Using Spark Simulations in Drone Navigation for Reducing Uncertainty when Fighting Wildfires

Christian Fuchs, Sascha Wolf

christian-klaus.fuchs@stud.uni-bamberg.de

sascha-alexander.wolf@stud.uni-bamberg.de

AISE-Proj-B: Ethics of intelligent Vehicles

Bachelor Applied Computer Science

08.02.2023

Outline

- Motivation
- Applications
- Project roadmap
- Data Simulation
- Data Analysis
- Prediction of risks
- Firefly-Algorithm
- Conclusions
- Future Work
- References

Motivation

- Wildfires causes significant economic and human losses globally
- Small improvement in the fight against wildfire can significantly reduce total damage
- **Goal:** Improvement of the determination of high-risk zones
- **Method:** Predict the *high-risk-damage probability* for a zone based on real data

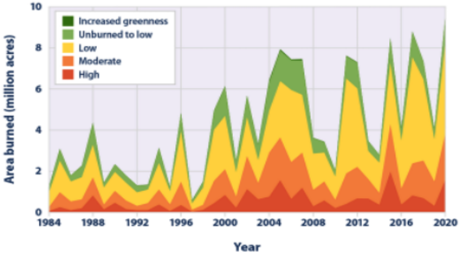


Figure: (left) Damage Caused by Wildfires in the United States, 1984–2020 (right) Bushfire in Australia 2019 (damaged 60-84 million acres)

Applications

- **Situation:** Existing wildfire
- **Question:** Which zones to fight to minimize damage?

Figure: Wildfire from above in Turkey 2021

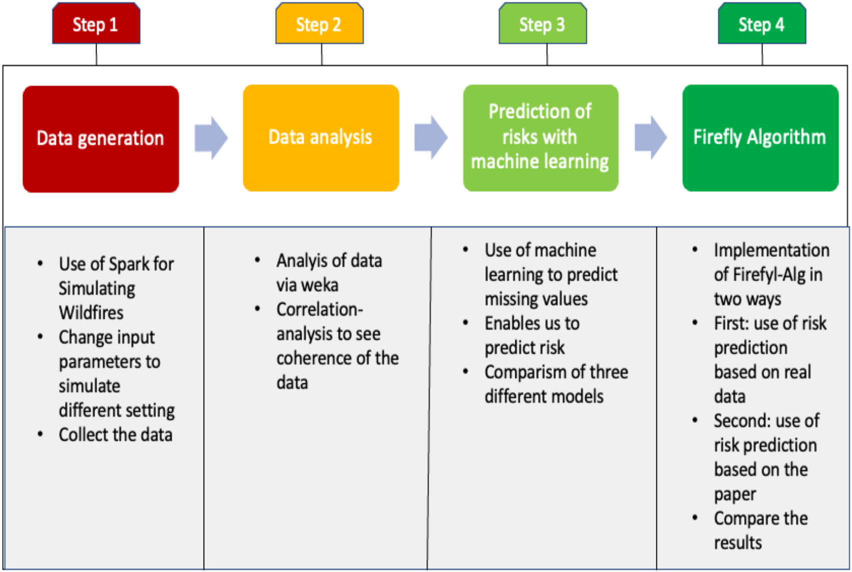
Applications

- **Answer:** Fight zones with highest damage probability

64%	70%	91%
54%	46%	44%
28%	32%	12%
12%	34%	21%

Figure: Categorization in zones with risks

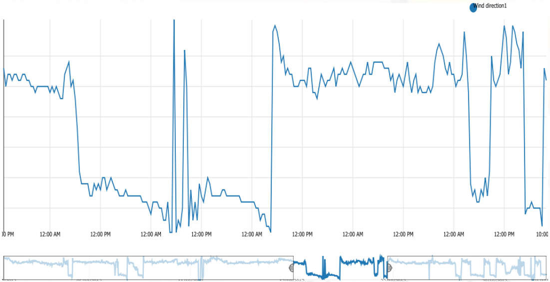
Project roadmap

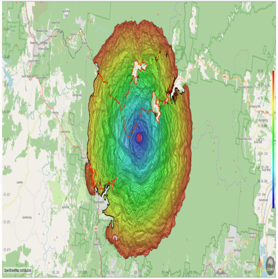


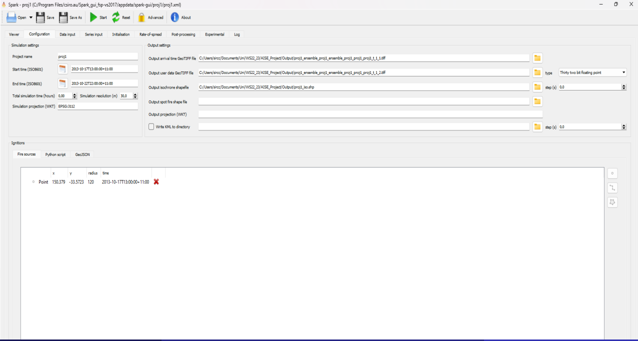
Spark Outline

- Introduction
- Wildfire
- How the Simulation works
- Presenting GUI

Spark


Wind direction1
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM
12:00 AM
12:00 PM




Open
Save
Save As
Start
Reset
Advanced
About
Viewer
Configuration
Data input
Series input
Initialisation
Rate-of-spread
Post-processing
Experimental
Log
Simulation settings
Project name
proj1
Start time (ISO8601)
2013-10-17T13:00:00+11:00
End time (ISO8601)
2013-10-22T22:00:00+11:00
Simulation projection (WKT)
EPSG:3112
Output settings
Output arrival time GeoTIFF file
Output user data GeoTIFF file
Output isochrone shapefile
Output spot fire shape file
Output projection (WKT)
Write KML to directory
Thirty two bit floating point
Ignitions
Fire sources
Python script
GeoJSON
Point
150.379
-33.5723
120
2013-10-17T13:00:00+11:00

Introduction to Spark

- Spark is a Wildfire Simulation toolkit
- Created by the Research Team of CSIR O Research
- Allows to visualize and output Data
- Can be used for planning, warning, response and manly research

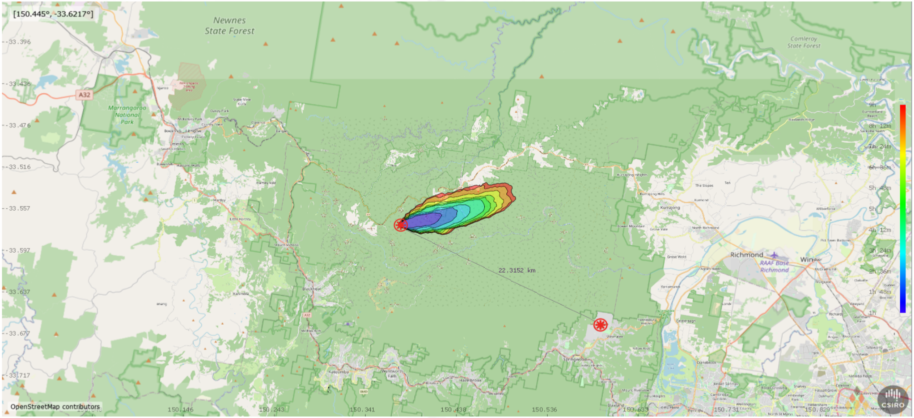

[150.445°, -33.6217°]
Newnes
State Forest
Marrangaroo
National
Park
A32
Comleroy
State Forest
22.3152 km
Richmond
RAAF Base
Richmond
OpenStreetMap contributors
-33.396
-33.436
-33.476
-33.516
-33.557
-33.597
-33.637
-33.677
-33.717
150.146
150.243
150.341
150.438
150.536
150.633
150.731
150.829
CSIRO

Figure: View

Spark

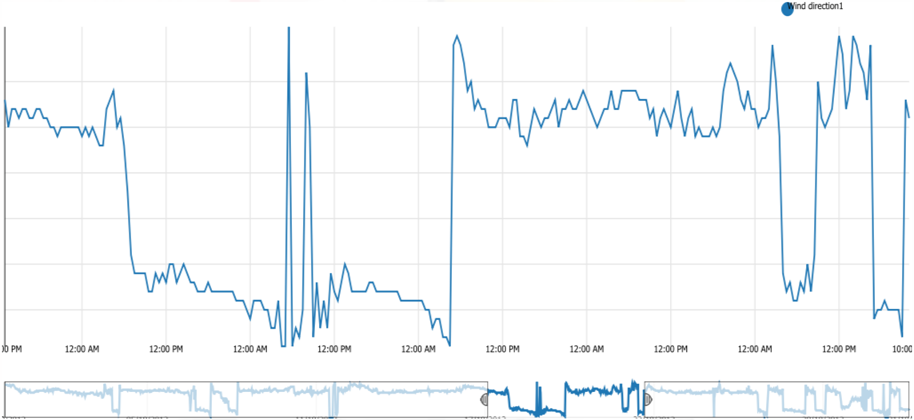


Figure: Graph analysis

Spark

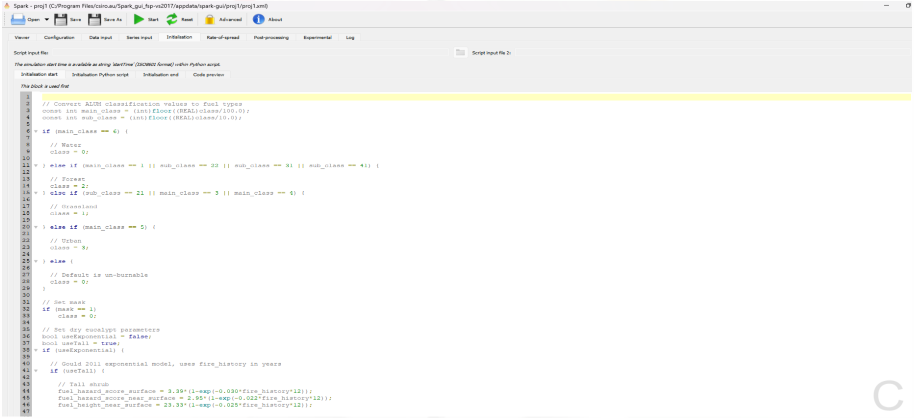


Figure: Landscape$_{C}$*lassification*

Data Analysis

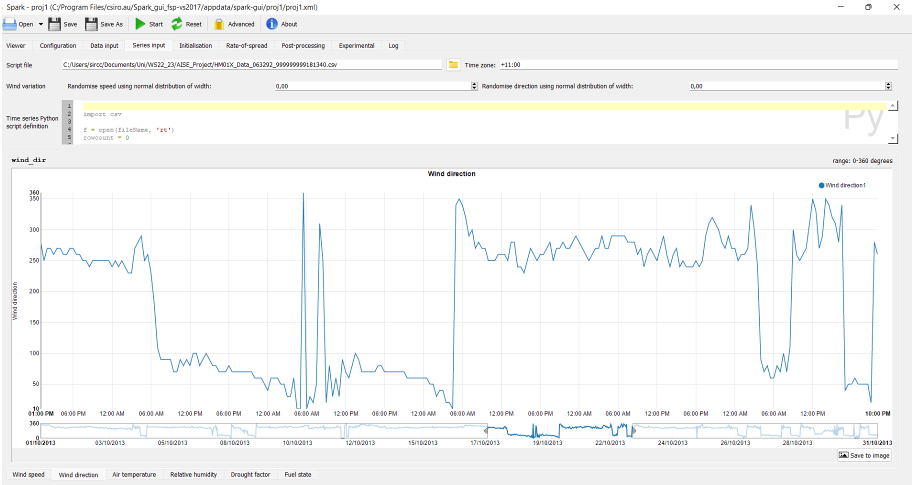


Figure: Data analysis

Data Analysis

```
Start time: Do Okt 17 13:00:00 2013 GMT+1100
End time: Di Okt 22 22:00:00 2013 GMT+1100
Simulation time: 5d 9h 0s
Time: Do Okt 17 13:01:00 2013 GMT+1100; area: 4.41 ha; tiles: 1 (1); [0%]
Time: Fr Okt 18 01:54:00 2013 GMT+1100; area: 557.1 ha; tiles: 1 (1); [10%]
Time: Fr Okt 18 14:48:00 2013 GMT+1100; area: 1992.51 ha; tiles: 1 (1); [20%]
Time: Sa Okt 19 03:42:00 2013 GMT+1100; area: 4323.69 ha; tiles: 5 (5); [30%]
Time: Sa Okt 19 16:36:00 2013 GMT+1100; area: 7400.88 ha; tiles: 5 (5); [40%]
Time: So Okt 20 05:30:00 2013 GMT+1100; area: 11459.3 ha; tiles: 9 (9); [50%]
Time: So Okt 20 18:24:00 2013 GMT+1100; area: 16070.5 ha; tiles: 9 (9); [60%]
Time: Mo Okt 21 07:18:00 2013 GMT+1100; area: 22085.7 ha; tiles: 9 (9); [70%]
Time: Mo Okt 21 20:12:00 2013 GMT+1100; area: 28680.5 ha; tiles: 9 (9); [80%]
Time: Di Okt 22 09:06:00 2013 GMT+1100; area: 35230.6 ha; tiles: 10 (10); [90%]
Time: Di Okt 22 22:00:00 2013 GMT+1100; area: 42050.4 ha; tiles: 17 (17); [100%]
Execution completed in 60.5441 s
Output: shapefile 'C:/Users/sircc/Documents/Uni/WS22_23/AISE_Project/Output\proj1_proj1_ensemble_proj1_iso_3.shp' written
Output: raster arrival time 'C:/Users/sircc/Documents/Uni/WS22_23/AISE_Project/Output\proj1_proj1_ensemble_proj1_ensemble_proj1_proj1_proj1_t_1_1.tiff' written
Average speed: 0.034 m/s
Maximum intensity: 9300.000 kW/m
Maximum flame height: 5.186 m
Fire area: 89476.013 ha, perimeter (estimate): 261.247 km

Output: raster data 'C:/Users/sircc/Documents/Uni/WS22_23/AISE_Project/Output\proj1_proj1_ensemble_proj1_ensemble_proj1_proj1_proj1_t_1_3.tiff' written
WARNING: No nodes in mesh, no shapefile written
Output: shape file 'C:/Users/sircc/Documents/Uni/WS22_23/AISE_Project/Output\proj1_proj1_ensemble_proj1_iso_5.shp' written
```

Figure: Data analysis

Weka

- Weka tool for data mining tasks
- Open Source Software

Weka

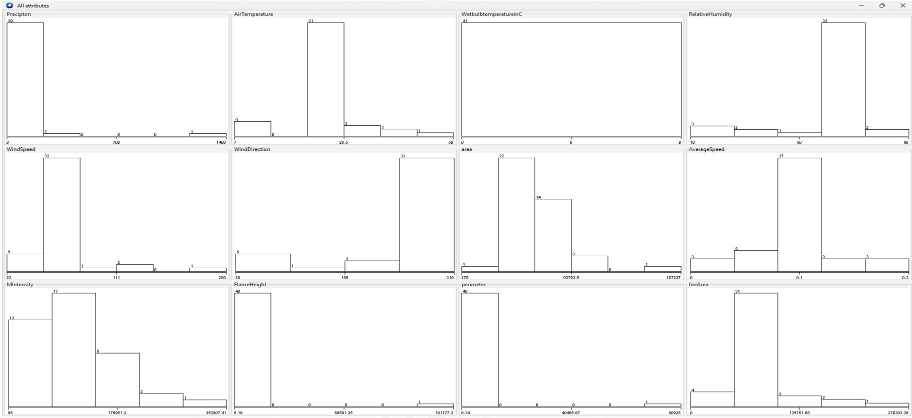


Figure: Graphs

Weka

```
=== Run information ===

Evaluator:    weka.attributeSelection.CorrelationAttributeEval
Search:       weka.attributeSelection.Ranker -T -1.7976931348623157E308 -N -1
Relation:     teste
Instances:    41
Attributes:   12
              Precipton
              AirTemperature
              WetbulbtemperatureinC
              RelativeHumidity
              WindSpeed
              WindDirection
              area
              AverageSpeed
              MIntensity
              FlameHeight
              perimeter
              fireArea
Evaluation mode:    evaluate on all training data



=== Attribute Selection on all input data ===

Search Method:
        Attribute ranking.

Attribute Evaluator (supervised, Class (numeric): 2 AirTemperature):
        Correlation Ranking Filter
Ranked attributes:
 0.33618   6 WindDirection
 0.15797   4 RelativeHumidity
 0.09865   9 MIntensity
 0.08723  12 fireArea
 0.07765   7 area
 0.01283  11 perimeter
 0         3 WetbulbtemperatureinC
-0.00925  10 FlameHeight
-0.01146   1 Precipton
-0.03998   8 AverageSpeed
-0.05316   5 WindSpeed

Selected attributes: 6,4,9,12,7,11,3,10,1,8,5 : 11
```

Figure: Correlations

Weka

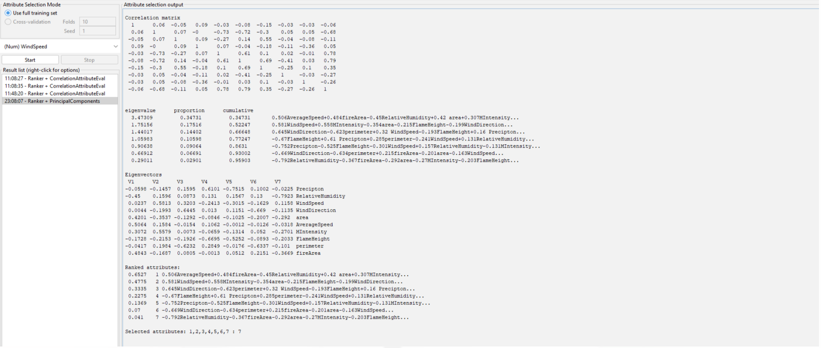


Figure: Matrix

Prediction of risks

- **Problem:** some feature-values may be unknown which are necessary for risk calculation
- **Goal:** Estimate missing values with machine-learning algorithms $\rightarrow$ predict risk for a zone
- **Performance measurement:**

$$Error_{model} = \sum_{i=1}^{j} |risk_{model} - risk_{expected}|$$

and j = max number of zones

Prediction of risks

- **Training Data:** Problem with data generation → partial use of fake data
- **Assumption:** Expert knowledge for weights
- **Provisional risk formula for zone i:**

$$risk_{expected} = 0,3 * FlameHeight_i + 0,8 * \frac{1}{ArrivalTime_i}$$

- **Desired risk formula for zone i:**
  $risk_{expected} =$
  $w_1 * FlameHeight_i + w_2 * \frac{1}{ArrivalTime_i} + w_3 * FireIntensity + w_4 * SoilValue..$

Prediction of risks

- **Method 1:** Neural network

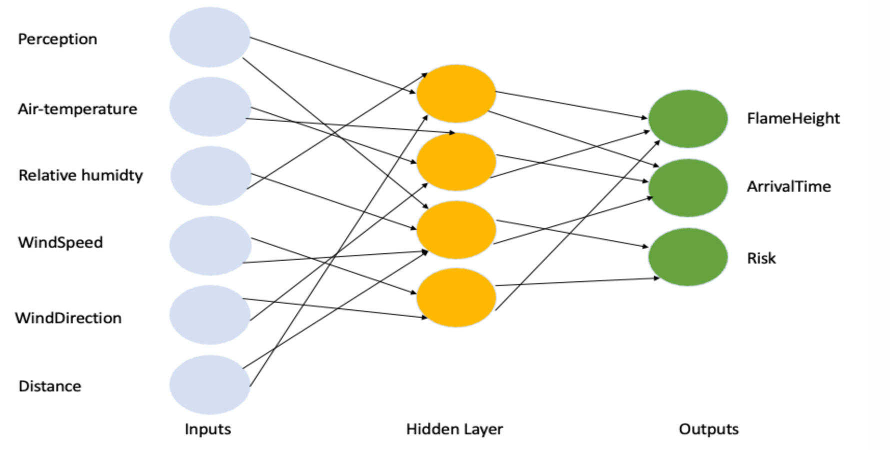


Figure: Trained neural network

Prediction of risks

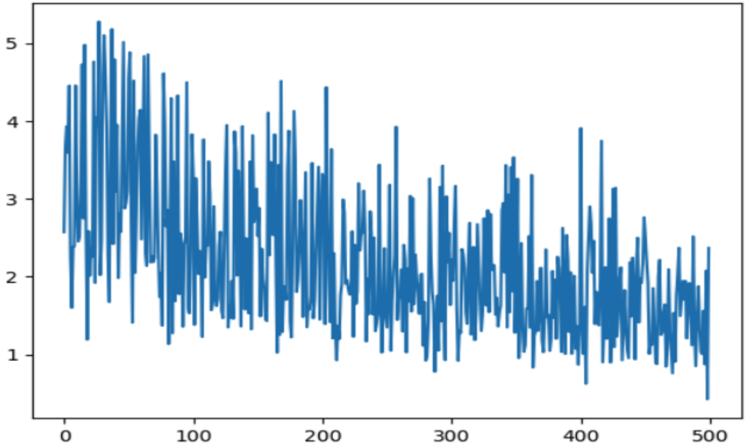


Figure: Expected loss over n=500 steps

Prediction of risks

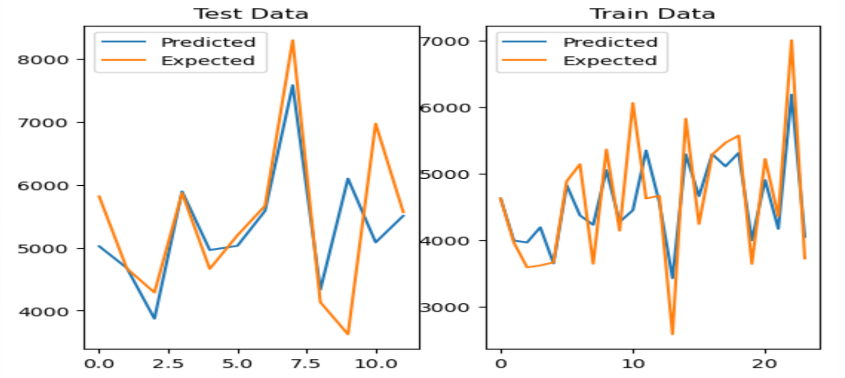


Figure: Plot of risk prediction

- **Mean error over n=20 runs:** 565

Prediction of risks

- **Method 2: Multi-Output Regressor**
- Divides problem into 3 subproblems
- Problem 1: Given X, predict FlameHeight
- Problem 2: Given X and FlameHeight, predict ArrivaTime
- Problem 3: Given X, FlameHeight and ArrivalTime, predict Risk

Prediction of risks

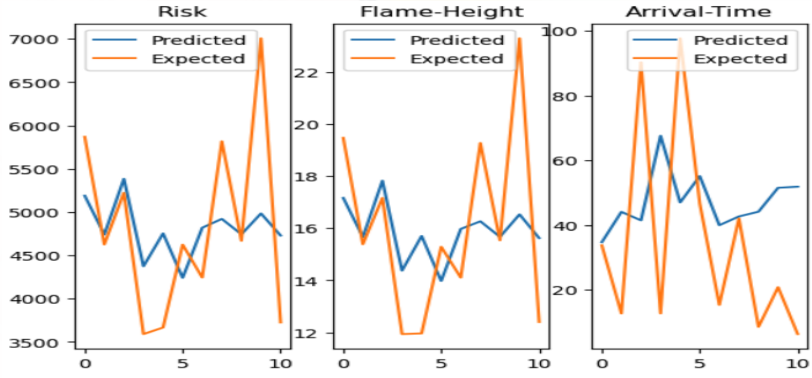


Figure: Plot of risk, arrival-time and flame-height prediction

- **Mean error:** 707
- Neural Network (565) performs better than the Multi-Output Regressor (707)

Firefly-Algorithm

Algorithm 1: The Firefly Algorithm

Inputs: G_R, r, m, C, η
for $t = 1, \ldots, T$ **do**
  Environment generates fire strength vector a_t and reward vector k_t
  $u_t \leftarrow$ Fire location vector (if available)
  $v_t \leftarrow$ Greedy max-m coverage on $\hat{G}_t$ (Sec 3.1)
  Estimate $\hat{a}_{i,t}$ and $\hat{k}_{i,t}$ (Sec 3.2)
  $w^*_{i,t} \leftarrow$ Solve perturbed knapsack from Eq (7)
  $d_{i,t} = \lceil \hat{a}_{i,t} \rceil w^*_{i,t}$
  $\forall i$: Allocate $d_{i,t}$ firefighters to i and observe true reward $f_t(d_{i,t})$ (Sec 3.4)
  Update $\hat{A}_{i,t}$ and $\hat{K}_{i,t}$ (Sec 3.2 and 3.3)
end

Figure: Firefly-Algorithm

- **Goal:** Minimize damage by assigning firefighters to high-risk areas
- Interest in estimated reward: $\hat{k_{i,t}} = k_{i\,t}$,if i is covered
- Otherwise: $\hat{k_{i,t}} = \frac{1}{t-1} * K_{i,t-1}$ and K = cumulative reward
- Distribution of firefighters by maximizing the sum of the reward of each zone

Firefly-Algorithm

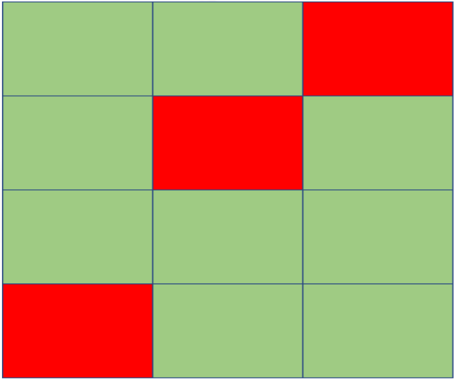


Figure: red: high-risk area; green: save area

- **Performance measurement:** Number of red zones to which firefighters are sent to
- Compare which version performs better

Conclusions

- Spark allows us to simulate specific wildfire in fixed Area
- We can change and create new data
- We're able to take the simulated data and analyze them in weka
- Through the analyzed data we get the Possibility to calculate risks through flame height and arrival time
- this data we compare to our machine learning Alg

Future Work

- Collect more data with simulation to train Machine-Learning Algorithm
- Implement a third Machine-Learning Algorithm and compare to the other two
- **Final:** Compare performance of the Firefly-Algorithm based on presented formula

References

- https://research.csiro.au/spark/
- https://www.cs.waikato.ac.nz/ ml/weka/
- https://weather.com/photos/news/2021-08-02-turkey-wildfires-satellite-images
- https://www.epa.gov/climate-indicators/climate-change-indicators-wildfires
- https://www.nbcnews.com/science/environment/one-year-australia-s-devastating-wildfires-anger-grows-climate-change-n1256714
- Fighting WildfiresunderUncertainty: A Sequential Resource Allocation Approach Hau Chan , Long Tran-Thanh and Vignesh Viswanathan

Thank you!