



Introduction

“Decision-Driven Data Analytics for Fast Well Placement in Field Development Scenario-Powered by Machine Learning”

Peyman Kor, M.Sc Reservoir Engineering, UiS
Supervisors: Reidar B Bratvold, Aojie Hong



Outlines

1

**Development of Proxy Model Utilizing
Machine Learning Algorithm for Reservoir
Simulation**

2

**Value of Information in Data Analytic
Project**

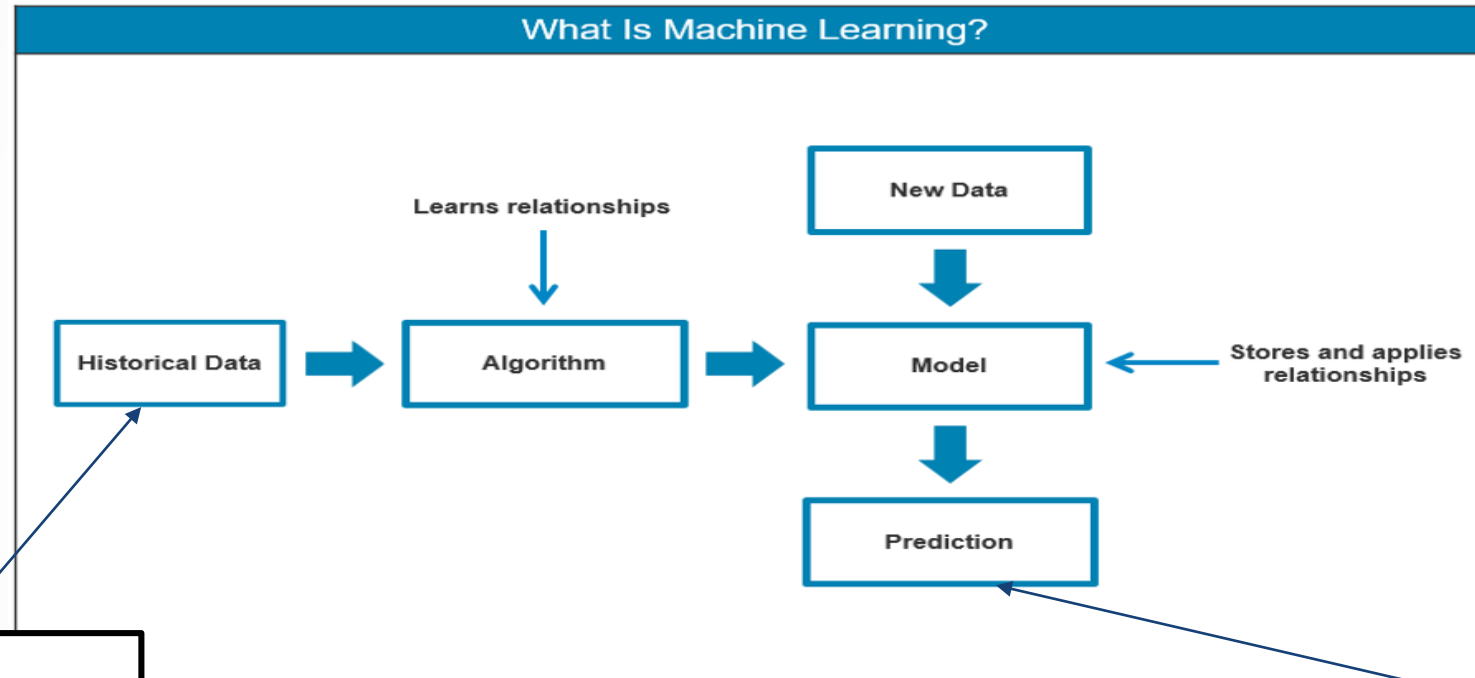
1. Proxy Model

Numerical Reservoir Simulator
Vs.
Machine Learning Based
Simulator

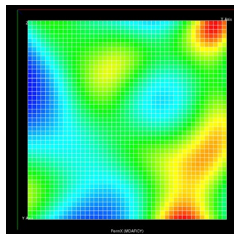


1. Proxy Model

ML Based Simulator:



1. Porosity
2. Permeability
3. Distance
4. Compressibility
5. Geological Model,...



45x45 Grid
Size

2025 Perm Values
2025 Porosity Value
2025 Compressibility
values,...

$$NPV = \sum_{k=1}^{n_T} \frac{[(q_o^k P_o - q_w^k P_w - I^k P_{wi} \Delta t_k)]}{(1 + b)^{t_k/D}} - CAPEX$$

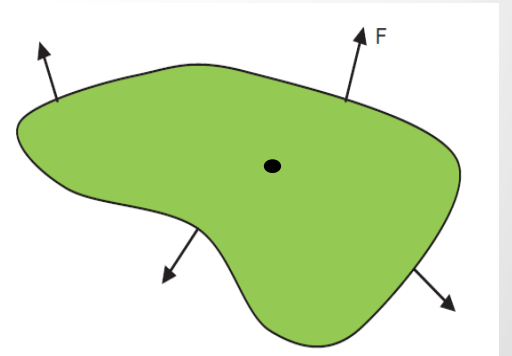
1. Proxy Model

Connectivity: Fast Marching Method

Eikonal Form of Equation:

The equation to track advancing surfaces on grid based reservoir:

$$F(x) | \nabla \tau(x) | = 1$$



1. Proxy Model

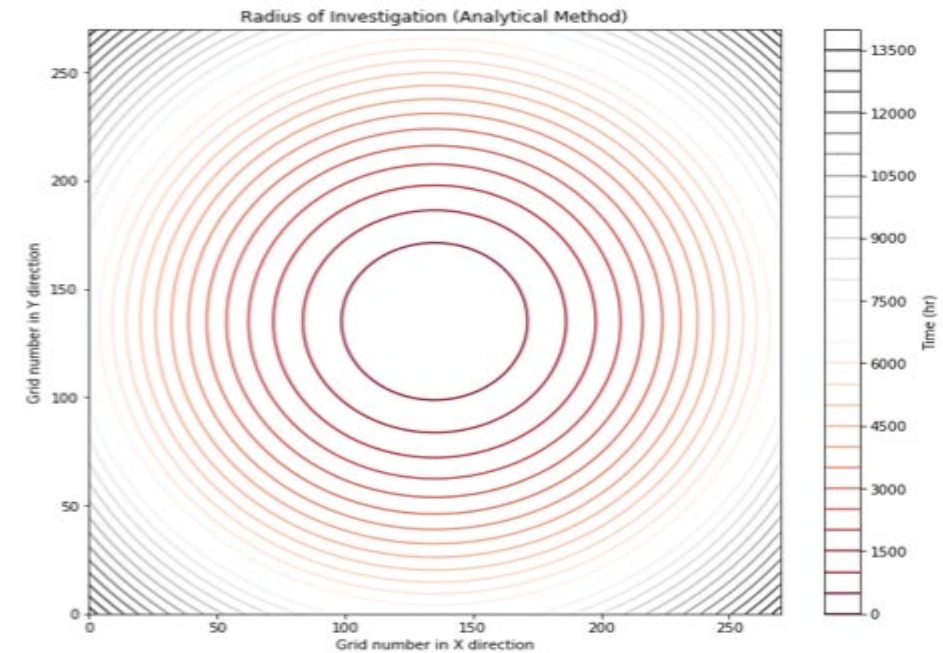
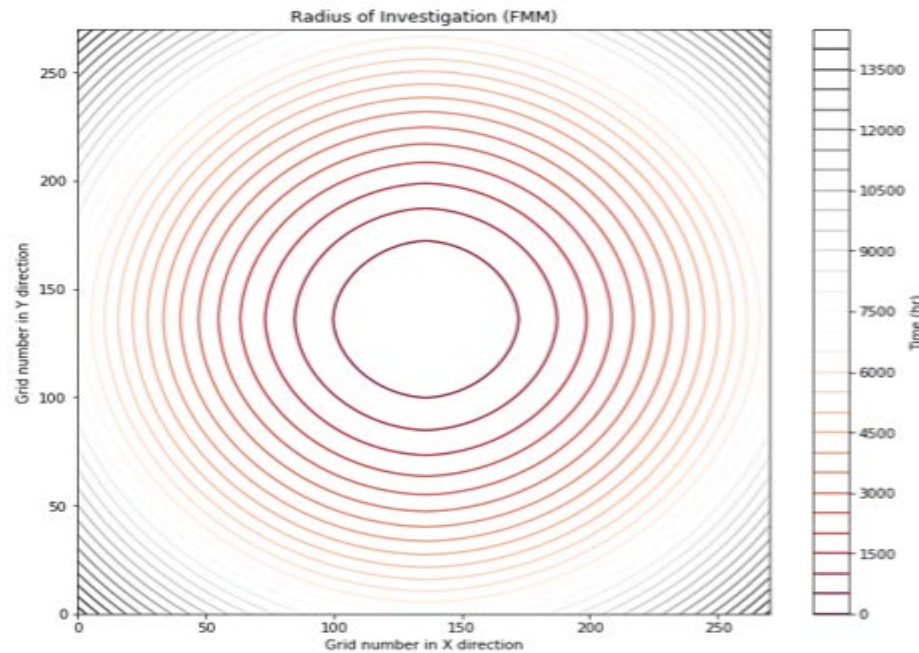
Validation of FMM

Radius of investigation
as a radius of impulse
–response. (Lee 1982)

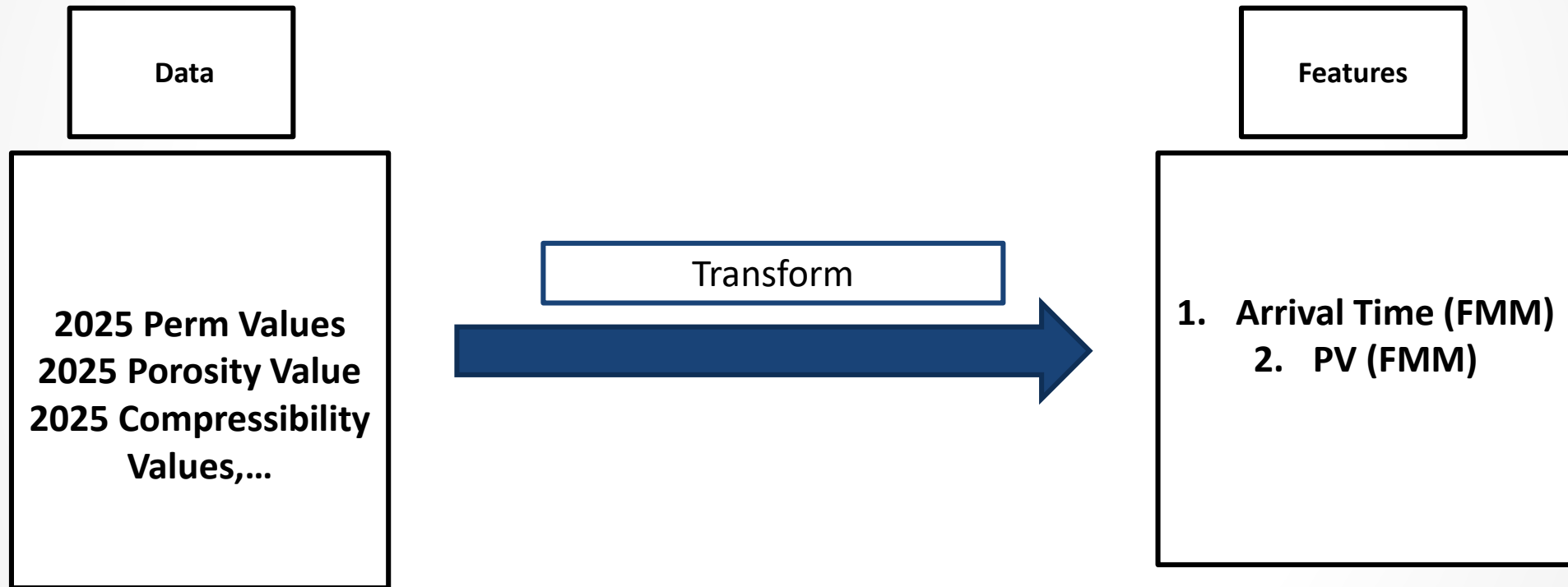
$$r = \sqrt{\frac{kt}{948\mu c_t \phi}}$$

Reservoir Properties

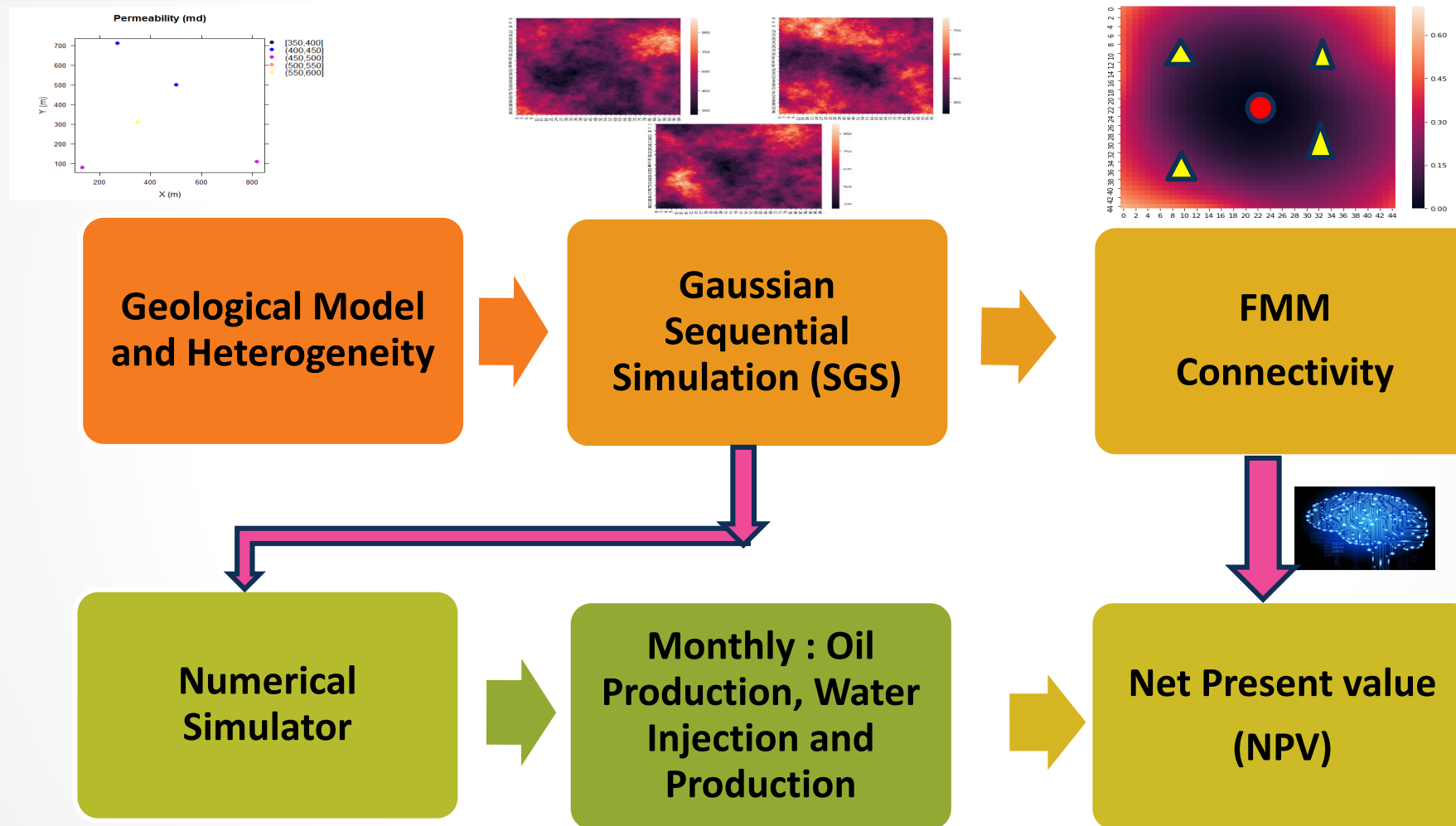
Grid block Size	20 by 20 by 20 ft
Grid block numbers	271 by 271
Porosity	10%
Permeability	1 md
Compressibility	10 ⁻⁵ (1/psi)
Viscosity	1 cp
Initial Pressure	4000 psi



1. Proxy Model Connectivities as Features



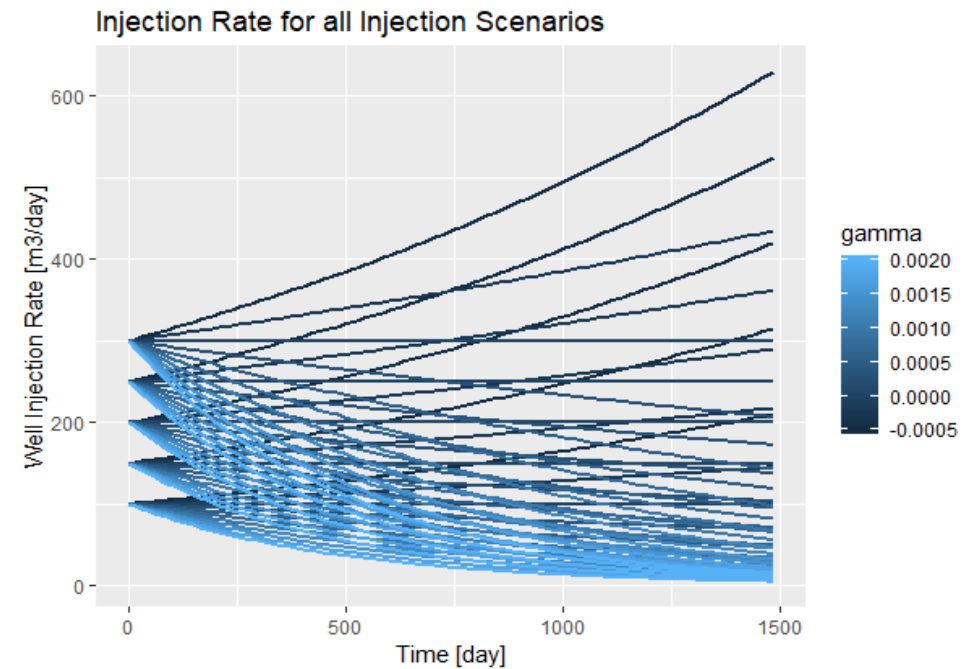
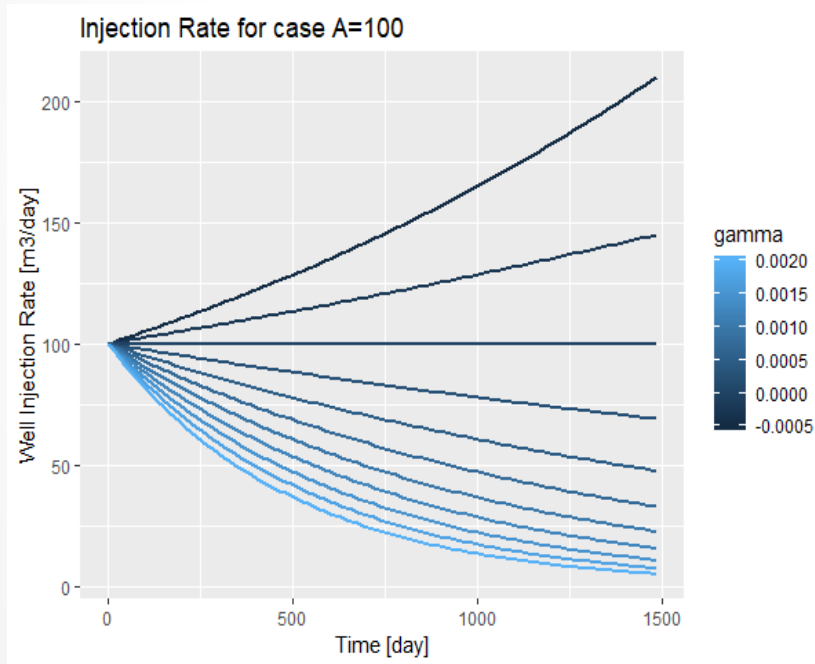
1. Proxy Modeling Workflow



1. Proxy Modeling

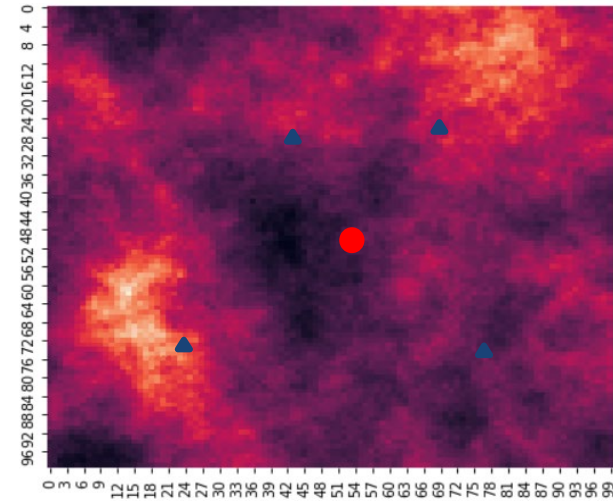
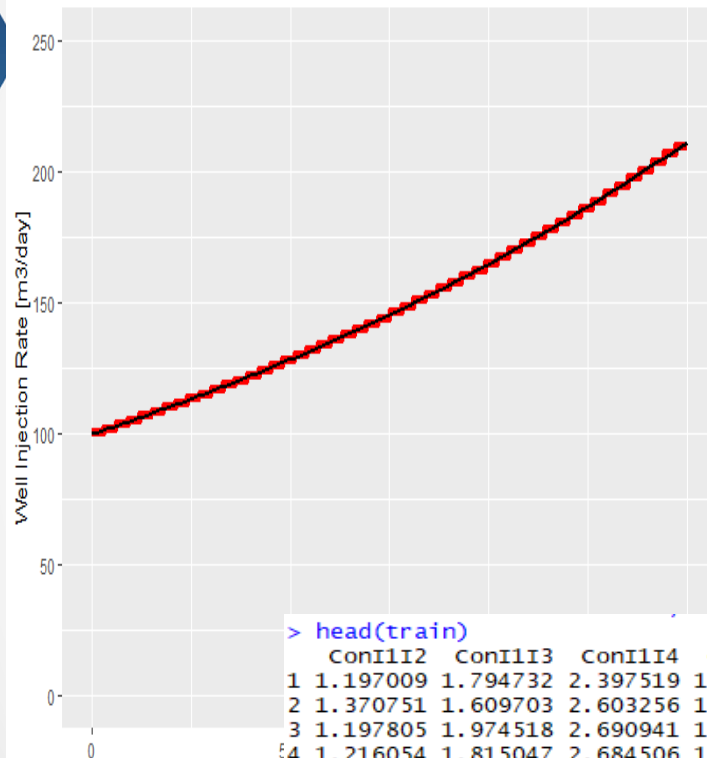
Injection Rate Scenarios:

$$Inj = Aexp(-\gamma t)$$



1. Proxy Modeling Injection Rate Scenarios:

ECLIPSE Mounthly Injection Rate (red) in secnario A=100, gamma=-0.0005



```
WCONINJE
INJ1 WATER OPEN RATE 100 /
INJ2 WATER OPEN RATE 300 /
INJ3 WATER OPEN RATE 150 /
INJ4 WATER OPEN RATE 250 /
/
TSTEP
30 /
WCONINJE
INJ1 WATER OPEN RATE 94.1764533584249 /
INJ2 WATER OPEN RATE 284.65629631674 /
INJ3 WATER OPEN RATE 141.264680037637 /
INJ4 WATER OPEN RATE 244.437809298334 /
/
TSTEP
30 /
WCONINJE
INJ1 WATER OPEN RATE 88.6920436717158 /
INJ2 WATER OPEN RATE 270.09735677588 /
INJ3 WATER OPEN RATE 133.038065507574 /
INJ4 WATER OPEN RATE 238.999370458275 /
/
TSTEP
30 /
WCONINJE
INJ1 WATER OPEN RATE 83.5270211411272 /
INJ2 WATER OPEN RATE 256.283044082544 /
INJ3 WATER OPEN RATE 125.290531711691 /
INJ4 WATER OPEN RATE 233.681930154007 /
/
TSTEP
```

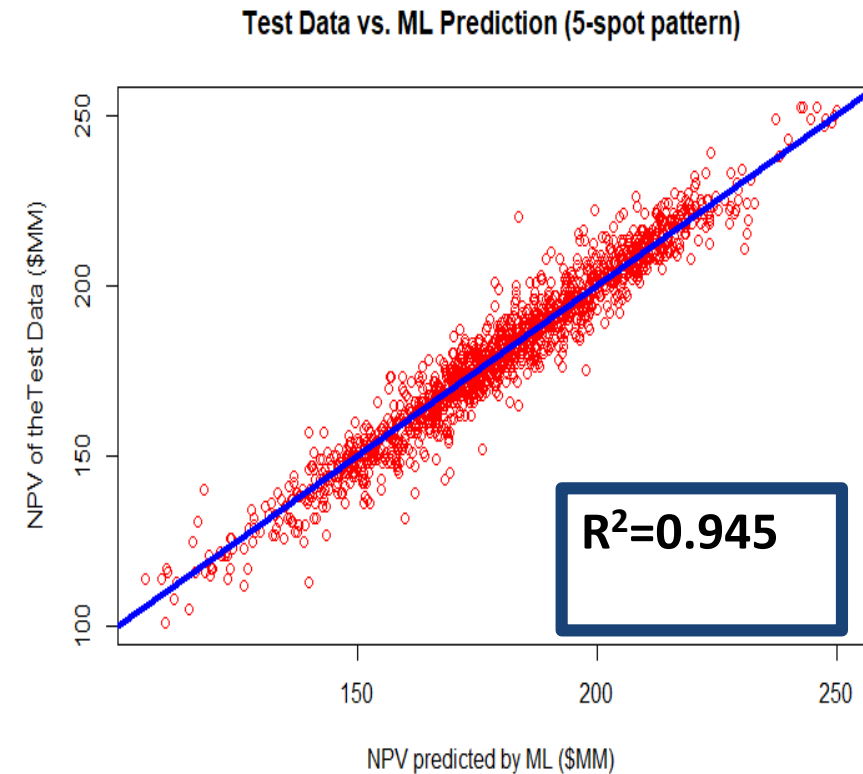
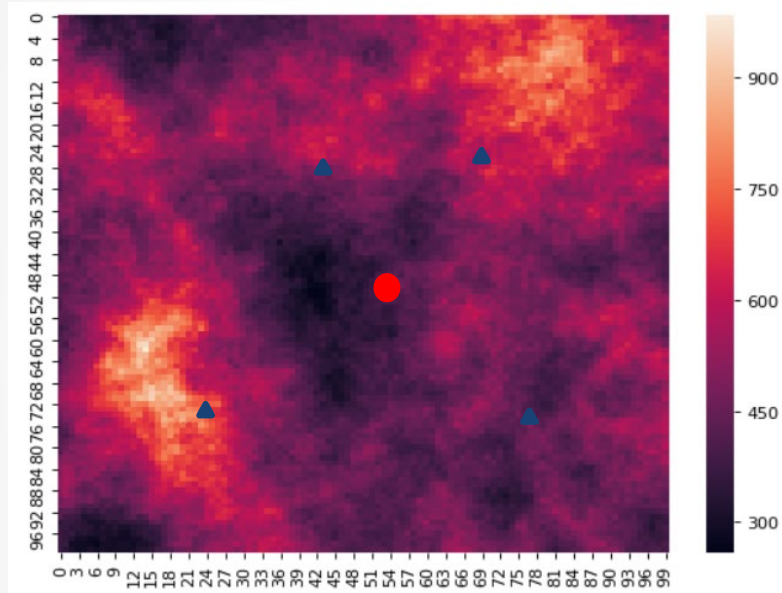
```
> head(train)
ConI1I2 ConI1I3 ConI1I4 ConI2I1 ConI2I3 ConI2I4 ConI3I1 ConI3I2 ConI3I4 ConI4I1 ConI4I2 ConI4I3
1 1.197009 1.794732 2.397519 1.136494 1.811036 1.178921 1.769486 1.798020 0.4180600 2.477331 1.179474 0.4583601
2 1.370751 1.609703 2.603256 1.369754 1.848122 1.364106 1.545308 1.778901 0.4235951 2.530953 1.275130 0.4156282
3 1.197805 1.974518 2.690941 1.275293 1.819897 1.247667 1.968648 1.810238 0.4729509 2.692909 1.223844 0.4231628
4 1.216054 1.815047 2.684506 1.218889 1.763886 1.281996 1.889774 1.810357 0.4962542 2.732164 1.347532 0.4472813
5 1.104374 1.688002 2.573770 1.112539 1.773235 1.375900 1.771935 1.804519 0.4730142 2.593494 1.298356 0.5127484
6 1.063912 1.979038 2.538925 1.116667 1.859795 1.186824 2.048105 1.853593 0.4864869 2.561240 1.188823 0.4351454

ConPI1 ConPI2 ConPI3 ConPI4 PV_flight A1 A2 A3 A4 gam1 gam2 gam3 gam4 NPV
1 0.6774903 0.3192029 0.6450933 0.5529229 87.55556 150 150 100 300 0.00025 -0.00025 0.00100 0.00100 56.68
2 0.7440811 0.3318827 0.5679226 0.6125266 91.75309 250 150 300 250 0.00150 0.00100 0.00025 0.00100 56.29
3 0.7891240 0.3660942 0.6038898 0.5804768 89.03704 300 150 200 100 0.00125 0.00100 0.00100 0.00175 57.09
4 0.8146611 0.2968731 0.6144062 0.5837607 84.34568 150 100 300 150 0.00000 -0.00050 0.00075 0.00150 56.93
5 0.7111817 0.3235421 0.6059673 0.7048939 86.51852 150 250 200 100 0.00200 0.00050 0.00025 0.00125 56.61
6 0.7337789 0.3306681 0.6428683 0.5968821 88.93827 200 200 300 100 0.00050 0.00175 0.00075 0.00175 57.36

> view(train)
```

1. Proxy Modeling

5-spot pattern result- (25 Features)



Tuning parameter of (Xgboost) Algorithm

Nrounds	Max_depth	Eta	gamma	Min_child_weight	subsample
2000	6	0.02	0	2.25	1

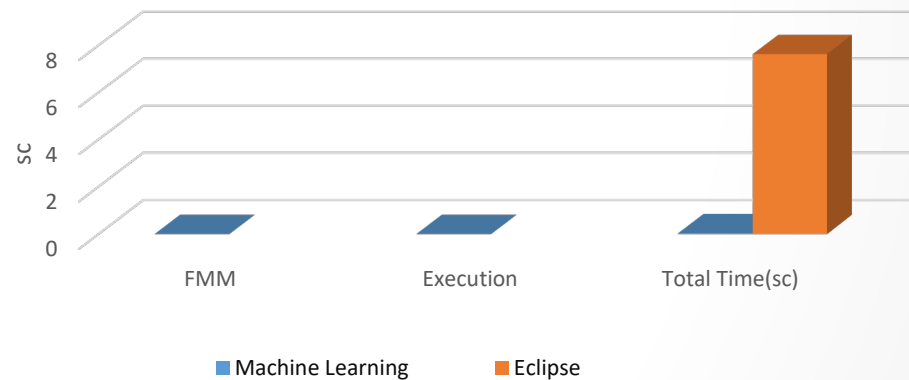
1. Proxy Modeling

Running Time, ML Vs. Eclipse

Numerical Reservoir Simulator Vs. Machine Learning

	Machine Learning	Eclipse
FMM	0,034 sc	
Execution	0,03 ml	
Total Time(sc)	0,034	7,63

Speed (ML vs. Eclipse)



~200X Faster



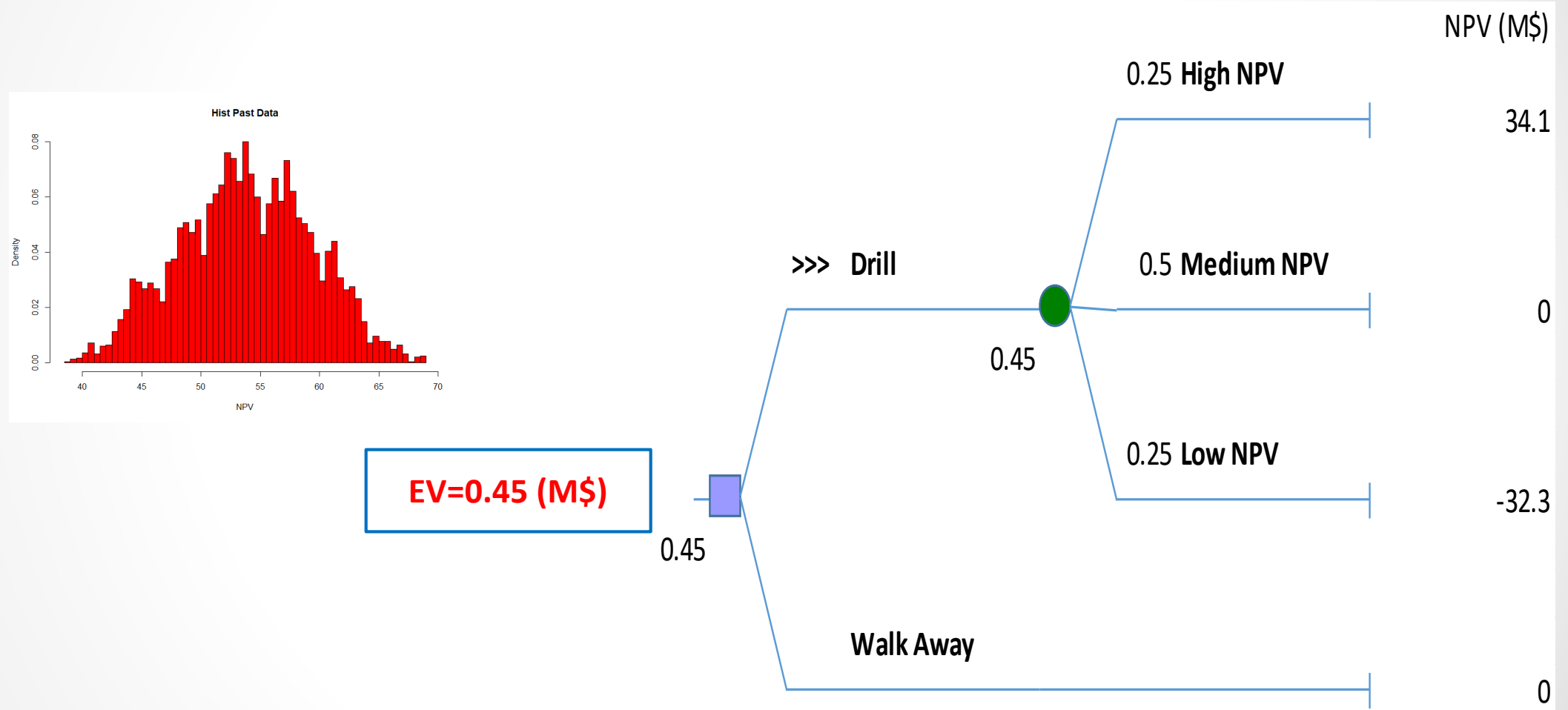
2. Value of Information (VOI)

Value of Information in Data Analytic Project



2. Value of Information (VOI)

a. Expected Value without Information



2. Value of Information (VOI)

a. Expected Value with Information

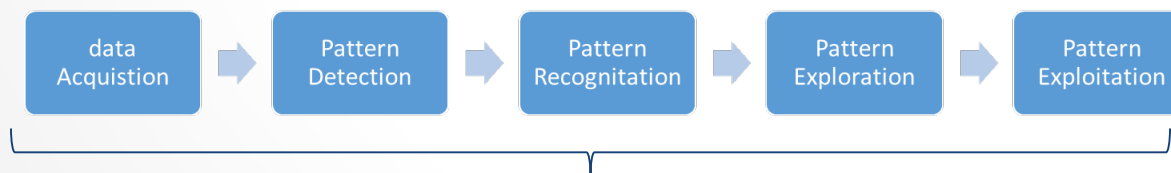
ML Says

	H	M	L	Total
"H"	0,133	0,083	0,017	0,233
"M"	0,117	0,300	0,083	0,267
"L"	0,000	0,117	0,150	0,500
Total	0,250	0,500	0,250	1,000

Real Test Data Says

$$VOI = 8.52 - 0.45 = \$8.07 \text{ M}$$

$$EV = 8.52 \text{ (M\$)}$$



Data Analytic Project Cost!

