Design of a diagnosis and follow-up platform for patients with chronic headaches

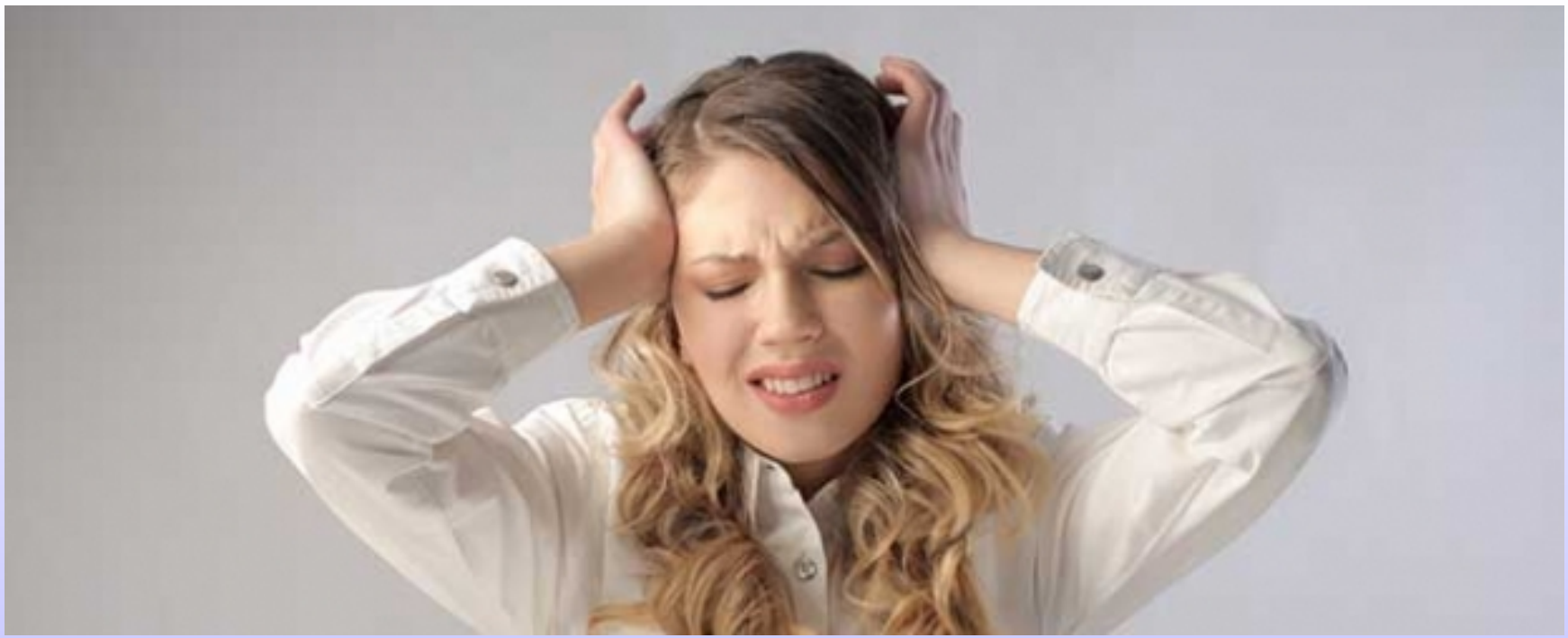
Kiani Lannoye & Gilles Vandewiele

Faculty of Engineering and Architecture


UNIVERSITEIT GENT

FACULTY OF **ENGINEERING AND ARCHITECTURE**

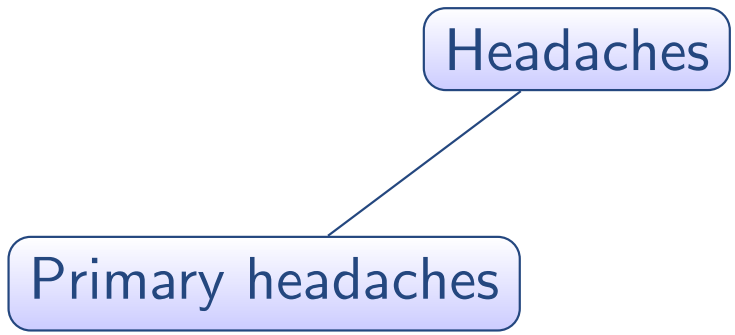
Headaches



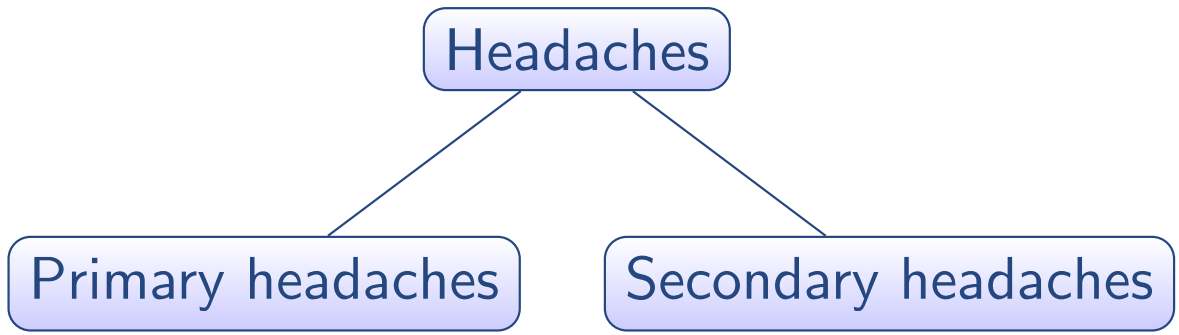
Headaches

Headaches

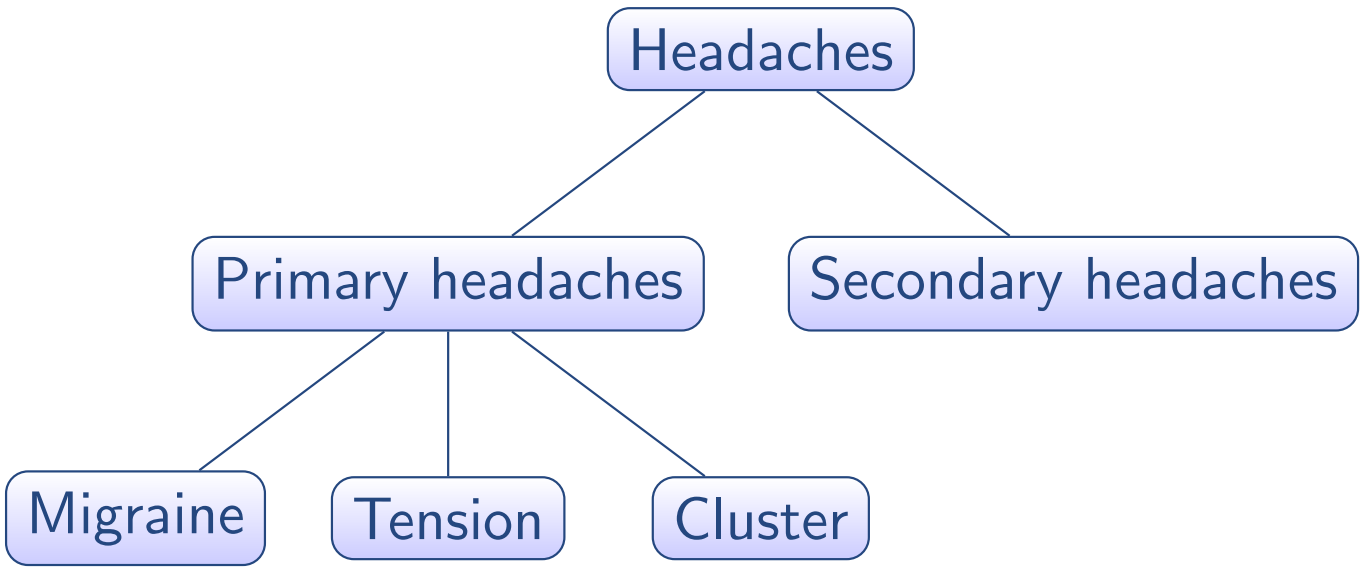
Headaches



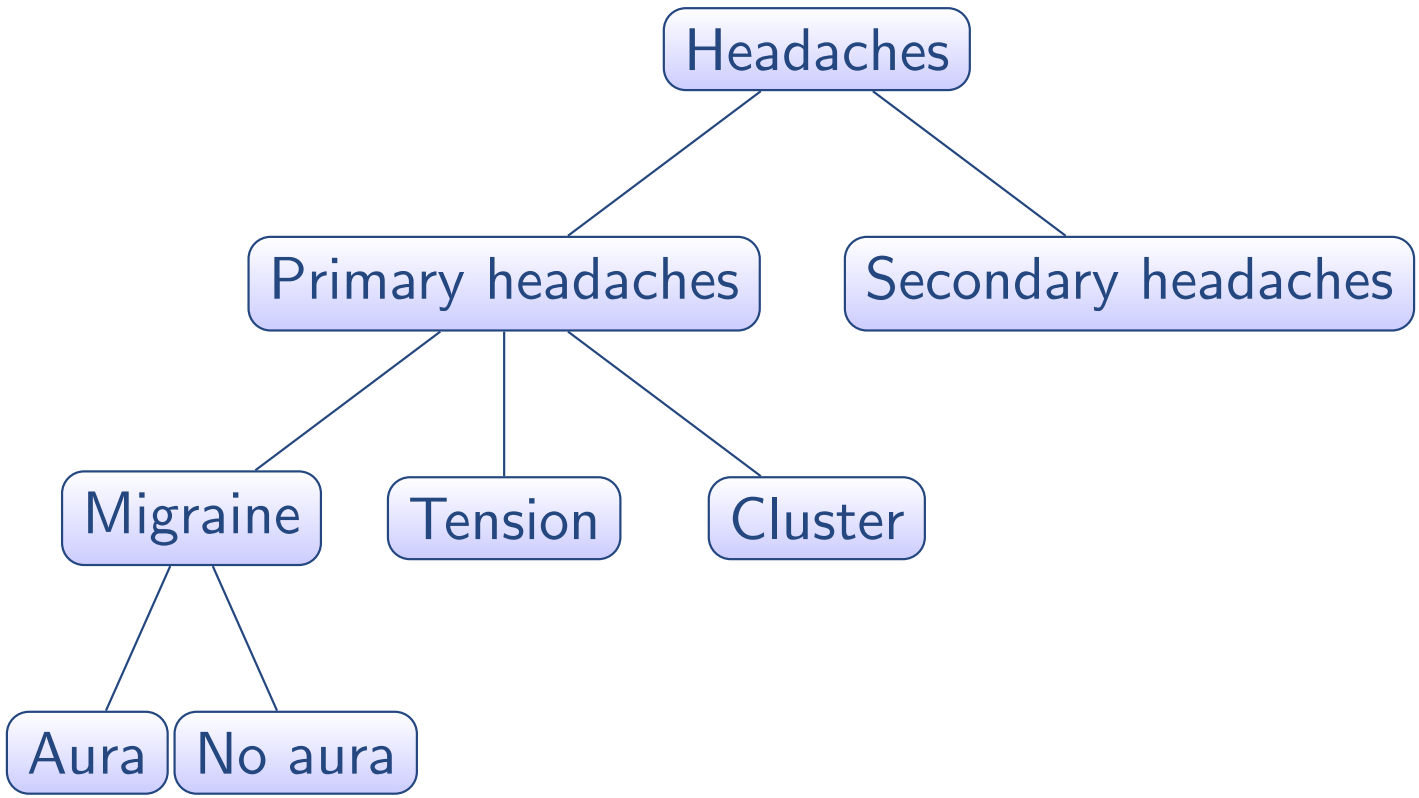
Headaches



Headaches


Headaches
Primary headaches
Secondary headaches
Migraine
Tension
Cluster

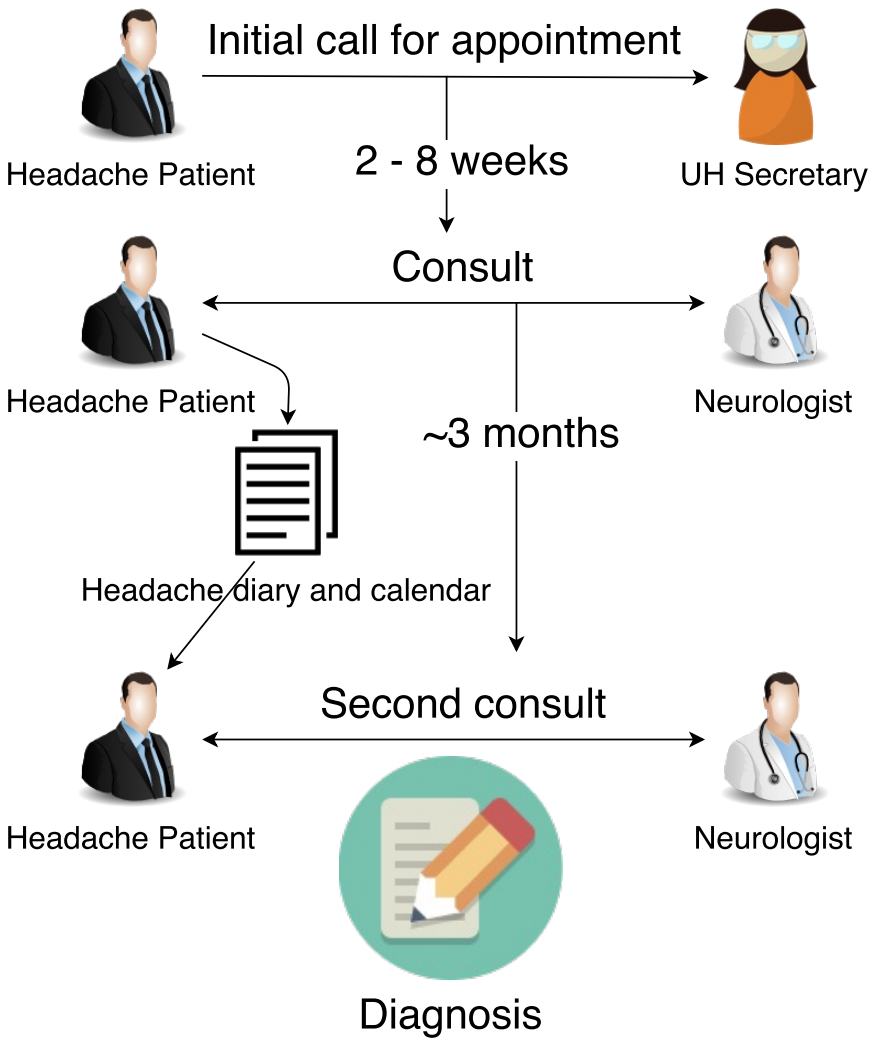
Headaches


Headaches
Primary headaches
Secondary headaches
Migraine
Tension
Cluster
Aura
No aura

Current process UH Ghent

Current process at UH Ghent is:

- Not digital
- cumbersome
- long-lasting


Initial call for appointment
Headache Patient
2 - 8 weeks
UH Secretary
Consult
Headache Patient
Neurologist
~3 months
Headache diary and calendar
Second consult
Headache Patient
Neurologist
Diagnosis

So there is need for a better (digital) alternative! This alternative has to:

- capture at least the same information as current solution
- be more efficient
- provide a second opinion for the doctors (auto-diagnose)


UNIVERSITEIT GENT

FACULTY OF **ENGINEERING AND ARCHITECTURE**

Platform requirements

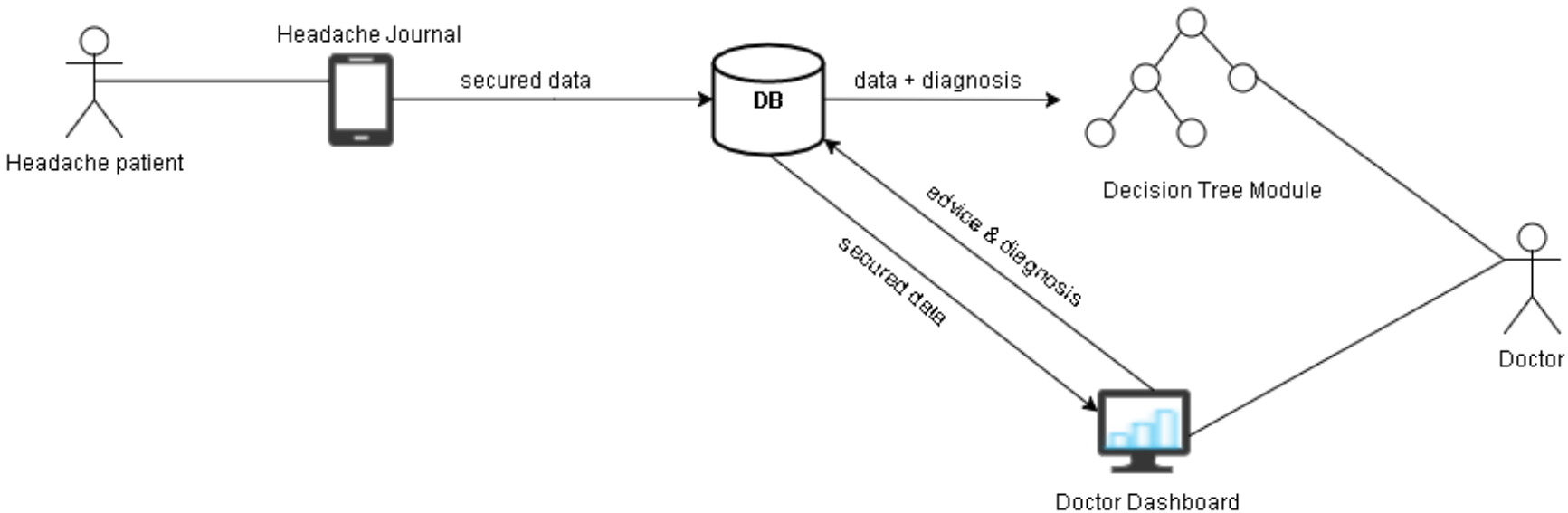
Our proposed alternative consists of:

- Headache journal: mobile app
- Doctor Dashboard: web application
- Machine learning module: decision support

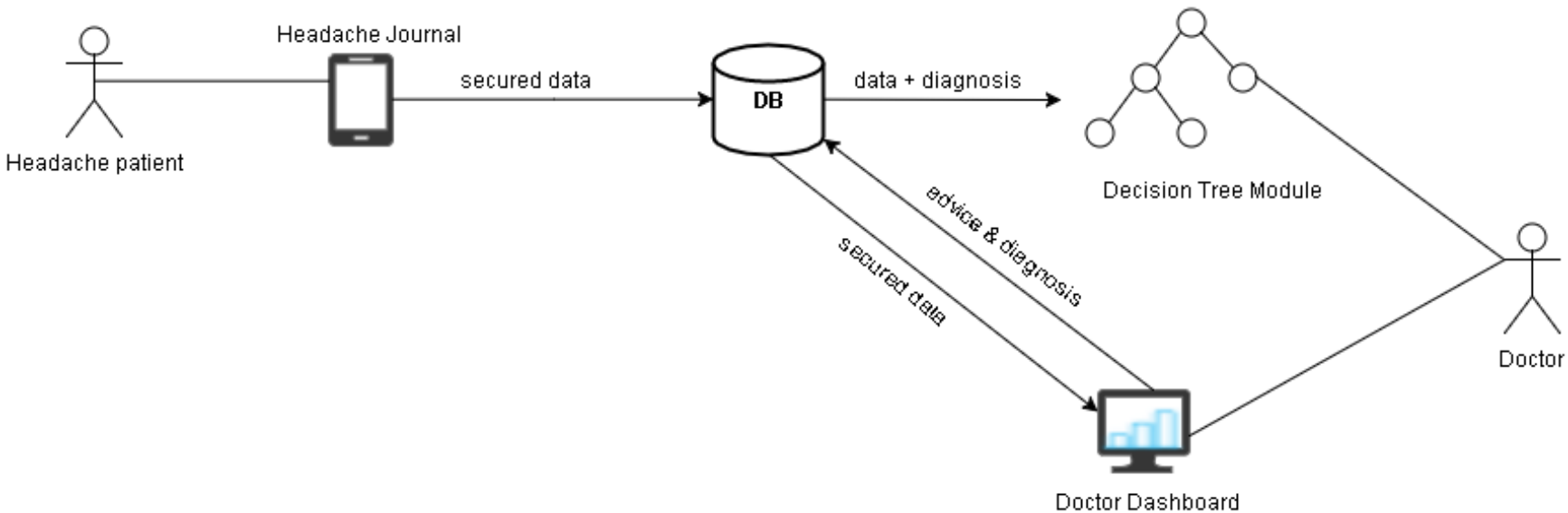
Solution non-functional requirements:

- Security
- Availability
- Performance & learning curve
- Usability

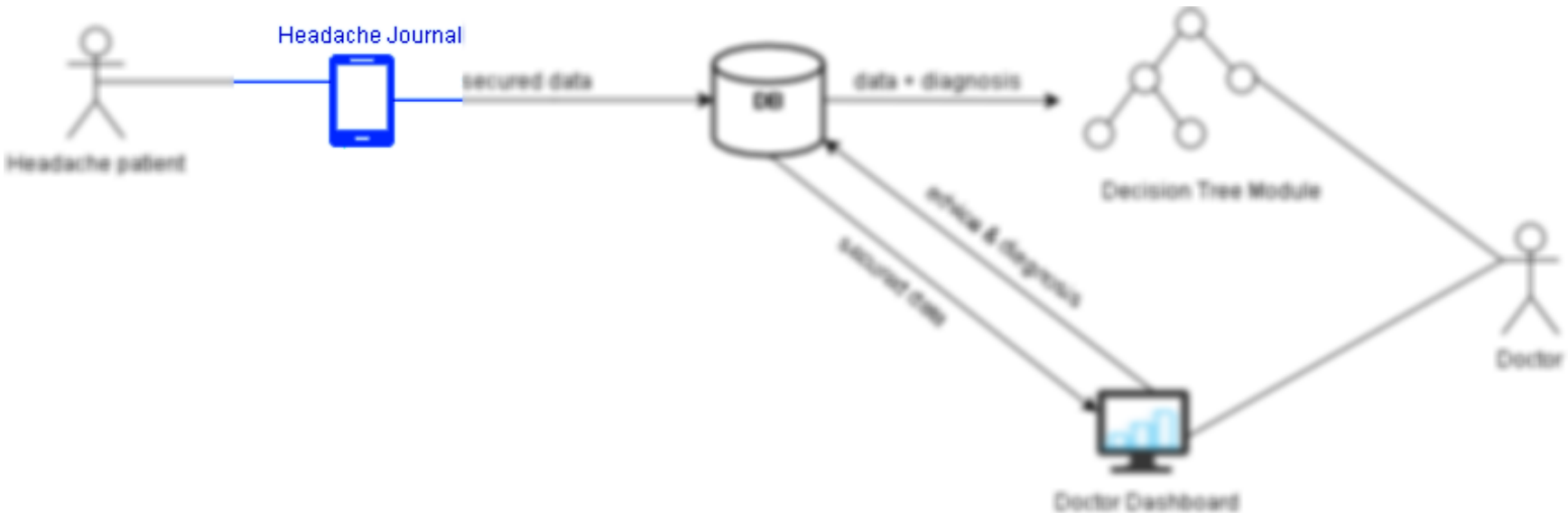
Platform requirements



Mobile Application



Mobile Application



Mobile Application

Why create a new application?

Competition

- Migraine Buddy
- Headache Diary
- Pfizer headache journal

Mobile Application

Why create a new application?

Competition

- Migraine Buddy
- Headache Diary
- Pfizer headache journal

All good, but:

Mobile Application

Why create a new application?

Competition

- Migraine Buddy
- Headache Diary
- Pfizer headache journal

All good, but:

- none captures all data needed
- none offers usable data export

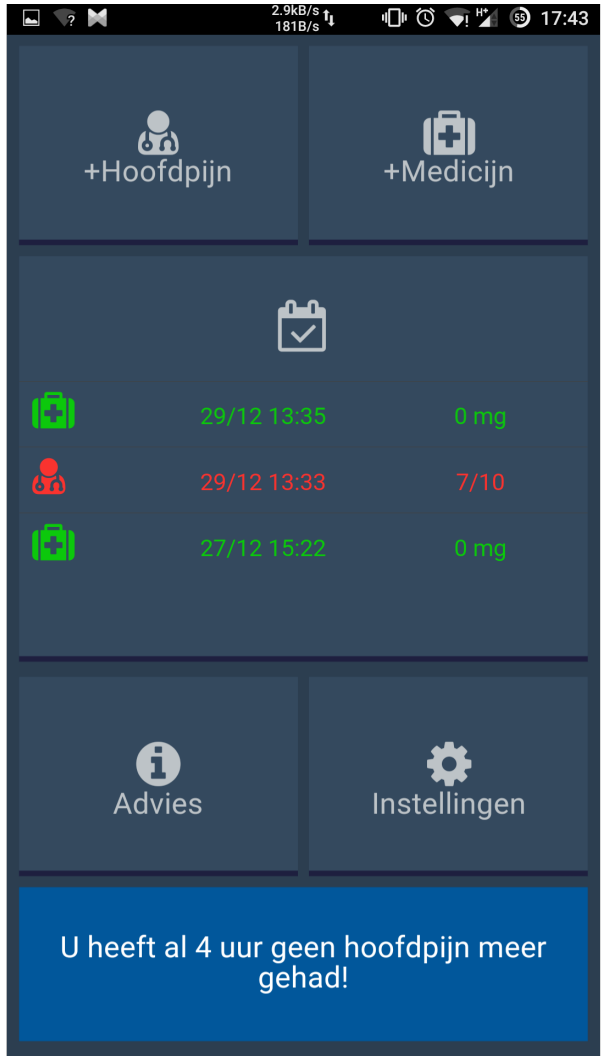
Cross platform vs Native

	Native	**Cross-platform**
+	+ Native UX + device-specific features + Better performance	+ 1 language + Write once, run everywhere + Less maintenance
-	- Multiple languages - Time consuming (development)	- Slower (lower performance) - Less device specific features - Harder to release online (Play Store/App Store)

Cross platform vs Native

	Native	**Cross-platform**
+	+ Native UX + device-specific features + Better performance	+ 1 language + Write once, run everywhere + Less maintenance
-	- Multiple languages - Time consuming (development)	- Slower (lower performance) - Less device specific features - Harder to release online (Play Store/App Store)


HTML
CSS
Onsen UI
PhoneGap

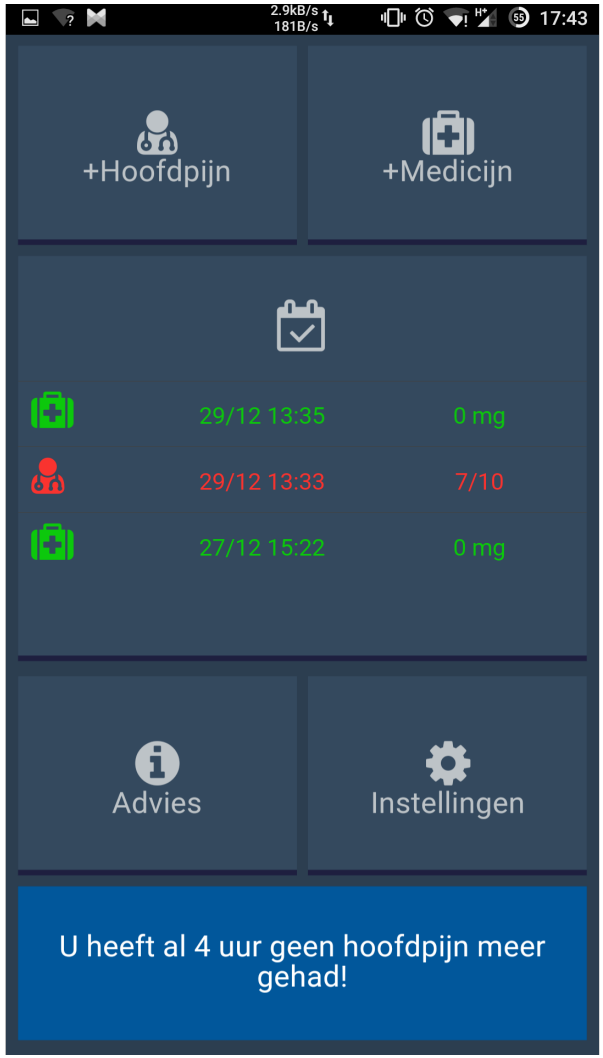

2.9kB/s
181B/s
17:43
+Hoofdpijn
+Medicijn
29/12 13:35
0 mg
29/12 13:33
7/10
27/12 15:22
0 mg
Advies
Instellingen
U heeft al 4 uur geen hoofdpijn meer gehad!

HTML

CSS

Onsen UI

PhoneGap



Chronicals

Chronicals


17:44
Terug
29 dec. 17:44
?
Locatie
Toon op welke plaats(en) u pijn voelt.
Tip: u kan het model draaien
Annuleer
Overslaan
Volgende

Chronicals

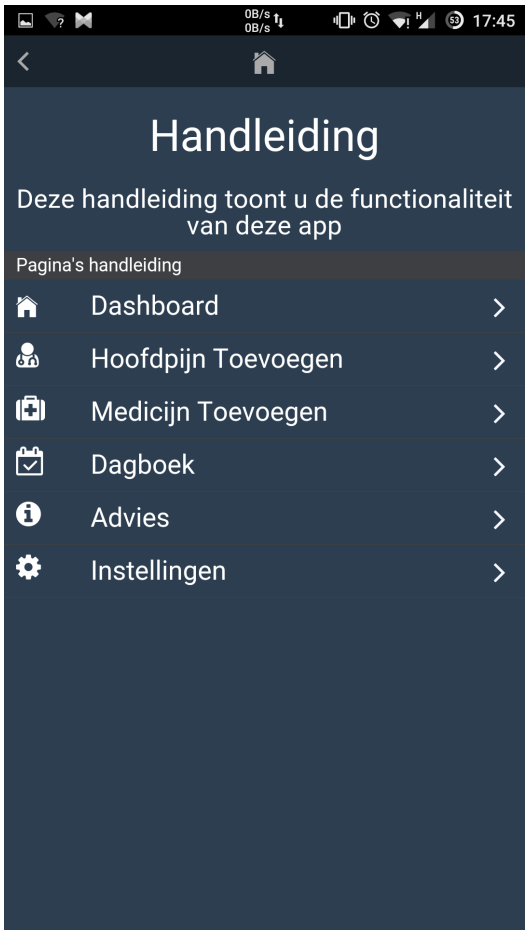

17:44
Terug
29 dec. 17:44
?
Locatie
Toon op welke plaats(en) u pijn voelt.
Tip: u kan het model draaien
Annuleer
Overslaan
Volgende


13:09
Terug
29 dec. 17:44
?
Braken
Gevoeligheid aan inspanning
Misselijkheid
Gevoeligheid aan licht
Gevoeligheid aan geluid
Gebrek aan eetlust
Hoofdpijn omschrijving
Autonoom
Aurasymptomen
Visueel aura
Sensibel aura
Motorisch aura
Spraakproblemen
Annuleer
Overslaan
Volgende

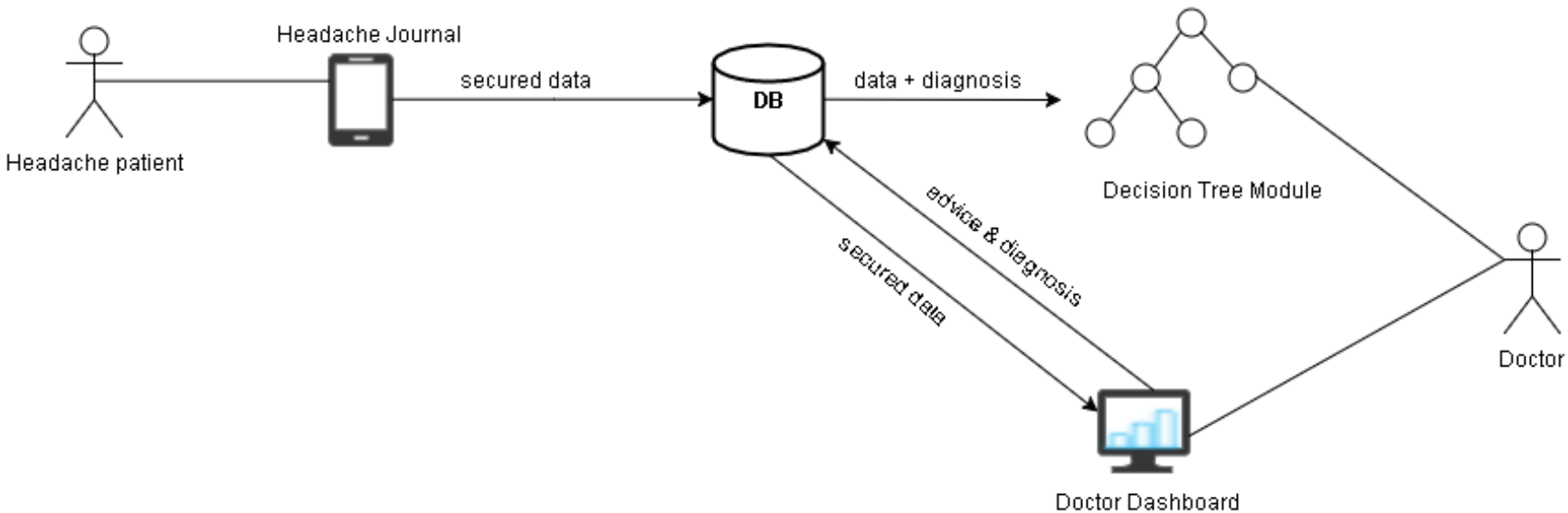
Chronicals


17:44
Terug
29 dec. 17:44
Locatie
Toon op welke plaats(en) u pijn voelt.
Tip: u kan het model draaien
Annuleer
Overslaan
Volgende

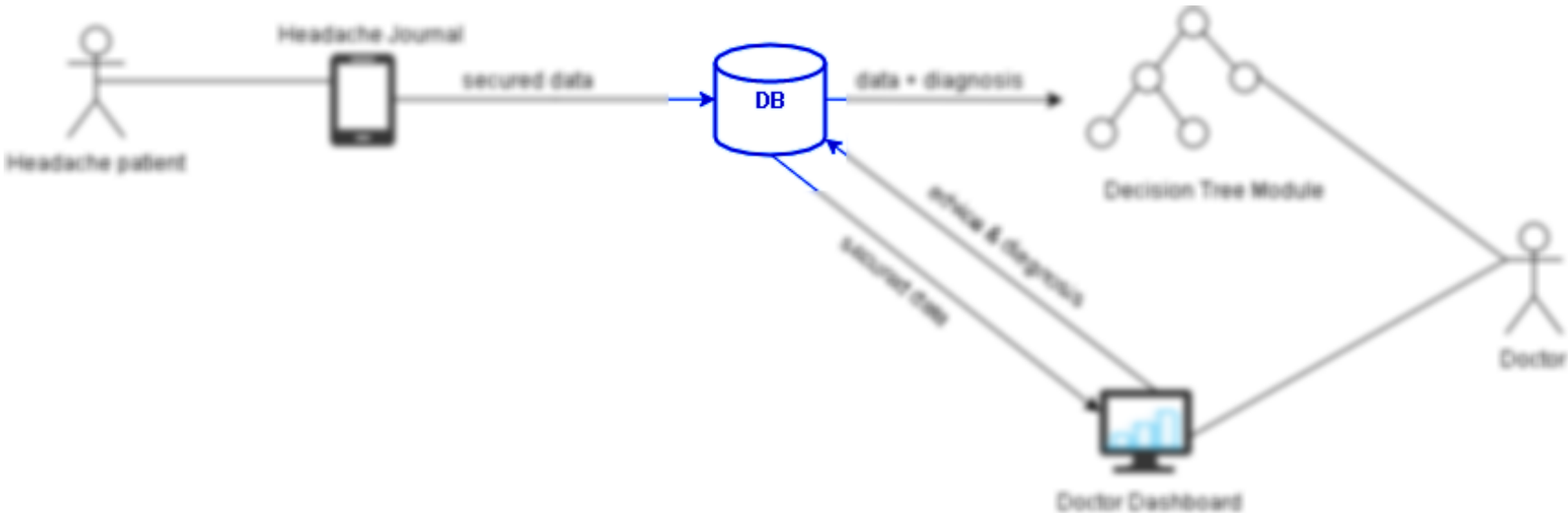

13:09
Terug
29 dec. 17:44
Braken
Gevoeligheid aan inspanning
Misselijkheid
Gevoeligheid aan licht
Gevoeligheid aan geluid
Gebrek aan eetlust
Hoofdpijn omschrijving
Autonoom
Aurasymptomen
Visueel aura
Sensibel aura
Motorisch aura
Spraakproblemen
Annuleer
Overslaan
Volgende


17:45
Handleiding
Deze handleiding toont u de functionaliteit van deze app
Pagina's handleiding
Dashboard
Hoofdpijn Toevoegen
Medicijn Toevoegen
Dagboek
Advies
Instellingen

Backend and data exposure



Backend and data exposure

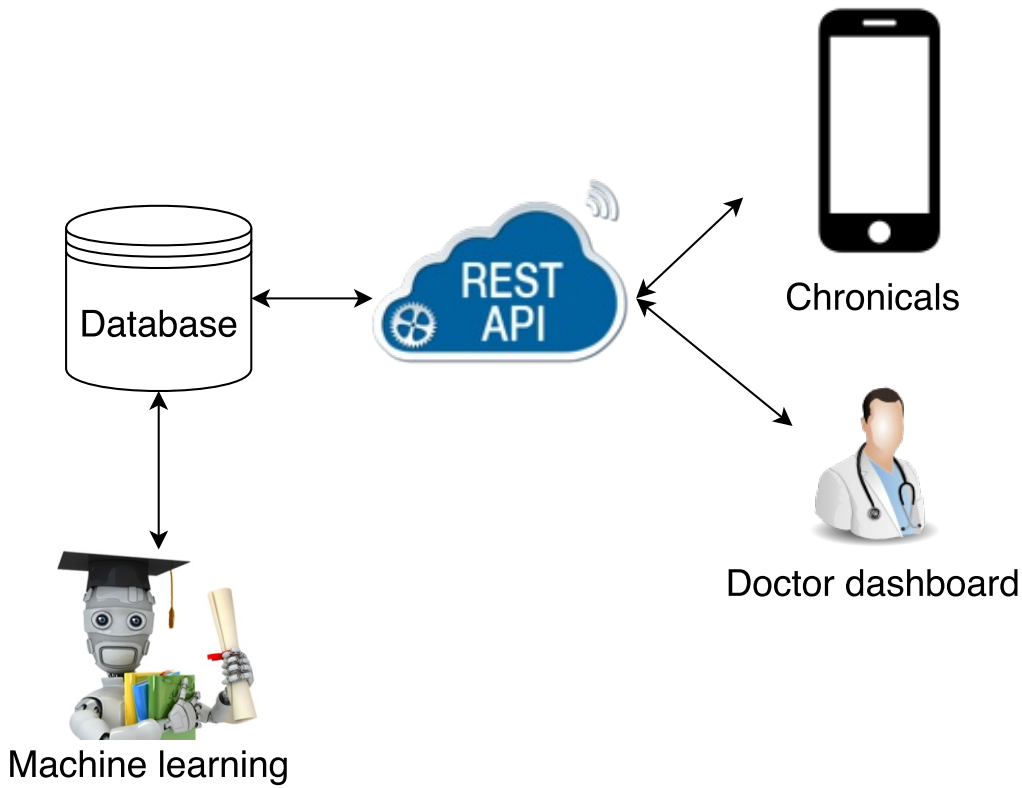


Backend and data exposure

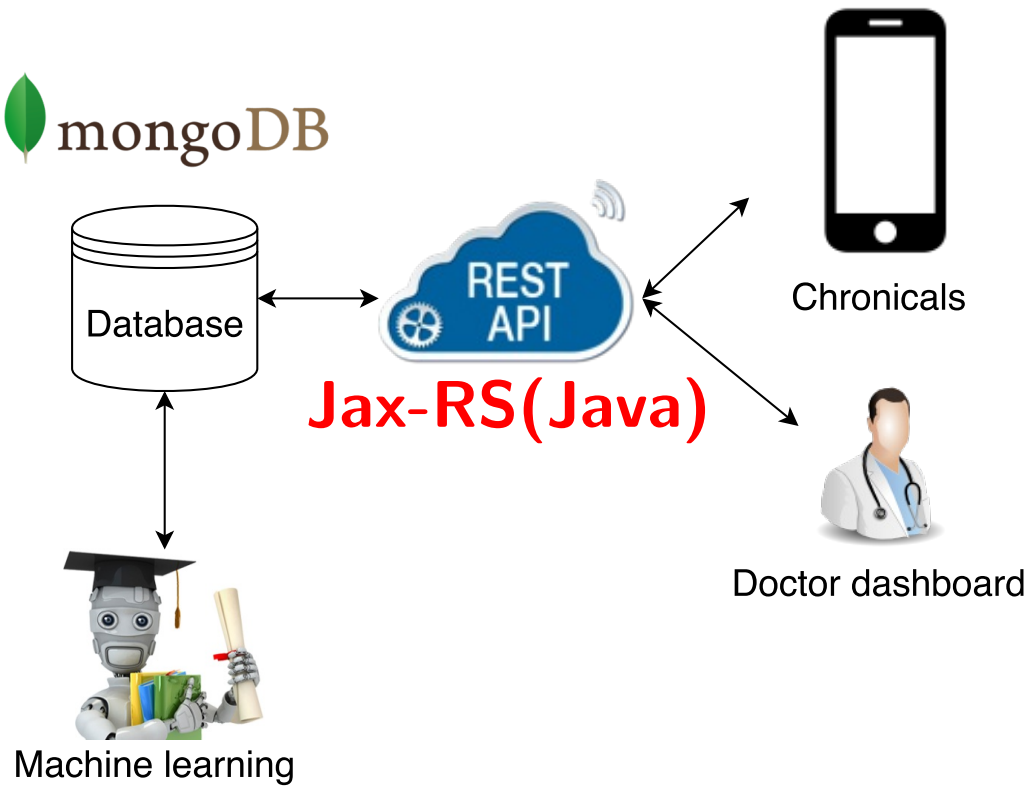
Components

- Database
- Connection to App
- Connection to Docter Dashboard
- Connection Machine learning module

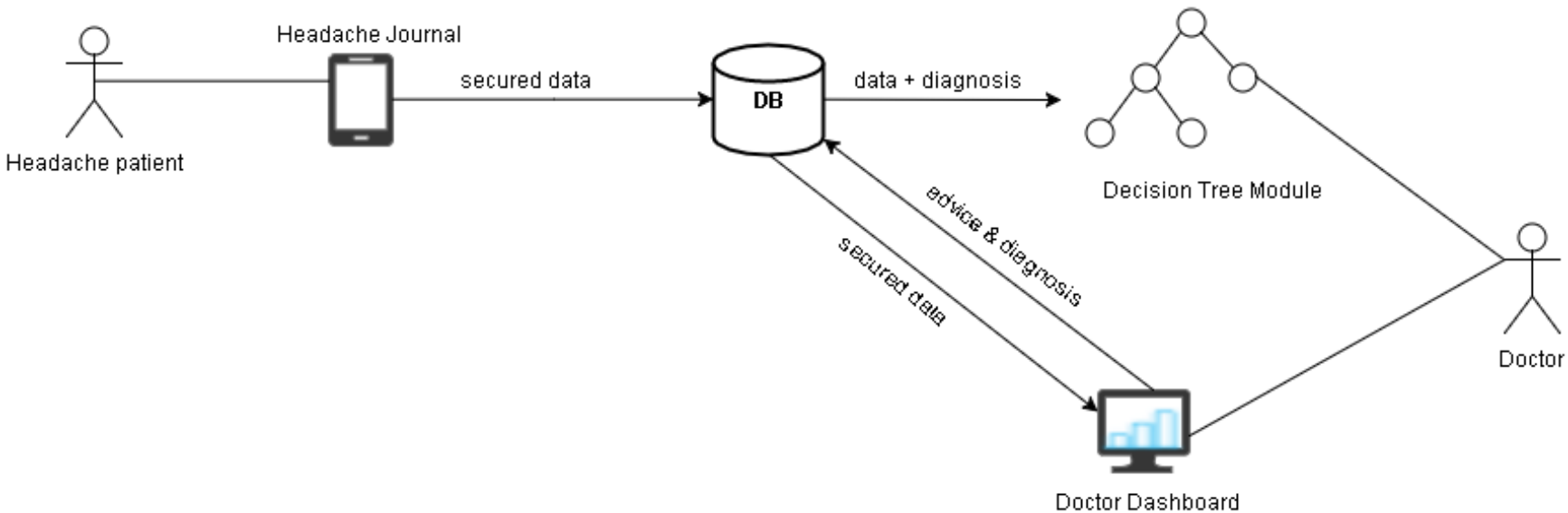
System


Database
REST API
Chronicals
Doctor dashboard
Machine learning

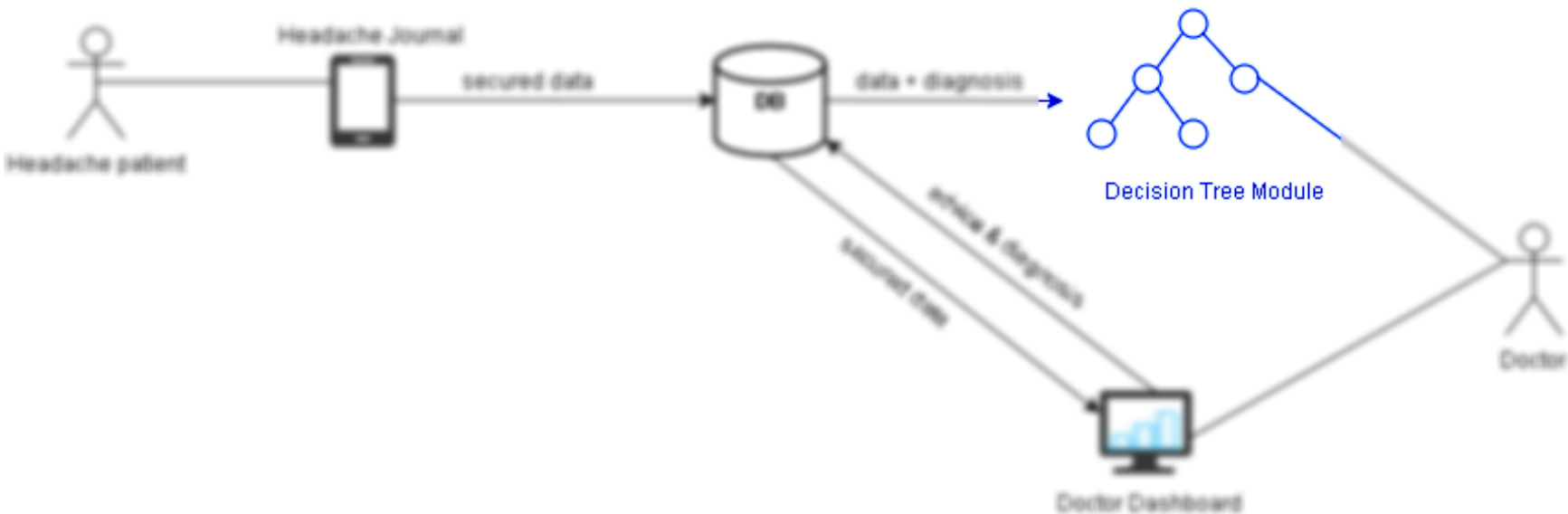
System


mongoDB
Database
REST API
Jax-RS(Java)
Chronicals
Doctor dashboard
Machine learning

Machine learning



Machine learning



Machine Learning

Decision support ($\neq$ decision making) $\Rightarrow$ White box model

Possible models

- Decision trees
- Random Forests (Gray box)
- Bayesian networks

Machine Learning

Decision support ($\neq$ decision making) $\Rightarrow$ White box model

Possible models

- Decision trees
- Random Forests (Gray box)
- Bayesian networks

Genetic merging of DT's

C4.5 (C5.0)

CART

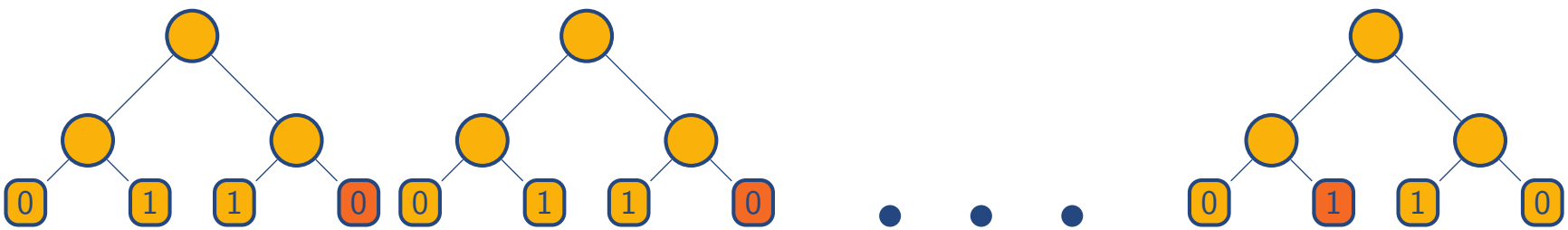
QUEST

...

→ **Which tree is the most beautiful?**

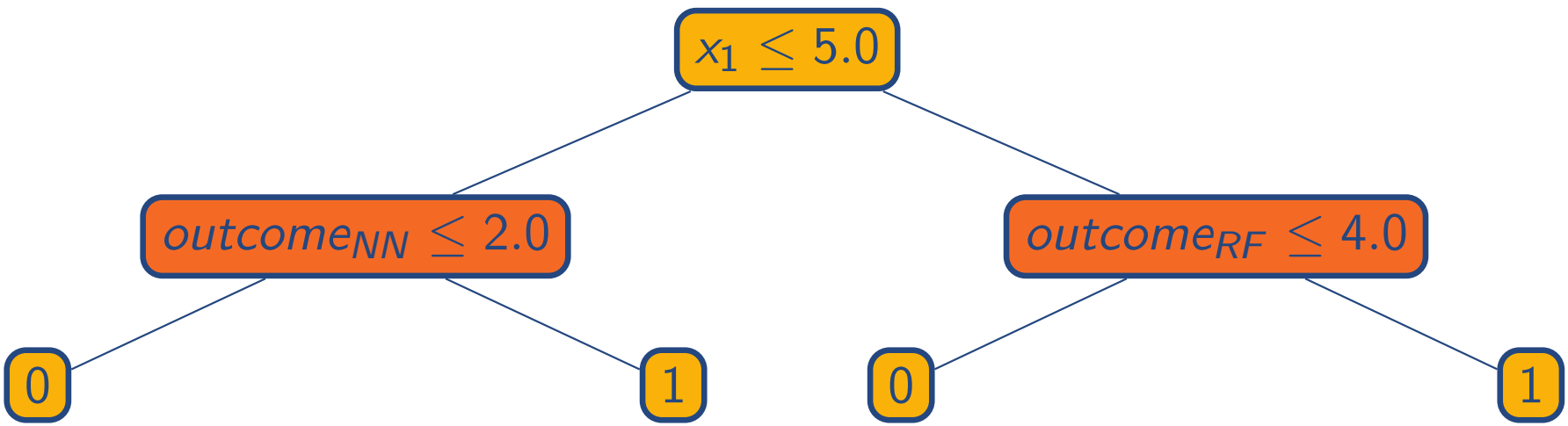
Current ensembles lack interpretability

Boosting, bagging, random forests, etc. require majority voting (classification) or mean calculation (regression) to obtain prediction



Current ensembles lack interpretability

The final decision tree obtained by **stacking** contains uninterpretable internal nodes

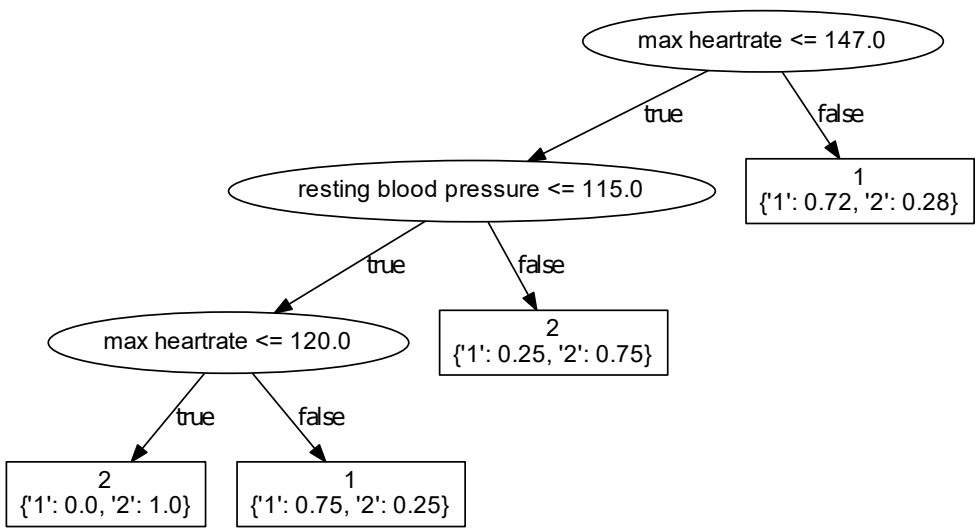


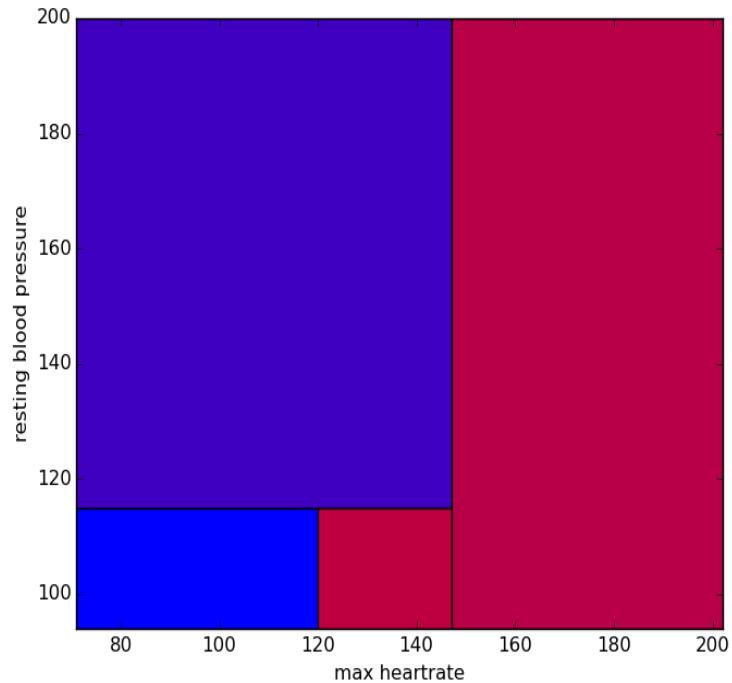
Decision tree $\rightarrow$ decision space

Converting decision trees to decision spaces

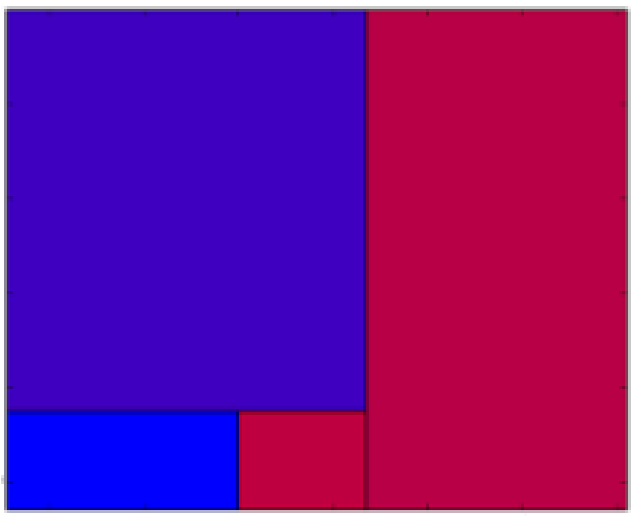
We can define a one-to-one mapping between a decision tree and a set of k-dimensional hyperplanes ($k = \#\text{features}$), called **decision space**. Each node in the decision tree corresponds to a hyperplane in the decision space.

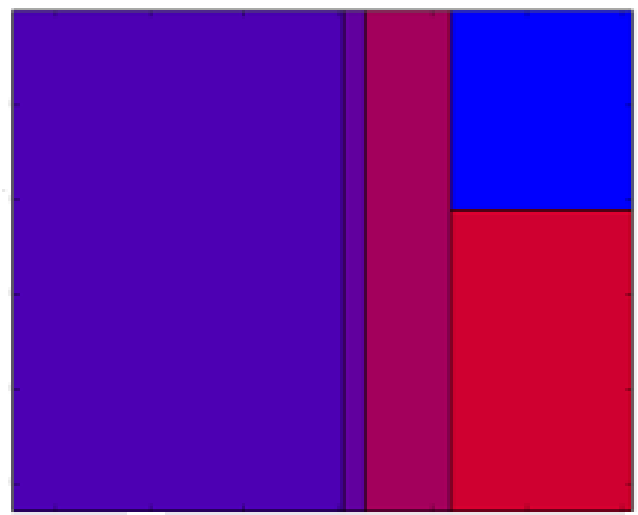
Decision tree → decision space



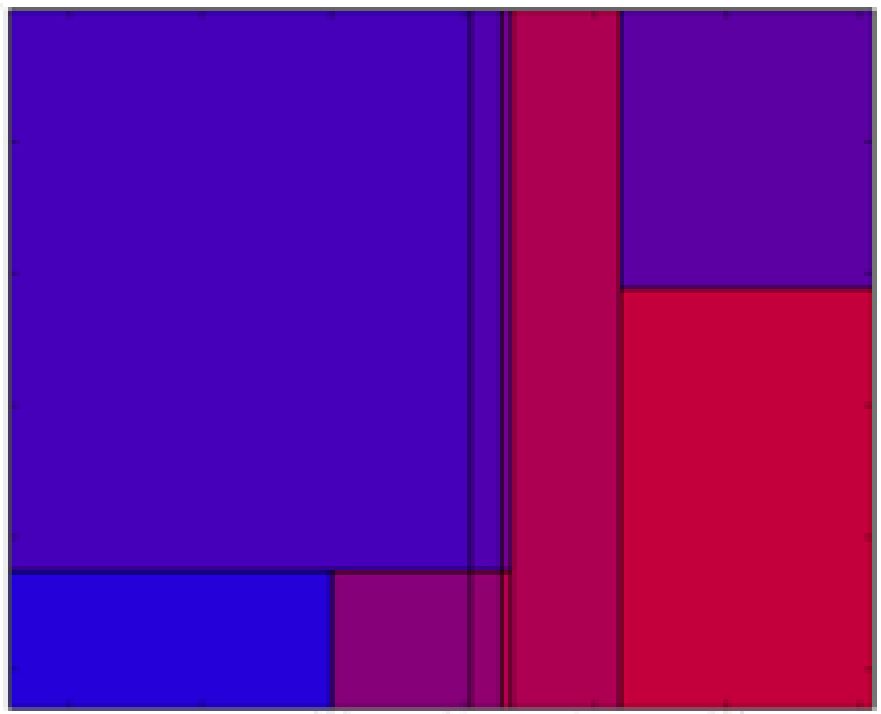


Merging decision spaces

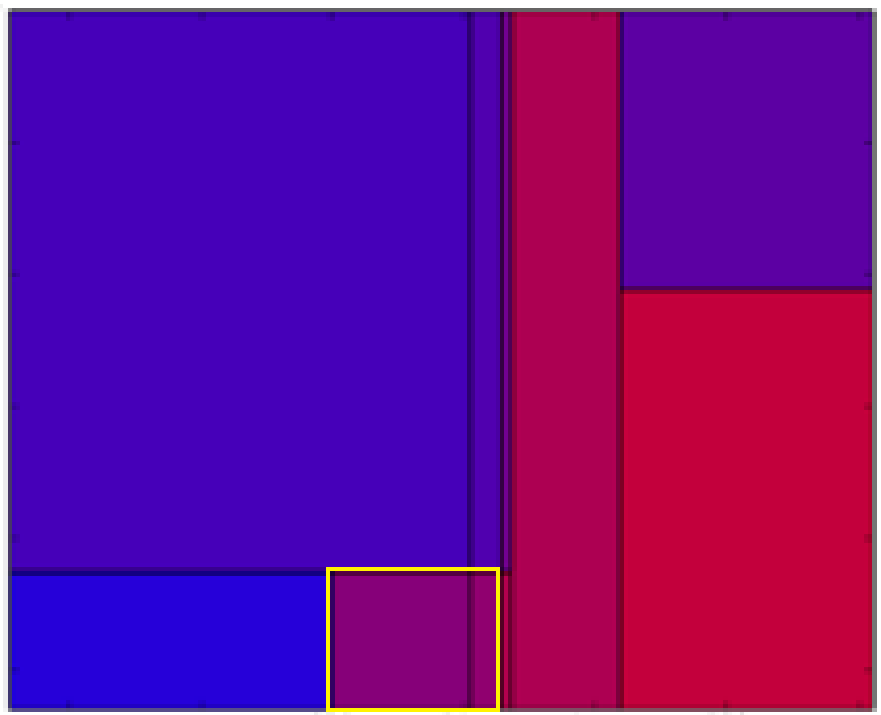




Merging decision spaces



Pruning decision spaces

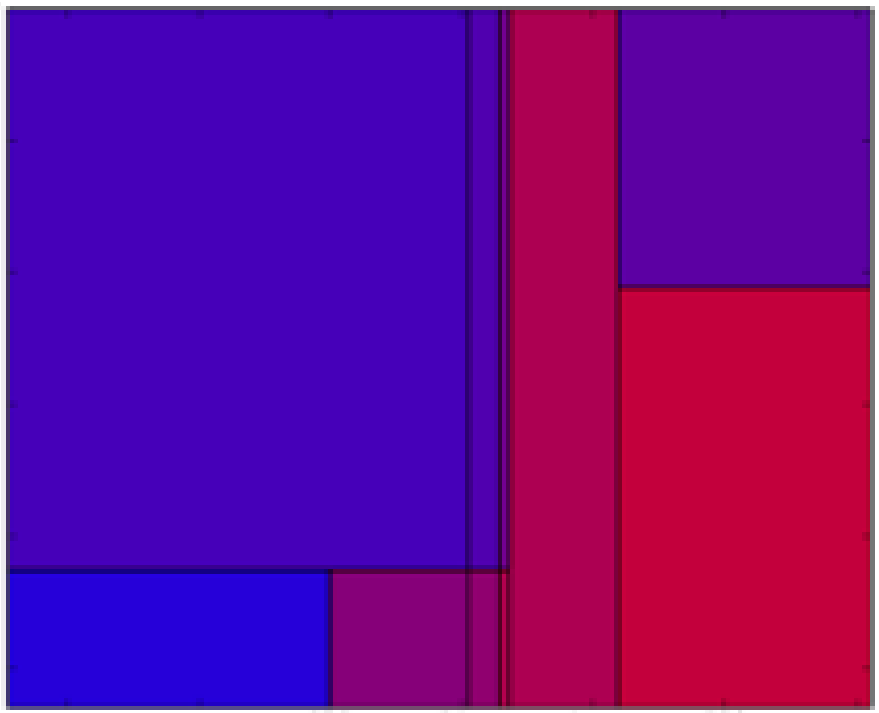


Decision space $\rightarrow$ decision tree

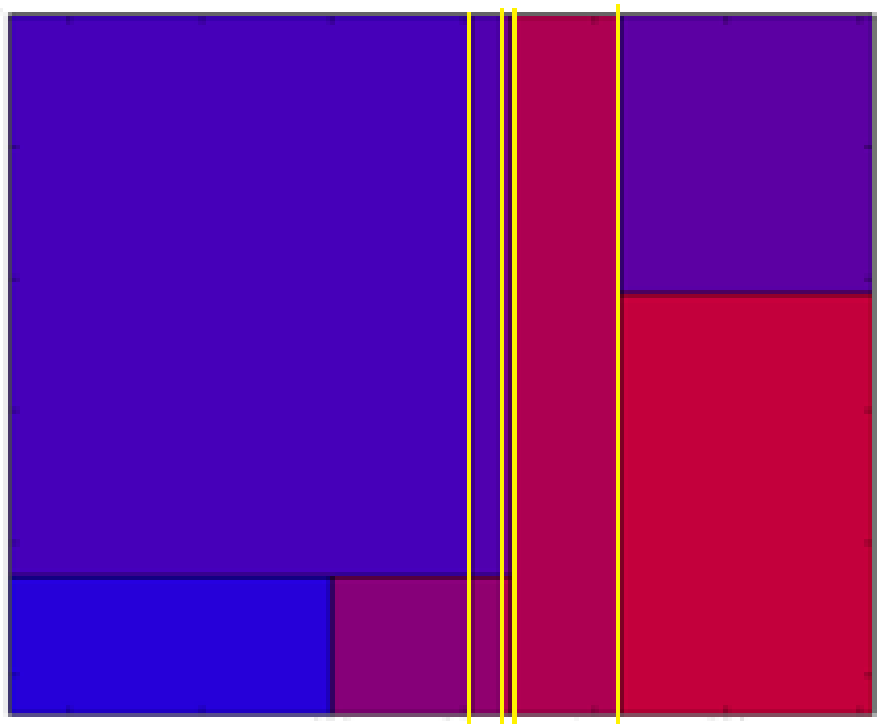
Converting decision spaces to decision trees

One-to-one mapping from decision tree to space is lost during conversion because the order is lost. Therefore, a **heuristic** approach must be taken, identifying **hyperplane candidates** and calculating a metric to choose the 'best' plane.

Decision space → decision tree



Decision space $\rightarrow$ decision tree

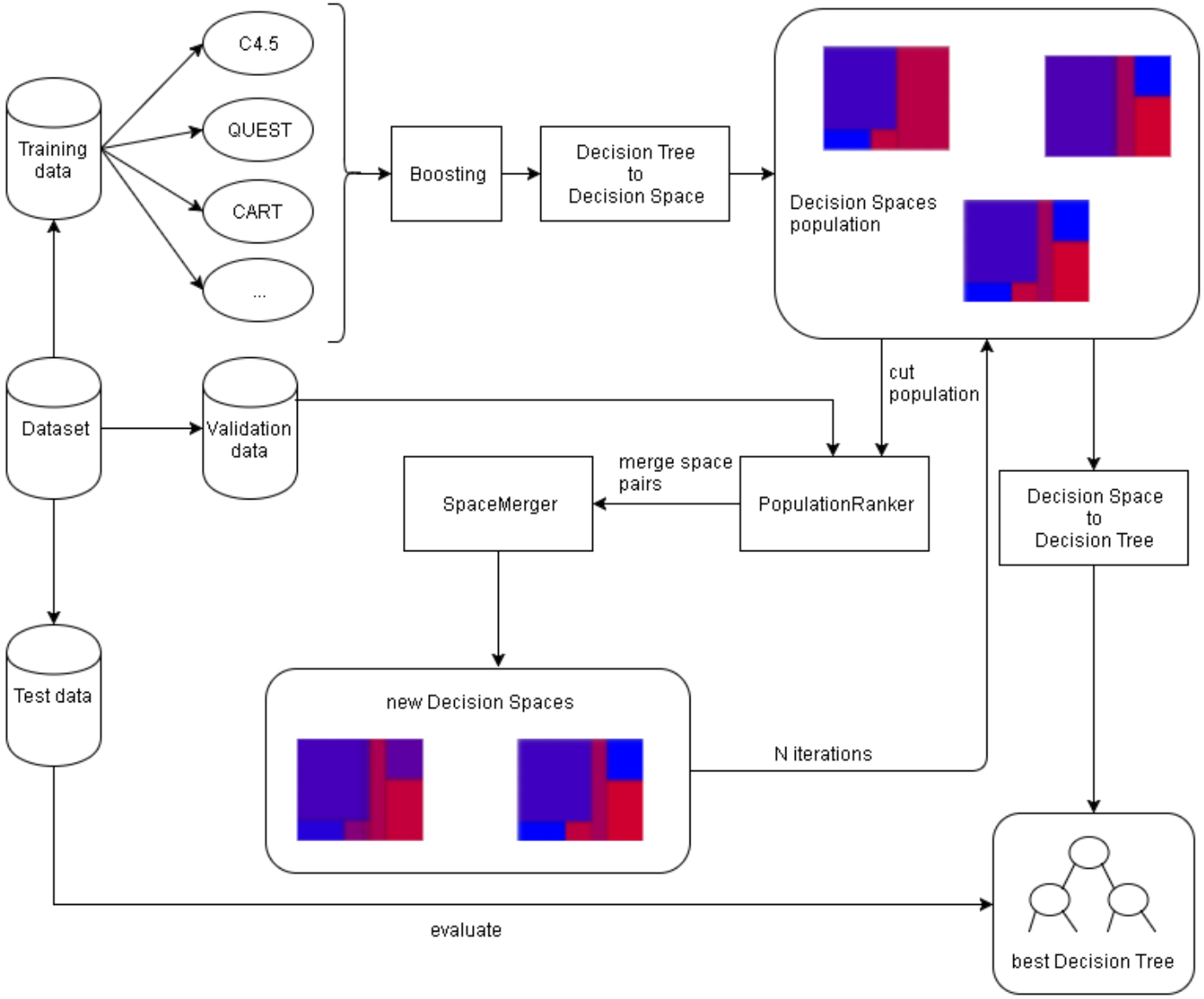


Decision space $\rightarrow$ decision tree

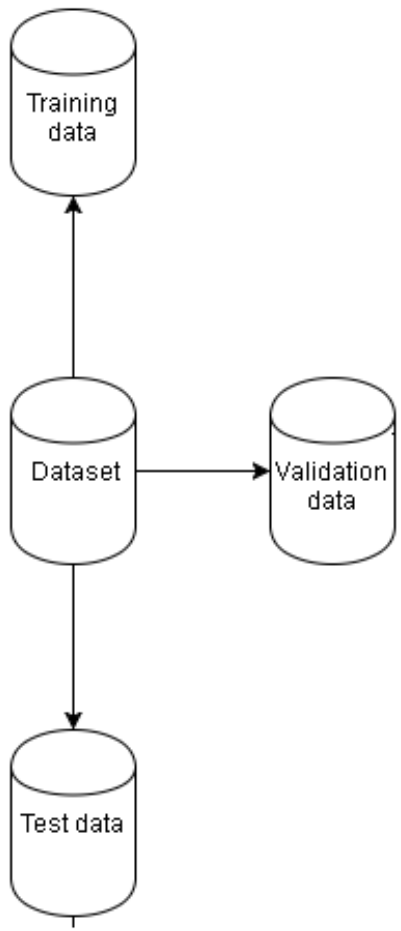
Finding 'best' candidate hyperplane

Apply metric function to each plane, these include:

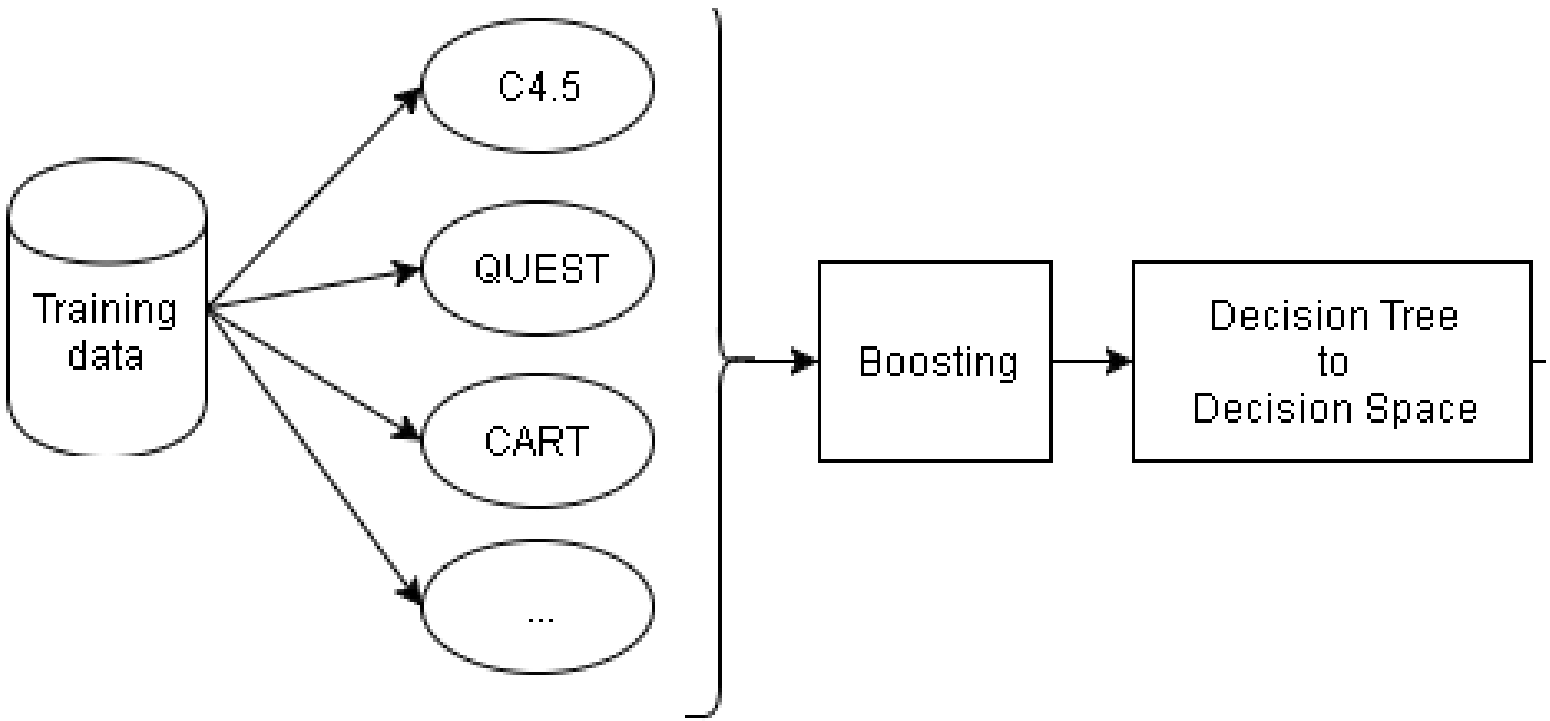
- information gain and Gini
- pick plane from most correlated feature
- pick plane that divide space in two most equal subspaces
- combination


C4.5
QUEST
CART
...
Training data
Boosting
Decision Tree to Decision Space
Decision Spaces population
cut population
Dataset
Validation data
SpaceMerger
merge space pairs
PopulationRanker
Decision Space to Decision Tree
Test data
new Decision Spaces
N iterations
evaluate
best Decision Tree

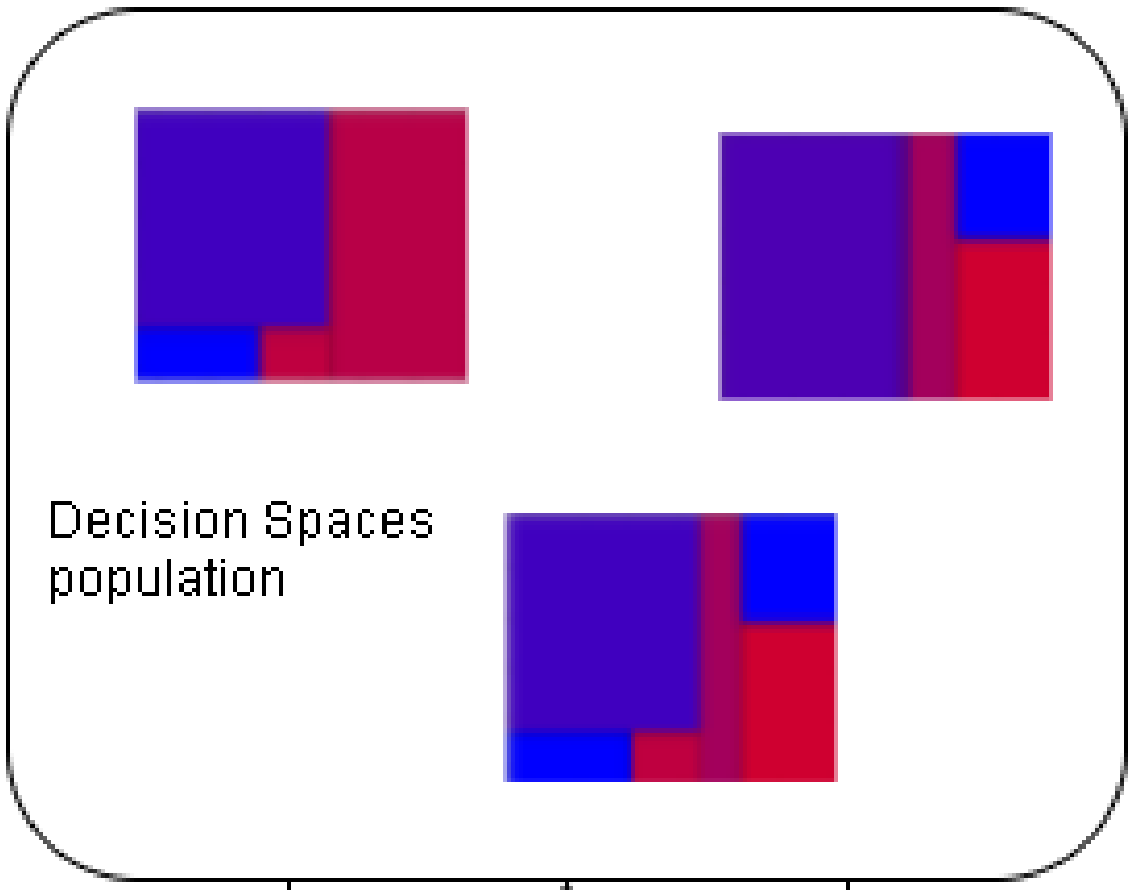
Splitting the data



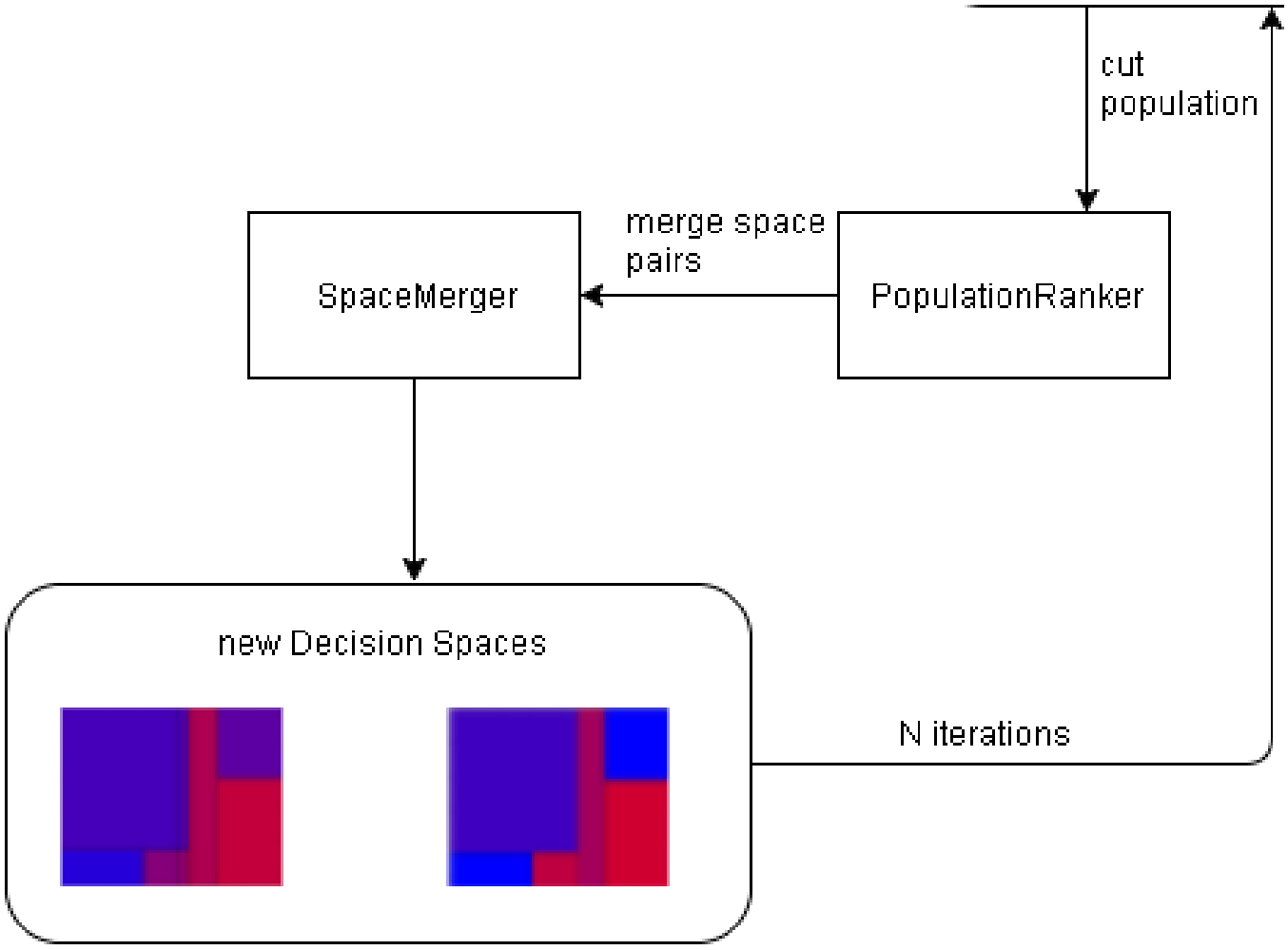
Generate different decision trees



Generate different decision trees



Genetic merging

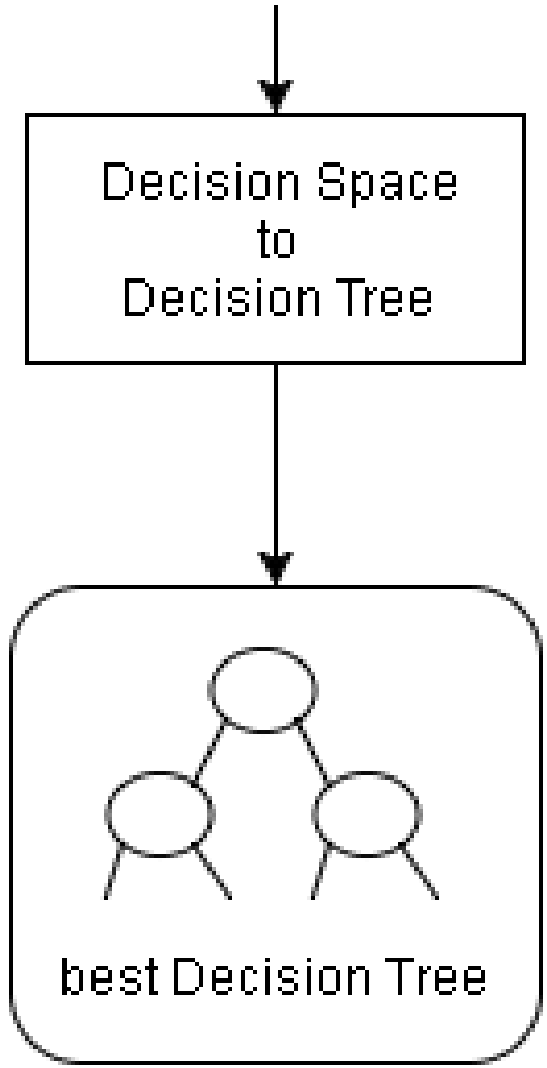


PopulationRanker

Fitness function

A high accuracy is the most important property of a decision tree, followed by its' size ($\rightarrow$ comprehensibility). Genetic algorithms are well suited for **multi-objective optimization**.

Final iteration

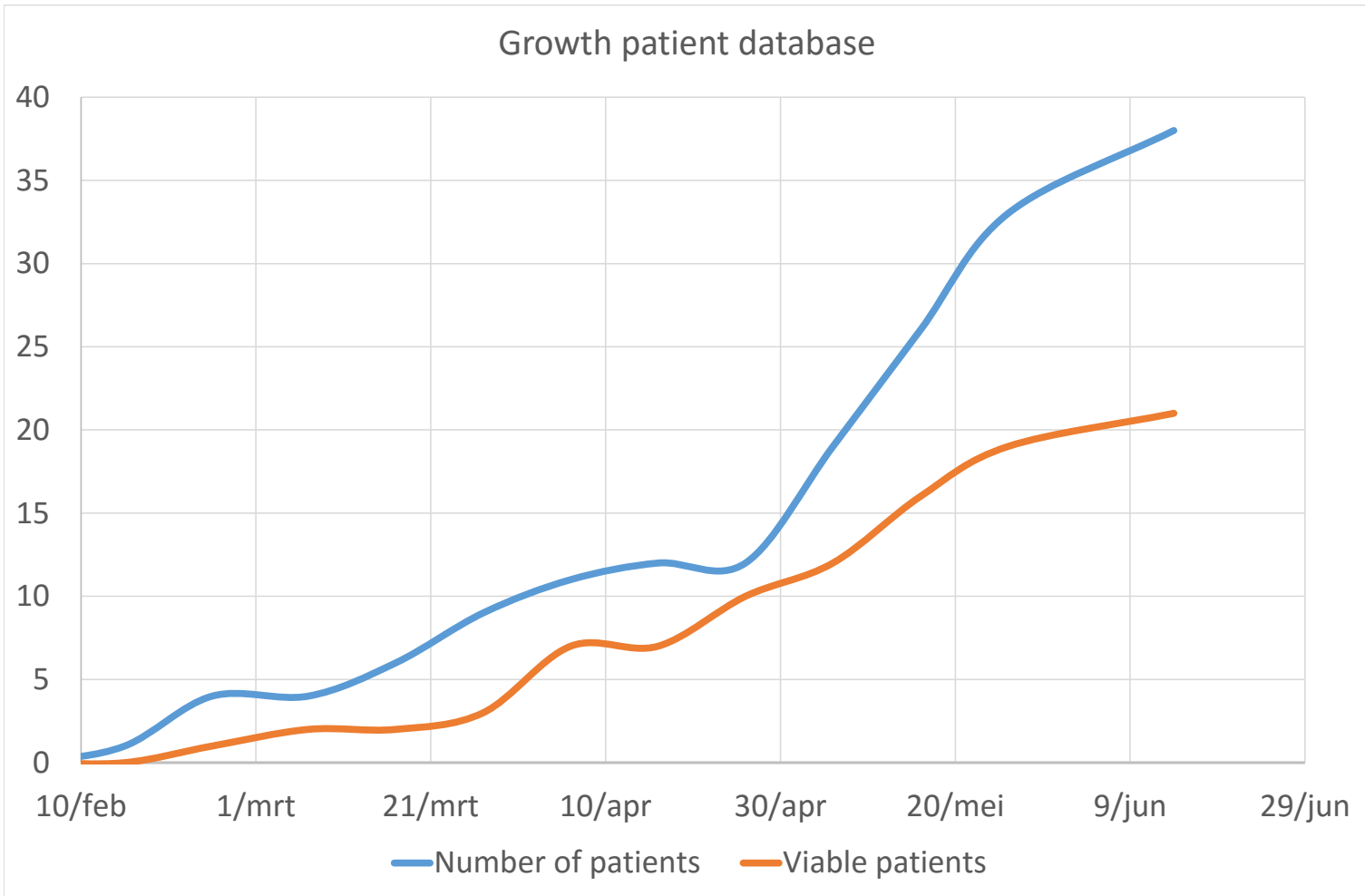


Headache dataset

Data collection could only start in March:

- the mobile application had to be finished first
- an ethical committee had to approve our application

$\rightarrow$ too few samples for machine learning


Growth patient database
40
35
30
25
20
15
10
5
0
10/feb
1/mrt
21/mrt
10/apr
30/apr
20/mei
9/jun
29/jun
Number of patients
Viable patients

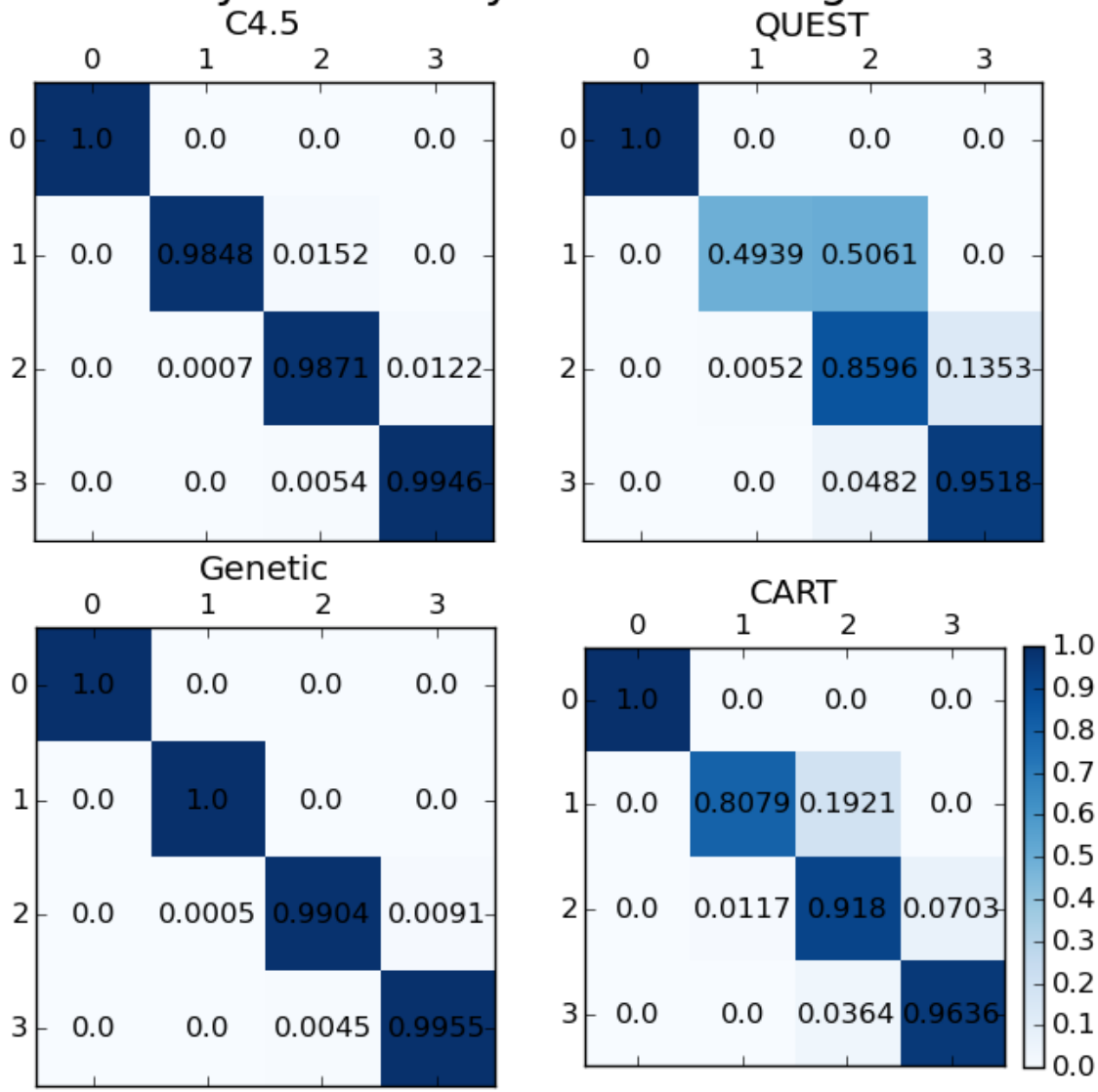
Evaluating our algorithm

5 datasets from UCI
optimal parameters, feature selection when needed and k-fold CV

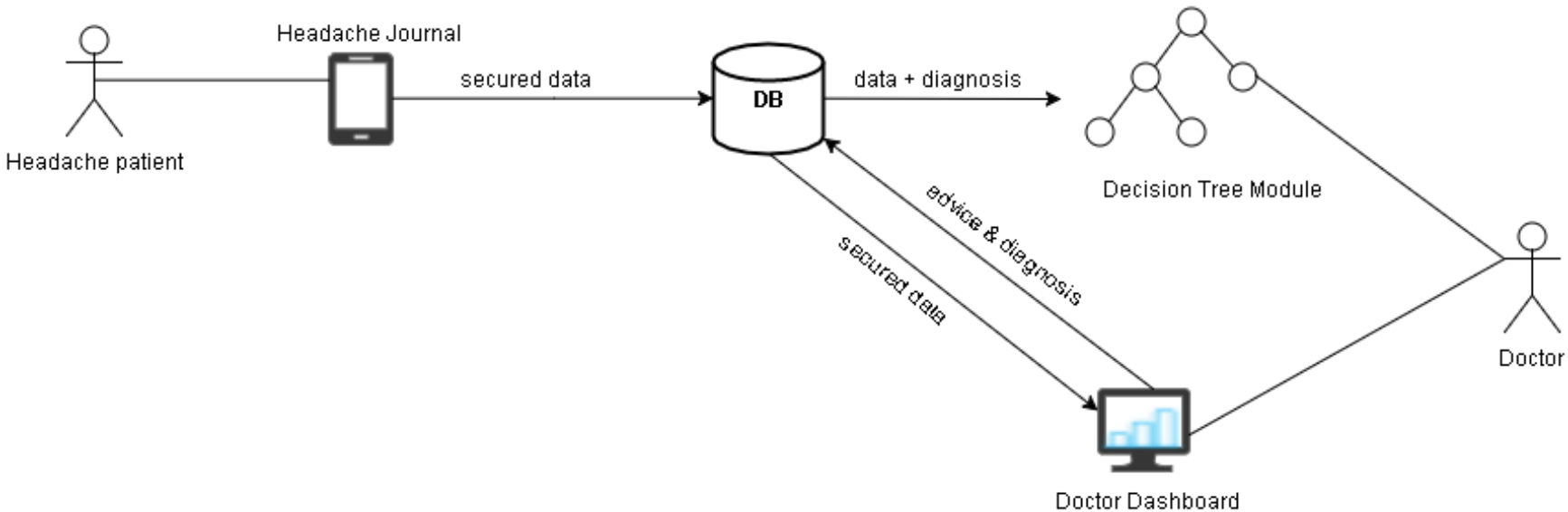
Name	#Samples	#Disc	#Cont	#Class	Imbalance rate
Heart	270	7	6	2	0.058
Car	1728	6	0	4	0.225
Iris	150	0	4	3	0
Shuttle	14500	0	9	7	0.18308
Nursery	12960	8	0	5	0.1498

Dataset	Folds	C4.5	CART	QUEST	Genetic
Heart disease	5	**0.8067**	0.7844	0.7844	**0.8067**
	10	**0.8104**	0.7732	0.7881	0.7993
Iris	3	0.9533	0.9467	0.9467	**0.96**
	5	0.9467	0.9333	0.9467	**0.9533**
Cars	3	**0.9722**	0.9693	0.9229	0.9693
	5	0.9711	0.9682	0.9241	**0.9786**
	10	0.9756	0.9751	0.9265	**0.9803**
Shuttle	3	0.9987	0.9983	0.9964	**0.9988**
	5	0.9986	0.9981	0.9962	**0.9988**
	10	0.9990	0.9987	0.9941	**0.9992**
Nursery	3	0.9890	0.9431	0.9147	**0.9914**
	5	0.9918	0.9498	0.9251	**0.9958**
	10	0.9937	0.9568	0.9259	**0.9954**

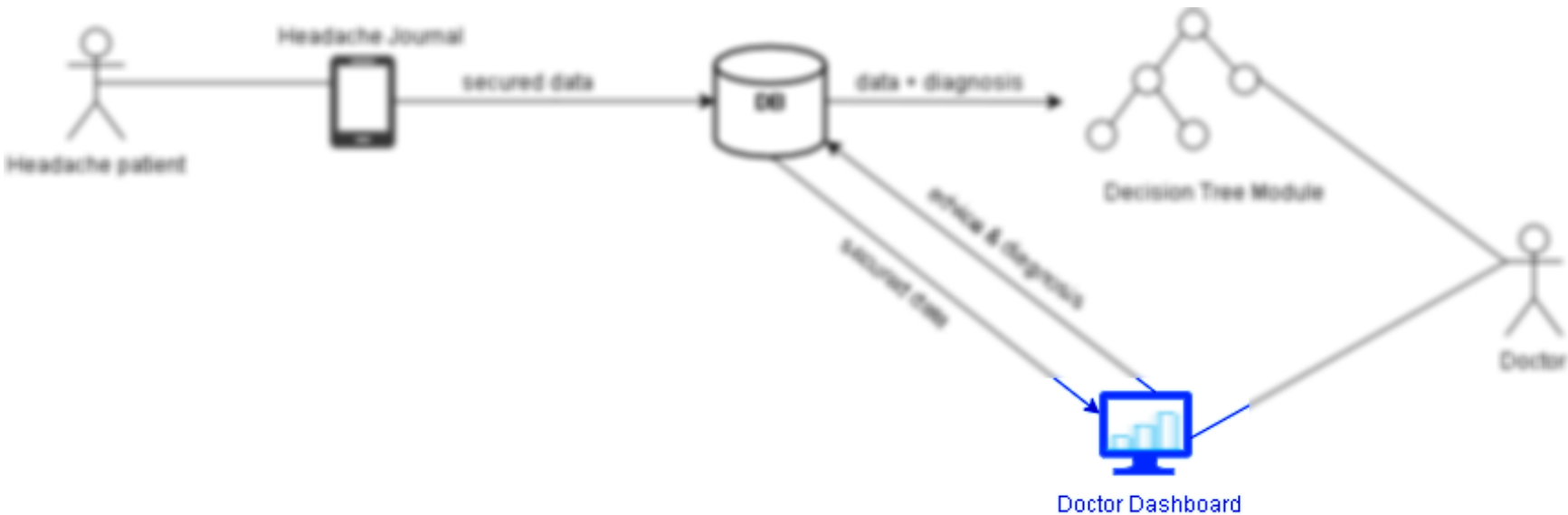
Accuracy on nursery dataset using 10 folds



Doctor dashboard



Doctor dashboard



Doctor Dashboard

- Web application in order for the doctors to access the data exposed by our REST API
- Preferably in the form of visualizations, which allow to process a lot of data in a small amount of time
- Developed by Maarten Vanden Berghe

Conclusion

- It is shown that the current procces in the UH of Ghent can be completely digitized. Our solution can significantly improve the efficiency and reduce the frequency of consults, leading to a reduction in health care costs.

- The foundations for a diagnosis support system are built, using a genetic approach to merge different induced decision trees to obtain a single decision tree with enhanced accuracy.

Future work

- Develop native applications for iOS and Android to enhance look-&-feel
- Re-evaluate our machine learning models on a larger headache dataset
- Implement more induction algorithms and ensemble techniques to create a more diverse initial population
- Experiment with other selection techniques and fitness functions
- Optimize the heuristic approach to convert decision spaces to decision trees

UNIVERSITEIT GENT

FACULTY OF **ENGINEERING AND ARCHITECTURE**

Thank you for your attention!

Intro

Platform requirements

Mobile application

Backend and data exposure

Machine learning

Doctor dashboard

Conclusion & future work