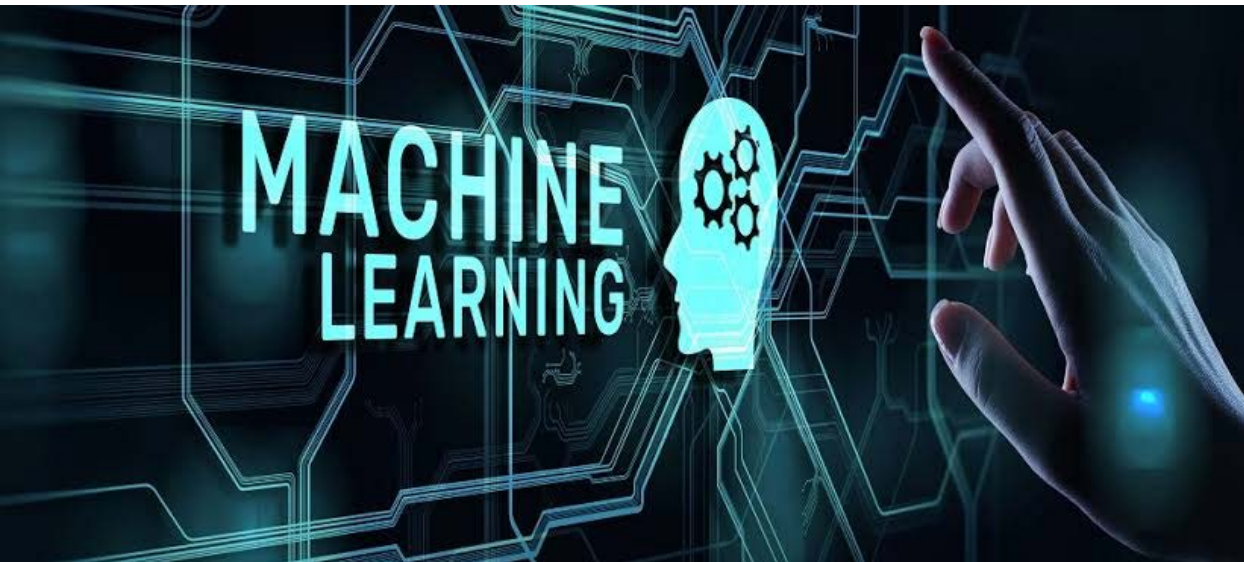


Tilstandsmodellering av avløpsrør ved bruk av maskinlæring

Kilde: freecodecamp.com



Kilde: trenchlesstechnology.com

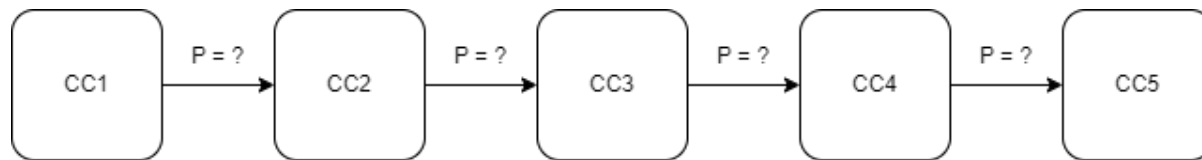


2011

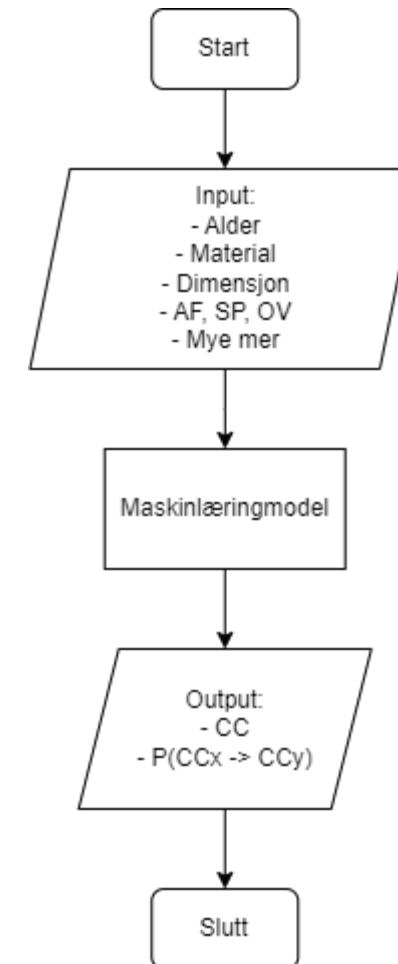
2021

Mål for oppgaven

- Undersøke maskinlæringsalgoritmer
- Anvende på inspeksjonsdata
- Forutse rørtilstand
- Overgang i tilstandsklasse



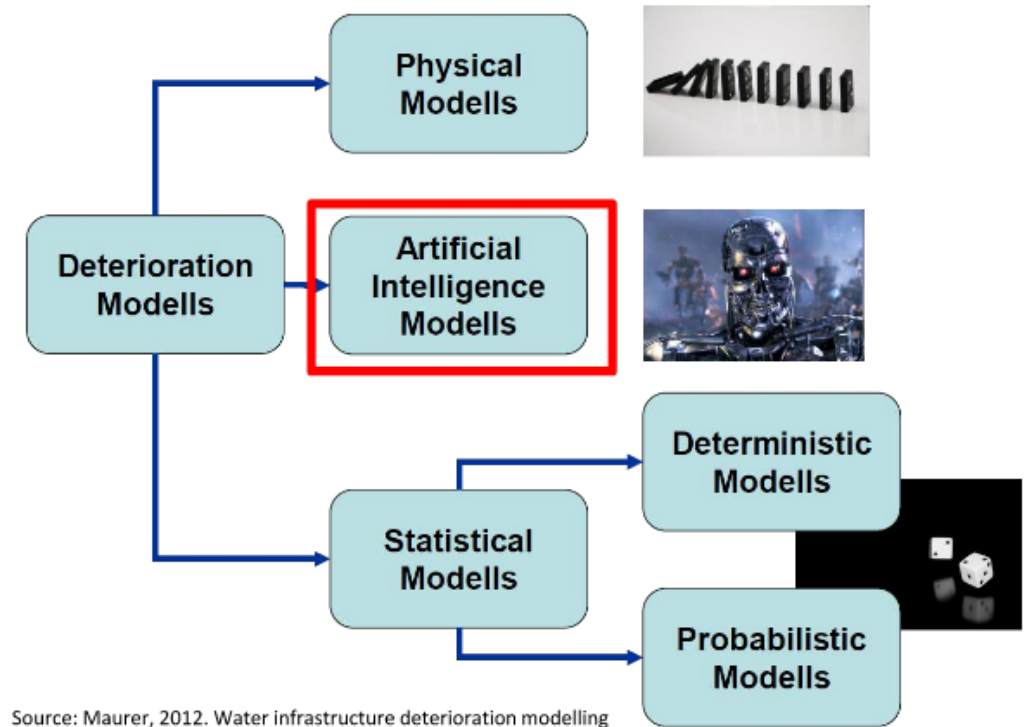
Kilde: Egen



Kilde: Egen

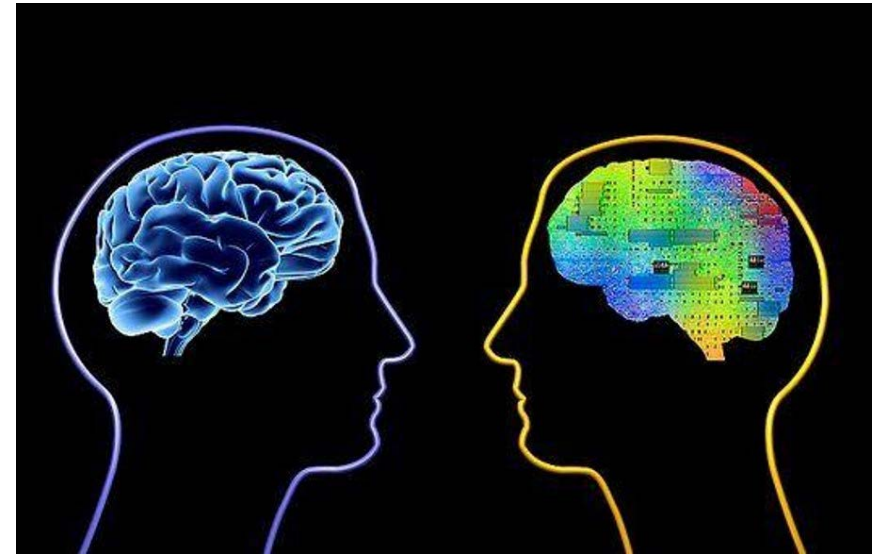
Tilstandsmodellering

- Drift og vedlikehold
- Gjenværende levetid
- Ikke-inspiserte rør
- Fremtidig tilstand
- 3 typer modeller:
 - Fysisk
 - Statistisk
 - Kunstig intelligens



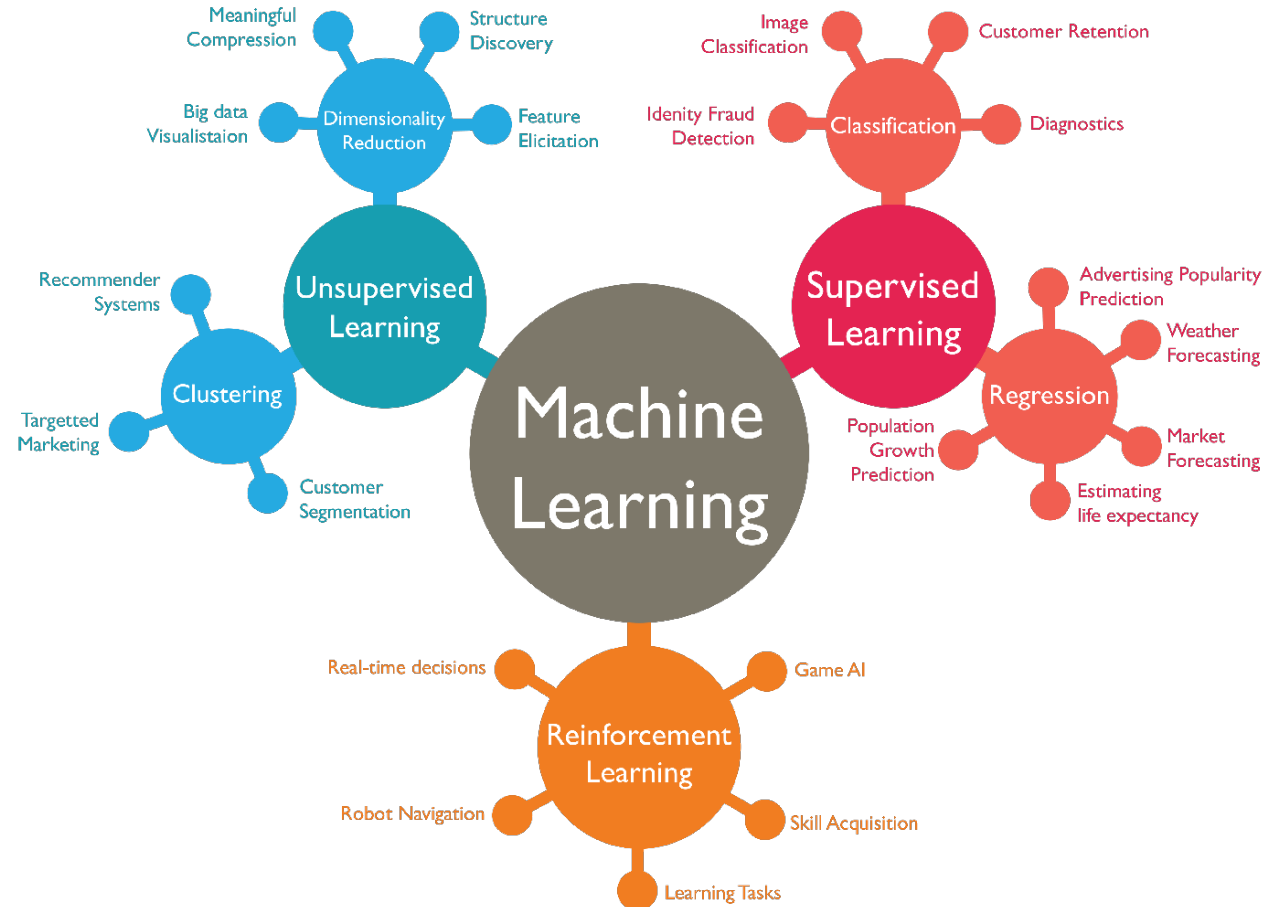
Hva er kunstig intelligens?

- Intelligente datasystemer
- Maskinlæring
- Datamaskinen lærer av data
- Gjenkjenning av komplekse mønster



Kilde: kdnugget.com

Maskinlæring

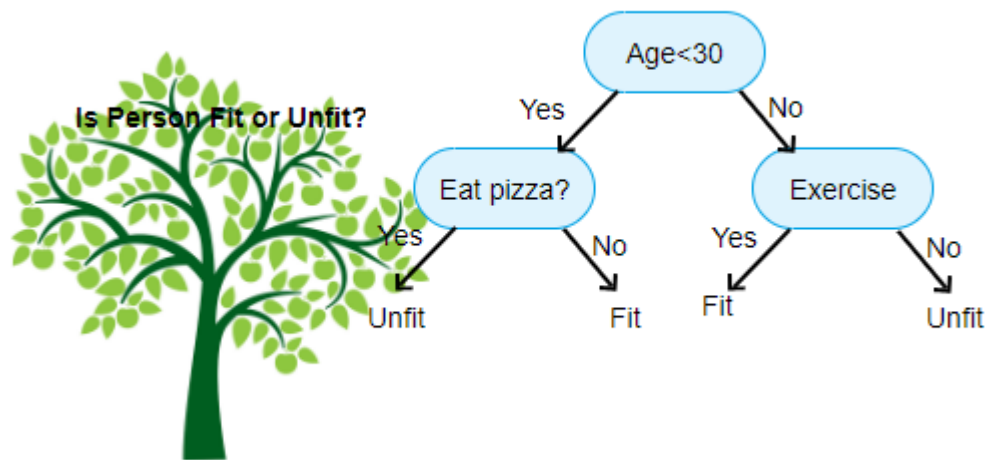


Kilde: wordstream.com

Hvilke algoritmer kan benyttes?

- Klassifisering

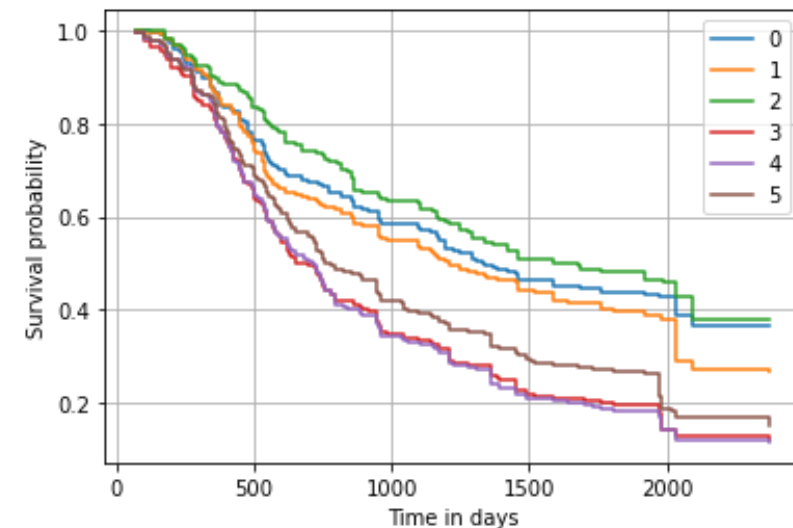
- Decision Tree
- Random Forest
- Support Vector Machines
- Neural Networks



Kilde: aitimejournal.com

- Overlevelsesmodeller

- Survival Tree
- Random Survival Forest
- Survival Support Vector machines



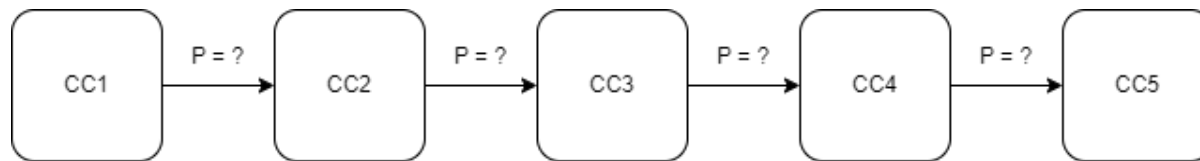
Kilde: Scikit-survival.readthedocs.io

Resultat

- Påliteligheten til estimert tilstand
- Sannsynlighet for skifte mellom tilstandsklasser
- Sammenligning av modellresultat

		True Class	
		Positive	Negative
Predicted Class	Positive	TP	FP
	Negative	FN	TN

Kilde: Charan Vaddepally (2021)



Kilde: Egen

		Predicted condition				
		1	2	3	4	5
Actual condition	1	201	8	11	3	0
	2	25	5	10	9	0
	3	28	5	9	10	0
	4	15	2	5	9	1
	5	3	1	3	0	0

Kilde: Harvey & McBean (2014)

Hvorfor bruke maskinlæring?

- Praktisk bruk av inspeksjonsdata
- Veiledning i inspeksjonsplanlegging
- Analyse av store datasett

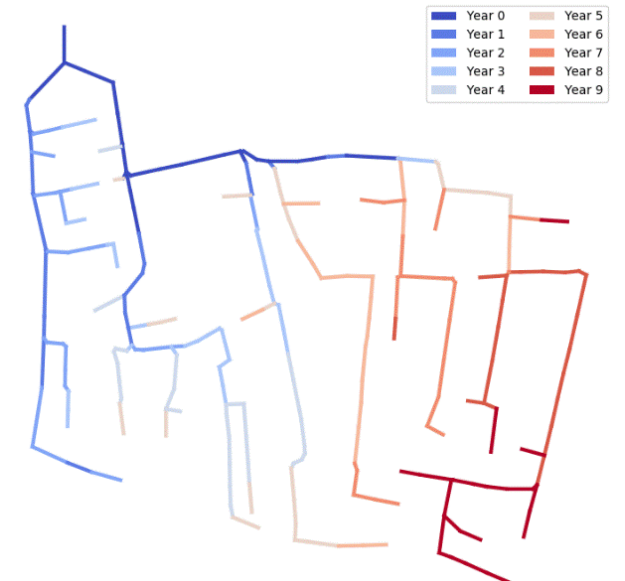


Kilde: bcacunderground.com

Drain[1]	Drain[1]	Gate[1]	Gate[1]	Drain[2]	Drain[2]	Gate[2]	Gate[2]	Drain[3]	Drain[3]	Gate[3]	Gate[3]	Drain[4]	Drain[4]	Gate[4]	Gate[4]	Drain[5]	Drain[5]	Gate[5]	Gate[5]
3.29E-07	0.00E+00	1.52E-07	1.00E+00	2.97E-07	0.00E+00	1.57E-07	0.00E+01	2.57E-07	0.00E+00	1.83E-07	0.00E+01	2.19E-07	0.00E+00	1.62E-07	7.00E-01	1.83E-07	0.00E+00	1.42E-07	6.00E-01
4.33E-06	1.00E-02	1.93E-07	1.00E+00	4.24E-06	1.00E-02	1.77E-07	9.00E-01	4.14E-06	1.00E-02	1.72E-07	8.00E-01	4.01E-06	1.00E-02	1.88E-07	7.00E-01	3.87E-06	1.00E-02	1.52E-07	6.00E-01
1.27E-05	2.00E-02	1.47E-07	1.00E+00	1.22E-05	2.00E-02	1.22E-07	9.00E-01	1.17E-05	2.00E-02	1.52E-07	8.00E-01	1.11E-05	2.00E-02	1.88E-07	7.00E-01	1.05E-05	2.00E-02	2.18E-07	6.00E-01
1.91E-05	3.00E-02	1.42E-07	1.00E+00	1.83E-05	3.00E-02	1.62E-07	9.00E-01	1.75E-05	3.00E-02	1.62E-07	8.00E-01	1.66E-05	3.00E-02	1.47E-07	7.00E-01	1.56E-05	3.00E-02	1.62E-07	6.00E-01
2.55E-05	4.00E-02	1.32E-07	1.00E+00	2.44E-05	4.00E-02	1.81E-07	9.00E-01	2.33E-05	4.00E-02	2.38E-07	8.00E-01	2.21E-05	4.00E-02	1.62E-07	7.00E-01	2.08E-05	4.00E-02	1.27E-07	6.00E-01
3.19E-05	5.00E-02	1.01E-07	1.00E+00	3.05E-05	5.00E-02	1.79E-07	9.00E-01	2.92E-05	5.00E-02	1.52E-07	8.00E-01	2.79E-05	5.00E-02	1.22E-07	7.00E-01	2.60E-05	5.00E-02	1.98E-07	6.00E-01
3.81E-05	6.00E-02	1.01E-07	1.00E+00	3.66E-05	6.00E-02	1.17E-07	9.00E-01	3.49E-05	6.00E-02	1.62E-07	8.00E-01	3.31E-05	6.00E-02	1.52E-07	7.00E-01	3.11E-05	6.00E-02	1.52E-07	6.00E-01
4.45E-05	7.00E-02	6.08E-08	1.00E+00	4.26E-05	7.00E-02	1.72E-07	9.00E-01	4.07E-05	7.00E-02	1.62E-07	8.00E-01	3.85E-05	7.00E-02	1.06E-07	7.00E-01	3.62E-05	7.00E-02	1.17E-07	6.00E-01
5.07E-05	8.00E-02	1.52E-07	1.00E+00	4.86E-05	8.00E-02	1.17E-07	9.00E-01	4.64E-05	8.00E-02	1.52E-07	8.00E-01	4.39E-05	8.00E-02	1.98E-07	7.00E-01	4.13E-05	8.00E-02	1.57E-07	6.00E-01
5.71E-05	9.00E-02	1.61E-07	1.00E+00	5.47E-05	9.00E-02	1.21E-07	9.00E-01	5.21E-05	9.00E-02	1.62E-07	8.00E-01	4.94E-05	9.00E-02	1.88E-07	7.00E-01	4.63E-05	9.00E-02	1.67E-07	6.00E-01
6.34E-05	1.00E-01	7.61E-08	1.00E+00	6.07E-05	1.00E-01	1.72E-07	9.00E-01	5.79E-05	1.00E-01	1.93E-07	8.00E-01	5.47E-05	1.00E-01	2.03E-07	7.00E-01	5.14E-05	1.00E-01	1.62E-07	6.00E-01
6.97E-05	1.10E-01	1.57E-07	1.00E+00	6.68E-05	1.10E-01	1.47E-07	9.00E-01	6.36E-05	1.10E-01	1.42E-07	8.00E-01	6.01E-05	1.10E-01	2.43E-07	7.00E-01	5.65E-05	1.10E-01	1.27E-07	6.00E-01
7.60E-05	1.20E-01	1.27E-07	1.00E+00	7.29E-05	1.20E-01	1.47E-07	9.00E-01	6.93E-05	1.20E-01	1.37E-07	8.00E-01	6.56E-05	1.20E-01	1.77E-07	7.00E-01	6.14E-05	1.20E-01	1.32E-07	6.00E-01
8.24E-05	1.30E-01	1.06E-07	1.00E+00	7.88E-05	1.30E-01	1.32E-07	9.00E-01	7.51E-05	1.30E-01	1.47E-07	8.00E-01	7.09E-05	1.30E-01	1.83E-07	7.00E-01	6.64E-05	1.30E-01	1.57E-07	6.00E-01
8.86E-05	1.40E-01	1.13E-07	1.00E+00	8.48E-05	1.40E-01	1.42E-07	9.00E-01	8.07E-05	1.40E-01	1.42E-07	8.00E-01	7.67E-05	1.40E-01	1.67E-07	7.00E-01	7.15E-05	1.40E-01	1.12E-07	6.00E-01
9.50E-05	1.50E-01	1.06E-07	1.00E+00	9.09E-05	1.50E-01	1.83E-07	9.00E-01	8.64E-05	1.50E-01	1.62E-07	8.00E-01	8.16E-05	1.50E-01	2.38E-07	7.00E-01	7.64E-05	1.50E-01	1.47E-07	6.00E-01
1.01E-04	1.60E-01	1.01E-07	1.00E+00	9.68E-05	1.60E-01	1.93E-07	9.00E-01	9.21E-05	1.60E-01	2.18E-07	8.00E-01	8.69E-05	1.60E-01	1.06E-07	7.00E-01	8.13E-05	1.60E-01	1.32E-07	6.00E-01
1.08E-04	1.70E-01	8.62E-08	1.00E+00	1.03E-04	1.70E-01	1.32E-07	9.00E-01	9.78E-05	1.70E-01	1.32E-07	8.00E-01	9.22E-05	1.70E-01	1.67E-07	7.00E-01	8.64E-05	1.70E-01	1.88E-07	6.00E-01
1.14E-04	1.80E-01	6.08E-08	1.00E+00	1.09E-04	1.80E-01	1.42E-07	9.00E-01	1.03E-04	1.80E-01	1.72E-07	8.00E-01	9.74E-05	1.80E-01	1.83E-07	7.00E-01	9.13E-05	1.80E-01	1.93E-07	6.00E-01
1.20E-04	1.90E-01	1.22E-07	1.00E+00	1.15E-04	1.90E-01	1.22E-07	9.00E-01	1.09E-04	1.90E-01	1.97E-07	8.00E-01	1.03E-04	1.90E-01	2.33E-07	7.00E-01	9.61E-05	1.90E-01	2.37E-07	6.00E-01
1.27E-04	2.00E-01	1.32E-07	1.00E+00	1.21E-04	2.00E-01	1.32E-07	9.00E-01	1.15E-04	2.00E-01	1.12E-07	8.00E-01	1.08E-04	2.00E-01	2.43E-07	7.00E-01	1.01E-04	2.00E-01	1.47E-07	6.00E-01
1.33E-04	2.10E-01	1.77E-07	1.00E+00	1.27E-04	2.10E-01	1.32E-07	9.00E-01	1.20E-04	2.10E-01	1.32E-07	8.00E-01	1.13E-04	2.10E-01	1.57E-07	7.00E-01	1.06E-04	2.10E-01	1.83E-07	6.00E-01
1.39E-04	2.20E-01	1.42E-07	1.00E+00	1.33E-04	2.20E-01	1.37E-07	9.00E-01	1.26E-04	2.20E-01	1.88E-07	8.00E-01	1.19E-04	2.20E-01	1.88E-07	7.00E-01	1.11E-04	2.20E-01	1.52E-07	6.00E-01
1.45E-04	2.30E-01	1.33E-07	1.00E+00	1.39E-04	2.30E-01	1.86E-07	9.00E-01	1.32E-04	2.30E-01	1.62E-07	8.00E-01	1.24E-04	2.30E-01	1.52E-07	7.00E-01	1.16E-04	2.30E-01	1.57E-07	6.00E-01
1.52E-04	2.40E-01	1.22E-07	1.00E+00	1.45E-04	2.40E-01	1.88E-07	9.00E-01	1.37E-04	2.40E-01	1.77E-07	8.00E-01	1.29E-04	2.40E-01	1.32E-07	7.00E-01	1.20E-04	2.40E-01	1.42E-07	6.00E-01
1.58E-04	2.50E-01	8.62E-08	1.00E+00	1.51E-04	2.50E-01	2.03E-07	9.00E-01	1.43E-04	2.50E-01	1.47E-07	8.00E-01	1.34E-04	2.50E-01	1.62E-07	7.00E-01	1.25E-04	2.50E-01	1.27E-07	6.00E-01
1.64E-04	2.60E-01	1.12E-07	1.00E+00	1.57E-04	2.60E-01	1.77E-07	9.00E-01	1.49E-04	2.60E-01	1.47E-07	8.00E-01	1.39E-04	2.60E-01	1.72E-07	7.00E-01	1.29E-04	2.60E-01	1.12E-07	6.00E-01
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1.83E-04	2.90E-01	1.17E-07	1.00E+00	1.75E-04	2.90E-01	1.12E-07	9.00E-01	1.65E-04	2.90E-01	1.37E-07	8.00E-01	1.55E-04	2.90E-01	9.63E-08	7.00E-01	1.44E-04	2.90E-01	1.77E-07	6.00E-01
1.90E-04	3.00E-01	6.59E-08	1.00E+00	1.81E-04	3.00E-01	1.57E-07	9.00E-01	1.71E-04	3.00E-01	1.72E-07	8.00E-01	1.60E-04	3.00E-01	1.17E-07	7.00E-01	1.49E-04	3.00E-01	1.57E-07	6.00E-01
1.96E-04	3.10E-01	6.08E-08	1.00E+00	1.87E-04	3.10E-01	1.32E-07	9.00E-01	1.76E-04	3.10E-01	1.27E-07	8.00E-01	1.65E-04	3.10E-01	1.06E-07	7.00E-01	1.54E-04	3.10E-01	1.22E-07	6.00E-01
2.02E-04	3.20E-01	1.01E-07	1.00E+00	1.92E-04	3.20E-01	1.12E-07	9.00E-01	1.82E-04	3.20E-01	1.06E-07	8.00E-01	1.70E-04	3.20E-01	8.11E-08	7.00E-01	1.58E-04	3.20E-01	1.37E-07	6.00E-01
2.09E-04	3.30E-01	1.01E-07	1.00E+00	1.98E-04	3.30E-01	1.22E-07	9.00E-01	1.87E-04	3.30E-01	1.27E-07	8.00E-01	1.75E-04	3.30E-01	1.12E-07	7.00E-01	1.63E-04	3.30E-01	1.47E-07	6.00E-01
2.15E-04	3.40E-01	1.23E-07	1.00E+00	2.04E-04	3.40E-01	2.18E-07	9.00E-01	1.93E-04	3.40E-01	9.63E-08	8.00E-01	1.81E-04	3.40E-01	1.52E-07	7.00E-01	1.67E-04	3.40E-01	1.67E-07	6.00E-01
2.21E-04	3.50E-01	9.63E-08	1.00E+00	2.10E-04	3.50E-01	1.77E-07	9.00E-01	1.99E-04	3.50E-01	1.32E-07	8.00E-01	1.85E-04	3.50E-01	1.27E-07	7.00E-01	1.72E-04	3.50E-01	1.77E-07	6.00E-01
2.27E-04	3.60E-01	1.17E-07	1.00E+00	2.16E-04	3.60E-01	1.47E-07	9.00E-01	2.04E-04	3.60E-01	1.77E-07	8.00E-01	1.90E-04	3.60E-01	1.57E-07	7.00E-01	1.77E-04	3.60E-01	1.52E-07	6.00E-01
2.34E-04	3.70E-01	1.06E-07	1.00E+00	2.22E-04	3.70E-01	2.48E-07	9.00E-01	2.09E-04	3.70E-01	1.88E-07	8.00E-01	1.95E-04	3.70E-01	1.42E-07	7.00E-01	1.81E-04	3.70E-01	2.08E-07	6.00E-01
2.40E-04	3.80E-01	9.63E-08	1.00E+00	2.28E-04	3.80E-01	1.33E-07	9.00E-01	2.15E-04	3.80E-01	1.22E-07	8.00E-01	2.01E-04	3.80E-01	9.63E-08	7.00E-01	1.86E-04	3.80E-01	1.77E-07	6.00E-01

Kilde: mathematica.stackexchange.com

Inspection Plan with weight (3, 1, 1)



Kilde: Tscheikner-Gratl (2021)

Veiledere

- Franz Tscheikner-Gratl (Førsteamanuensis)
- Marius Møller Rokstad (Førsteamanuensis)
- Shamsuddin Daulat (Stipendiat)
- Bardia Roghani (Postdoktor)