim(\mathbf{x};\P;\S)\,L\mathbf{x}\,L\P\,L\S \tag{3}$$

$$G(\ _j) = \sum_{\_=1}^{j} G(\ \_) \tag{4}$$

Our strategy to find a good value configuration is broadly the following:

1. **Construct the significance function**

   Climate data, topography data $)$

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   Input: a fixed $f\ \_g \xrightarrow{\text{Numerical Model}})$ Output: the best placement $f\mathbf{x}\_g$

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3. **Find optimizers:** We will select a Pareto efficient compromise between cost and quality.

To simplify the problem, we only consider the significant function with the following form:

$$\sim = q(\mathbf{x})X(\P)T(\S) \tag{5}$$

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$q(\mathbf{x})$: information on the population and topography.

$X(\P)$: meteorological information about what altitudes are important to observe for predicting an extreme rainfall event.

hQ bBKTHB7v i?2 T`Q#H2K- r2 QMHv +QMbB/2`
7QHHQrBM; 7Q`K,

a= T(t) ;(x) 7(i) U8

T(t) , BM7Q`K iBQM QM i?2 TQTmH iBQM M/ i
;(x) , K2i2Q`QHQ;B+ H BM7Q`K iBQM #Qmi r
iQ Q#b2`p2 7Q` T`2/B+iBM; M 2ti`2K2 ` BM7
7(i) , /2b+`BTiBQM Q7 /Bm`M H M/ b2 bQM H

LQr-r2K JFP2_1 bbmKTiBQMb

6Q` ?B;? [m HBiv BMbiMMQ KiQ-rB/2X
;(x) y iHQr M/ ?B;? HiBim/2bX

LQr- r2 K F2_1 bbmKTiBQMb

6Q` ?B;? [m HBiv BMbi`mK2Mib- r B/2X

;(x) y i HQr M/ ?B;? HiBim/2bX

h?2 ?B;? [m HBiv BMbi`mK2Mi + M #2 TT`Qt

LQr- r2 K F2_1 bbmKTiBQMb

6Q` ?B;? [m HBiv BMbi`mK2Mi- r B/2X

;(x) y i HQr M/ ?B;? HiBim/2bX

h?2 ?B;? [m HBiv BMbi`mK2Mi + M #2 TT`Qt

$$o_{t;k} \quad "(t; `_k) \quad R^+ \qquad Ue$$

$$o_{t;R} = "(t; `_R) \quad R^+ \qquad Ud$$

r?2`2 $`_B$ Bb i?2 ` /Bmb Q7 i?2 +B`+mH ` b2+iBQ

LQr- r2 K JFP2_1 bbmKTiBQMb

6Q` ?B;? [m HBiv BMbiMMQKi2QMQ -rB/2X
;(x) y i HQr M/ ?B;? HiBim/2bX
h?2 ?B;? [m HBiv BMbi`mK2Mi + M #2 TT`Qt

o t; k "(t; `k) R+ U e
o t; R = "(t; `R) R+ U d

r?2`2 `B Bb i?2 ` /Bmb Q7 i?2 +B`+mH ` b2+iBQ
6`QK eVUr2 + M bBKTHB7v i?2 pB2rBM; b2i b 7

!

o M = [M B R o t; B B   õ M = R+ [M B R "(t; B `B)

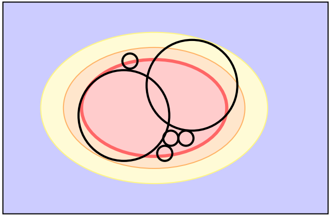
Z iR Z Z Z

Z(M) = T(t) ;(x) 7(i) / x/ t/ i= E T(t) / t:

iy [B "(t; B `B) R+ [ B "( t; B `B)

PTiBKBZ(B_M) + M #2 mM/2`biQQ/ b +B`+H2 T

$$\hat{Z}(t_R ::: t_M \; `_R ::: `_M) = \sum_{[_B "(t_B \, `_B)} T(t)/t \qquad U3$$



6B;m`2 ,2t KTH2 7 M (t) + BbQM #v ?2 iK T- M/ +?QB
+QM};m` iBQMX _2//2` +QHQ`b +Q``2bTQM/ iQ ?B;

h?2 :`22/v H;Q`Bi?K

h?Bb TT`Q +? Bb bi M/ `/ K2i?Q/ 7Q` b2Mb

h?2 :`22/v H;Q`Bi?K

h?Bb TT`Q +? Bb bi M/ `/ K2i?Q/ 7Q` b2Mb

; BM- BMbi2 / Q7 i`vBM; HH TQbbB#H2 TH

SH +2 H `;2` +B`+H2b 7B`bi- i?2M bK HH2` +B`+H h?2 :`22/v H;Q`Bi?K

h?Bb TT`Q +? Bb bi M/ `/ K2i?Q/ 7Q` b2Mb
; BM- BMbi2 / Q7 i`vBM; HH TQbbB#H2 TH

SH +2 H `;2` +B`+H2 b QM +2 #v Q`/2` +B`+H

AM Qm` 2tT2`BK2Mib- r2 7QmM/

:`22/v "B b2/ MB7Q`K /B2Mi .2b+2Mi

G i2`- r2 rBHH BKTH2K2Mi i?2 ;`22/v H;Q`B

h?2 j .BK2MbBQM H * b2

q2 M22/ H2bb bbmKTiBQMb M/ TT`QtBK iBQM

$$o_M = \bigcup^{M} o_{t_{\dot{B}}\,B}$$

$$Z(M) = \int_{\underline{B}\,R} \int_{i_R} \int \int_S \int_{i_y} \int \int_{o_{t_{\dot{B}}\,B}} a(t; x)\,7(i)\,/x\,/t\,/i$$

$$= \hat{E} \int_S \int_{o_{t_{\dot{B}}\,B}} a(t; x)\,/x\,/t:$$

h?2 j .BK2MbBQM H * b2

q2 M22/ H2bb bbmKTiBQMb M/ TT`QtBK iBQM

$$o_M = \left[^{M}\ o_{t_B^{\cdot} B}\right]$$

$$\mathrm{Z}(M) = \int_{\mathrm{B\,R}}^{} \cdots \mathrm{i_R}\ \mathrm{Z}\ \mathrm{Z} \quad \mathrm{S}\ o_{t_B^{\cdot} B}\ a(t;x)\,7(i)\,/x\,/t\,/i$$

$$= \hat{E}\ \mathrm{S}\ o_{t_B^{\cdot} B}\ a(t;x)\,/x\,/t:$$

JQbi Q7 i?2 b K2 H;Q`Bi?Kb M/ bi` i2;B2b
k. iQ i?2 j. + b2X

h?2 j .BK2MbBQM H * b2

q2 M22/ H2bb bbmKTiBQMb M/ TT`QtBK iBQM

$$o_M = [^{M}_{B=R} o_{t_B B}$$

$$Z(M) = \int\int_{i_R} \int\int_{i_y} \int_{S_{o_{t_B B}}} a(t; x)\, 7(i)\, /x\, /t\, /i$$

$$= \hat{E} \int_{S_{o_{t_B B}}} a(t; x)\, /x\, /t:$$

JQbi Q7 i?2 b K2 H;Q`Bi?Kb M/ bi` i2;B2b - k. iQ i?2 j. + b2X

h?2 K BM T`BM+BTH2b M/ +Q/2 7Q` i?2 k. M

*? HH2M;2b Q7 j .BK2MbBQM H * b2,

6Q`KmH iBQM Q7 i?2 bB;MB}+ M+2 7mM+iBQ

- *? HH2M;2b Q7 j .BK2MbBQM H * b2,
   - 6Q`KmH iBQM Q7 i?2 bB;MB}+ M+2 7mM+iBQ
   - L22/ KQ`2 / i X

*? HH2M;2b Q7 j .BK2MbBQM H * b2,

- 6Q`KmH iBQM Q7 i?2 bB;MB}+ M+2 7mM+iB
- L22/ KQ`2 / i X
- *QKTmi iBQM HHv bHQrX

*? HH2M;2b Q7 j .BK2MbBQM H * b2,

6Q`KmH iBQM Q7 i?2 bB;MB}+ M+2 7mM+iB

L22/ KQ`2 / i X

*QKTmi iBQM HHv bHQrX

AM i?2 M2ti 2t KTH2- r2 rBHH mb2 k. bB;MB}+

?BbiQ`B+ H T`2+BTBi iBQMV iQ QTiBK HHv TH

bB;MB}+ M+2 7mM+iBQM 7Q` hQFvQ

q2 mb2/ ` BM7 HH / [R] iQ 7`+Q`2 (c)X

[R] C T M J2i2Q`QHQ;B+ H ;2M+v

bB;MB}+ M+2 7mM+iBQM 7Q` hQFvQ

q2 mb2/ ` BM7 HH / [R] iQ 7Q`+Q bi (c)JX

JQ`2 ?2 pv ` BM7 HH BM+B/2M+2b `2+2Bp2/

*QmMi i?2 MmK#2` Q7 ?2 pv ` BM 2p2M

) AMi2`TQH i2 iQ 2ti2M/ #2vQM/ / i b

) LQ`K HBx2 bXiX i?2 K tBKmK Bb R

[R] C T M J2i2Q`QHQ;B+ H ;2M+v

bB;MB}+ M+2 7mM+iBQM 7Q` hQFvQ

q2 mb2/ ` BM7 HH / [R] iiQ7 `+Q`KT(t2)X

JQ`2 ?2 pv ` BM7 HH BM+B/2M+2b `2+2Bp2/

*QmMi i?2 MmK#2` Q7 ?2 pv ` BM 2p2M

) AMi2`TQH i2 iQ 2ti2M/ #2vQM/ / i b

) LQ`K HBx2 bXiX i?2 K tBKmK Bb R

.QMöi TH +2 b2MbQ`b Qp2` i?2 Q+2 M5

[R] C T M J2i2Q`QHQ;B+ H ;2M+v

bB;MB}+ M+2 7mM+iBQM 7Q` hQFvQ

q2 mb2/ ` BM7 HH /[R] i iQ 7`+Q`K T(i)2X

JQ`2 ?2 pv ` BM7 HH BM+B/2M+2b `2+2Bp2/

*QmMi i?2 MmK#2` Q7 ?2 pv ` BM 2p2M

) AMi2`TQH i2 iQ 2ti2M/ #2vQM/ / i b

) LQ`K HBx2 bXiX i?2 K tBKmK Bb R

.QMöi TH +2 b2MbQ`b Qp2` i?2 Q+2 M5

q2 mb2/ i?2 :`22/v H;Q`Bi?K iQ TH +2 R9 b2

[R]C T M J2i2Q`QHQ;B+ H ;2M+v

SH +BM; a2MbQ`b BM hQFvQ

6B;m`2 ,6Q,m` ?B;? [m HBiv b2MbQ`b M/ i2M HQr[m HB
hQFvQX h?2 bB;MB}+ M+2 7mM+iBQM Bb ;Bp2M b

S `2iQ PTiBK HBiv

#Qmi aB;MB}+ M+2 6mM+iBQM

$a(t; x_i)$ T`2/B+ib M 2ti`2K2 r2 i?2` 2p2Mi #27C
i?2 *mKmHQMBK#mbX

Ai + M #2 TT`QtBK i2/ #v bQK2 7mM+iBQM C
}2H/[k]

$$a(t; x_i) = 6(p(t; x_i); r(t; x_i))$$

h?2 b2MbQ`bp bMK+T H?2B+? Bb 2[mBp H2aMXi iQ b

[k] +im HHv- Bi HbQ /2T2M/b QM i?2 +?2KB+ H +QKTQM2
Qp2`@b im` iBQM +QM/BiBQM- 2i+X

#Qmi aB;MB}+ M+2 6mM+iBQM

a(t; x i) T`2/B+ib M 2ti`2K2 r2 i?2` 2p2Mi #27Q
i?2 *mKmHQMBK#mbX

Ai + M #2 TT`QtBK i2/ #v bQK2 7mM+iBQM Q
}2H[k] /

a(t; x i) = 6(p(t; x i); r(t; x i))

h?2 b2MbQ`b bMK+T+H?2B+? Bb 2[mBp H2Mi iQ b
h?2`2 `2 irQ T`Q#H2Kb,

q2 /Q MQi FMQr i?2 iKQbT?2`B+ b+B2M+2 i
q2 /Q MQi ? p2 ++2bb iQ ;QQ/ # X b2ib Q7

[k] +im HHv- Bi HbQ /2T2M/b QM i?2 +?2KB+ H +QKTQM2
Qp2`@b im` iBQM +QM/BiBQM- 2i+X

*QMbi`(m;+xi) $a(t, x)$ rBi? i?2 +Q``2+i / i ,

- aQK2 ` M/QK M/ bQK2 T2`BQ/B+ 72 im`2bX
- aKQQi? /2T2M/2M+2 Qp2` bT +2 M/ iBK2X

lbBM; ?BbiQ`B+ H / i - r2 r Mi iQ }M/ QTiBK i?2M r2 mb2 `2 /BM;b 7`QK i?Qb2 b2MbQ`b i bB;MB}+ M+2 7mM+iBQM Qp2` H `;2 `2 X q2 rBHH bim/v i?2 p `B #H2 ói2KT2` im`2ô B

- : i?2`BM; ói2KT2` im`2ô / i Bb bi` B;?i7Q`r
- h2KT2` im`2 M/ bB;MB}+ M+2 #Qi? ? p2 ` M/
- h2KT2` im`2 M/ bB;MB}+ M+2 `2 #Qi? `2 H p
- M/ bT +2X

q2 rBHH TH +2 7 2r TQBMi b2MbQ`b M/ mb2

ói2KT2` im`2 7mM+iBQMô 7Q` HH Q7 C T M

A7 ?BbiQ`B+ H bB;MB}+ M+2 / i b2i Bb ;Bp

+ M #2 mb2/ iQ TH +2 i?2 b2MbQ`bX

G2i #2 K2b? Q7 Qm` /QK2HBM2 K r2BM;?ib X

G2i #2 Qm` / i K i`Bt LB i?X b Bx2

h Bb i?2 MmK#2` Q7 iBK2 b KTH2b- r2 mb2/ ?Q

h?2 +QHmKM b Q7 i?2 i2KT2` im`2b Q7 HH Q7 C

Qp2` i?2 bT M Q7 v2 `X

G2i #2 K2b? Q7 Qm` /QK2BM L2 HB2KrBi?b X

G2i #2 Qm` / i K i`Bt LBi? XbBx2

h Bb i?2 MmK#2` Q7 iBK2 b KTH2b- r2 mb2/ ?Q

h?2 +QHmKMb Q7 i2KT2` im`2b Q7 HH Q7 C

Qp2` i?2 bT M Q7 v2 `X

TTHv bBM;mH ` p Hm2 /2+QKTQbBiBQM iQ

G2i #2 K2b? Q7 Qm` /QK2BM K2bX
G2i #2 Qm` / i K i`Bt LBi?Xb Bx2
h Bb i?2 MmK#2` Q7 iBK2 b KTH2b- r2 mb2/ ?Q
h?2 +QHmKMb Q7 i2KT2` im`2b Q7 HH Q7 C
Qp2` i?2 bT M Q7 v2 `X

TTHv bBM;mH ` p Hm2 /2+QKTQbBiBQM iQ

$$s = l \quad o^h$$

Bb b[m `2 /B ;QM H K i`Bt Q7 rBi? `2 H 2M
l M/o ? p2 Q`i?QMQ`K H +QHmKMbX
*QHmKMb Q7 `2bTQM/BM; iQ bK HH2` 2M`B2b` 2

s_i Bb i?2 i2KT2` im`2 }2H/ Qi7 CMLT RM p2iBQ2X
#2 i?2 MmK#2` Q7 tK Q/+2bHM2/ bi`2M;i?- #2 bm

$$s_i = \text{l}\,\grave{}\,t\,\grave{}\,+ \quad \grave{}$$

[j] Ai /2T2M/b QM

s_i Bb i?2 i2KT2` im`2 }2H/ Qi7 CMLT RM p2 iBQ2`X
#2 i?2 MmK#2` Q7 tKQ/+2b HM2/ bi`2M;i?- #2 bm

$$s_i = l \cdot t \cdot + \cdot$$

SH +2 TQBMi b2M Bb:Q BX hi?2Bi2kT2` im`2 `2 /

$$v_i = \begin{bmatrix} y & & R_{(R,B)} & y & & y \\ X & X & X & X & X & X \\ y & y & R_{(T,B)} & & & y \end{bmatrix} (l \cdot t \cdot + \cdot)$$

$$= > l \cdot t \cdot + > \cdot = * t \cdot + > \cdot$$

/2T2M/b QM bK HH2` bBM;mH ` p Hm2b- #m

[j] Ai /2T2MiX QM

q2 `2+QMbi`m+i i?2 i2KT2` im`2 }2H/ #v i?2

$$\tilde{s}_i = \mathrm{l}\text{`*}\ {}^{R}V_i$$

q?2`M Bb MQi b[m `2- i?2 BMp2`b2 Bb BM i?2 h?2 2``Q` BM i?2 TT`QtBK iBQM Bb,

$$\tilde{s}_i \quad s_i = \mathrm{l}\text{`*}\ {}^{R}>\ \text{`}$$

h?2 bBx2 Q7 i?2 2``Q` p2+i*Q ${}^{R}$Xr BHH /2T2M/ Q A7 i?2 /2i2`KBM Mi Bb H `;2- i?2M i?2 2``Q` hQ QTiBKBx2 Qm` TH +2K2Mi[9]- r2 b?QmH/ +Q

max / 2(i*) Q`min / 2(i* R)

SH +BM; b2Mb Q`:::b B iKb2BM2b i? i i?2 *QrBbHQH7# 2
B::: B Q1`X

q2 mb2 i?2 :`22/v H;Q`Bi?K M/ a+?m`@+QK
Q1`r?B+? BM/+2(i2) bb2 Km+? b TQbbB#H2X

[9] * = (* R) R

h2KT2` im`2 K i`Bt 7Q` C T M

q2 mb2/ i?2 i2KT2` im`2 / i Uk8yk[8]kQR∀7`Q2Ki?C2 K i`BtX

[8]C T M J2i2Q`QHQ;B+ H ;2M+v

h2KT2` im`2 K i`Bt 7Q` C T M

- q2 mb2/ i?2 i2KT2` im`2 / i Uk8yikQR+V`2`Q2ki?C2
K i`BtX
- h?Bb bi` i2;v Bb mb2/ iQ `2 / i2KT2` im`2- #r
`2 / i?2 bB;MB}+ M+2 7mM+iBQMX

[8] C T M J2i2Q`QHQ;B+ H ;2M+v

h2KT2` im`2 K i`Bt 7Q` C T M

- q2 mb2/ i?2 i2KT2` im`2 / i Uk[8]ykR∀ 7`QK i?2 J2i2Q`QHQ;B+ H ;2M+v
  K i`BtX
- h?Bb bi` i2;v Bb mb2/ iQ `2 / i2KT2` im`2- #mi
  `2 / i?2 bB;MB}+ M+2 7mM+iBQMX
- PM i?2 b+ H2 Q7 i?2 2MiB`2 h C JT* M /B22`2M+2
  #2ir22M G:a M/ >:aX

[8] C T M J2i2Q`QHQ;B+ H ;2M+v

h2KT2` im`2 K i`Bt 7Q` C T M

- q2 mb2/ i?2 i2KT2` im`2 / i Uk8yikQR ∀`Y`Q2Ki C2
  K i`BtX
- h?Bb bi` i2;v Bb mb2/ iQ `2 / i2KT2` im`2- #
  `2 / i?2 bB;MB}+ M+2 7mM+iBQMX
- PM i?2 b+ H2 Q7 i?2 2MiBL`2 h C JT*M /B2 2`22MBb+
  #2ir22M G:a M/ >:aX
- q2 mb2/ .`X LQMQKm` öb TT`Q +? iQ TH +2
  `QmM/ C T MX

[8] C T M J2i2Q`QHQ;B+ H ;2M+v

6B;m`2 ,Ry, TQBMi b2MbQ`b BM72` i?2 i2KT2` im`2

h2KT2` im`2 K i`Bt 7Q` hQFvQ

- q2 mb2/ i?2 i2KT2` im`2 / i U kyR+V[e] ' `iQsK ?C2J K i`BtX

[e] C T M J2i2Q`QHQ;B+ H ;2M+v

h2KT2` im`2 K i`Bt 7Q` hQFvQ

- q2 mb2/ i?2 i2KT2` im`2 / i UkyRV 7`QK i?2 J K i`BtX
- PM i?2 hQFvQ +Biv b+GH2 1?Bz`2 `2bM+2 #2ir22 M/ HQr ;` /2 b2MbQ`bX

h2KT2` im`2 K i`Bt 7Q` hQFvQ

- q2 mb2/ i?2 i2KT2` im`2 / i UKyi QR+V 7`QK ?C2J[e] i`Q?K ?C2J
  K i`BtX
- PM i?2 hQFvQ +Biv b+H_2: 1?B ž2 `B2bM+2 #2ir22
  M/ HQr ;` /2 b2MbQ`bX
- h?2 ?B;? ;` /2 b2MbQ`b + M b22 K Mv HQ+ iB
  T`Q}H2b Q7 /D +2Mi bBi2b `2 M2 `Hv HBM2

[e] C T M J2i2Q`QHQ;B+ H ;2M+v

h2KT2` im`2 K i`Bt 7Q` hQFvQ

- q2 mb2/ i?2 i2KT2` im`2 / i UKyiQR+V 7`iQ2sK?C2J
  K i`BtX
- PM i?2 hQFvQ +Biv b+GH_2: 1?B ż2 `B2bM+2 #2ir22
  M/ HQr ;` /2 b2MbQ`bX
- h?2 ?B;? ;` /2 b2MbQ`b + M b22 K Mv HQ+ iB
  T`Q}H2b Q7 /D +2Mi bBi2b `2 M2 `Hv HBM2
- q2 ? / iQ KQ/B7v i?2 K2i?Q/ BM Q`/2` iQ mb2

[e] C T M J2i2Q`QHQ;B+ H ;2M+v

>Qr ;QQ/ Bb ;QQ/ b2MbQ`\

A7 >:a ? b pB2rBM;` /Bmb Q7 Ry TBt2Hb- bBi2b HH iQM+2X

>Qr ;QQ/ Bb ;QQ/ b2MbQ`\

- A7 >:a ? b pB2rBM; ` /Bmb Q7 Ry TBt2Hb- bBi2b HH i QM+2X
- h?Qb2 jR9 p2+iQ`b KB;?i MmK2`B+ HHv bT M #mi bBM+2 i?2 i2KT2` im`2 T`Q}H2b Q7 M2 ` B/2MiB+ H- i?2 ó2bb2MiB H /BK2MbBQMô Q i? M jR9X

>Qr ;QQ/ Bb ;QQ/ b2MbQ`\

- A7 >:a ? b pB2rBM; ` /Bmb Q7 Ry TBt2Hb- bBi2b HH i QM+2X
- h?Qb2 jR9 p2+iQ`b KB;?i MmK2`B+ HHv bT M #mi bBM+2 i?2 i2KT2` im`2 T`Q}H2b Q7 M2 ` B/2MiB+ H- i?2 ó2bb2MiB H /BK2MbBQMô Q i? M jR9X
- q2 mb2 i?2 bBM;mH ` p Hm2b Q7 i?2 >:aöb p b2MbQ`b ó2bb2MiB H /BK2MbBQMôX

>Qr ;QQ/ Bb ;QQ/ b2MbQ`\

- A7 >:a ? b pB2rBM; ` /Bmb Q7 Ry TBt2Hb- bBi2b HH iQM+2X
- h?Qb2 jR9 p2+iQ`b KB;?i MmK2`B+ HHv bT #mi bBM+2 i?2 i2KT2` im`2 T`Q}H2b Q7 M2 B/2MiB+ H- i?2 ó2bb2MiB H /BK2MbBQMô Q i? M jR9X
- q2 mb2 i?2 bBM;mH ` p Hm2b Q7 i?2 >:aöb p b2MbQ`b ó2bb2MiB H /BK2MbBQMôX
- A7 >:a ? b ó2bb2MiB MH i/?B2KKG MabBrQMnôH/ ;Bp2 K2 bm`2K2Mi Q7 2[m H [m HBivX

h?2 1bb2MiB H .BK2MbBQM

Mbr2`b i?2 +Qbi@[m HBiv i` /2 QzX

>:aöb /2i2+i }M2 /2i BH M/ G:aöb /2i2+i H `;

h?2 1bb2MiB H .BK2MbBQM

Mbr2`b i?2 +Qbi@[m HBiv i` /2 QzX

>:aöb /2i2+i }M2 /2i BH M/ G:aöb /2i2+i H `;

h?2 2bb2MiB H /BK2MbBQM

BM+`2 b2b rBi? KQ`2 }M2Hv b KTH2/ / i X

h?2 1bb2MiB H .BK2MbBQM

Mbr2`b i?2 +Qbi@[m HBiv i` /2 QzX

>:aöb /2i2+i }M2 /2i BH M/ G:aöb /2i2+i H `;

h?2 2bb2MiB H /BK2MbBQM

BM+`2 b2b rBi? KQ`2 }M2Hv b KTH2/ / i X

BM+`2 b2b rBi? i?2 pB2rBM; ` /BmbX

h?2 1bb2MiB H .BK2MbBQM

Mbr2`b i?2 +Qbi@[m HBiv i` /2 QzX

- >:aöb /2i2+i }M2 /2i BH M/ G:aöb /2i2+i H `;
- h?2 2bb2MiB H /BK2MbBQM
  - BM+`2 b2b rBi? KQ`2 }M2Hv b KTH2/ / i X
  - BM+`2 b2b rBi? i?2 pB2rBM; ` /BmbX
  - /2T2M/b QM TH +2K2Mic Bi Bb ?B;?2` BM `2

h?2 1bb2MiB H .BK2MbBQM

- Mbr2`b i?2 +Qbi@[m HBiv i` /2 QzX
- >:aöb /2i2+i }M2 /2i BH M/ G:aöb /2i2+i H `;
- h?2 2bb2MiB H /BK2MbBQM
  - BM+`2 b2b rBi? KQ`2 }M2Hv b KTH2/ / i X
  - BM+`2 b2b rBi? i?2 pB2rBM; ` /BmbX
  - /2T2M/b QM TH +2K2Mic Bi Bb ?B;?2` BM `2
- AM Qm` 2tT2`BK2Mib- >:ab mbm HHv ? / 2bb
- i?Bb Bb #2+ mb2 Qm` / i r b iQQ +Q `b2Hv b

6B;m`2 hrQ ?B;? ;` /2 b2MbQ`b M/ 2B;?i HQr ;` /2 b2MbQ`b QM C Mm `v RR kykRX

GBKBi iBQMb

.m2 iQ #Qi? H +F Q7 / i M/ +QKTmi iBQM
B;MQ`2/ i?2 j. + b2X "Qi? b? T2 T +FBM; M/
/ Ti2/ iQ j.X

Limitations

Due to both a lack of data and computation power, we mostly ignored the 3D case. Both shape packing and SVD methods can be adapted to 3D.

We do not know how exactly to construct a good significance function and we assume it has enough similar properties to "temperature" to make the SVD approach feasible.

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Any method to interpret the sensors based on historical data will slowly degrade in quality because of climate change.

For our SVD methods we ignored the fact that HGS can see some of the ocean even if it is on the land, this can be remedied but we didn't have the time to implement it.

Conclusion

To solve the multi-objective optimization problem, we offer the circle packing approach and Dr. Nonomura's approach to optimally place the sensors.

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To solve the multi-objective optimization problem, we offer the circle packing approach and Dr. Nonomura's approach to optimally place the sensors.

Tokyo	
Shape-Packing	More high-grade sensors
SVD	Data dependent

Japan	
SVD	Low-grade sensors

Reference

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b0_Xn ³9h9L9J b«h_ i9c9_J ¦9c9´«c_ i9X9§9J b0_ «c0 8 9_J ³9 «n ~9 9c_J ³«a_ ~9_§nJ ¦9c« injnh«}9 9jL K9_ «c0 ¦ «@9c_jnu K0§0}h_j9j§]@9 0L T9 § X}00L´ 0j n} 0e0H§_nj 9eXn}_§\hu