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In-Database Machine Learning

Using Gradient Descent and Tensor Algebra

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HyPer + Tensors + Gradient Descent

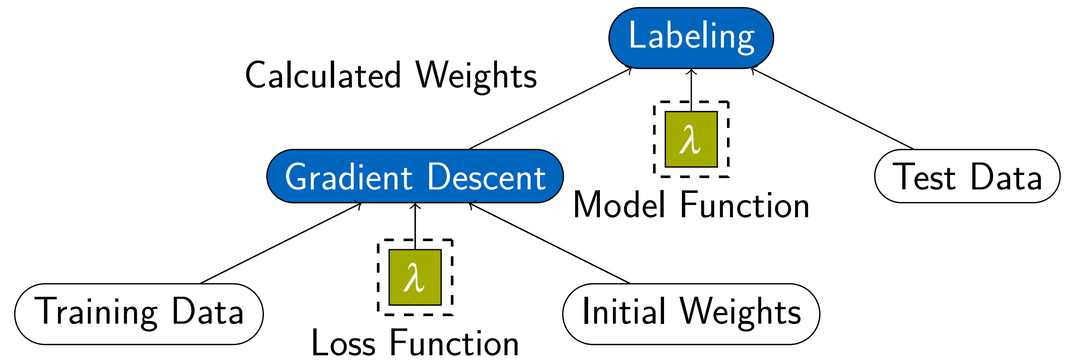
Machine Learning: Data in tensors and a loss function

- Operator for gradient descent:
  - Gradient needed for gradient descent: automatic differentiation necessary for arbitrary loss functions
  - Integration in relational algebra
  - Representation of a loss function

$$\lambda(R,S)(R.a*S.x+R.b-S.y)^2$$

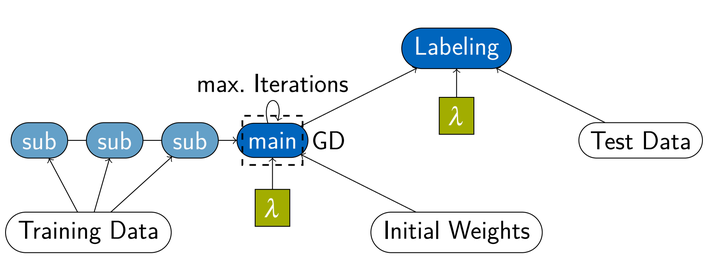
- Tensors: datatype with algebra

\+ optimisation problems solvable in the core of database systems




```
create table trainingdata (x float, y float);
create table weights(a float, b float);
insert into trainingdata ... insert into weights ...
select * from gradientdescent(
  -- the loss function is specified as λ-expression
  λ(data,weights) (weights.a*d.x+weights.b-d.y)^2,
  (select x,y from trainingdata d),
  (select a,b from weights),
  0.05, 100); -- learning rate and max. number of iterations
```

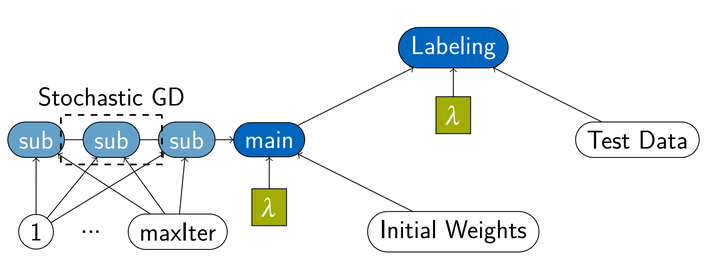
Materializing



\+ allows any optimization method

– Tuples need to be materialized

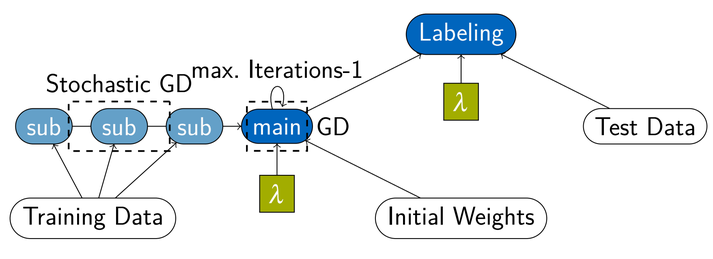
Pipelined



\+ No materialization required

– Iterations must be precompiled

Combined

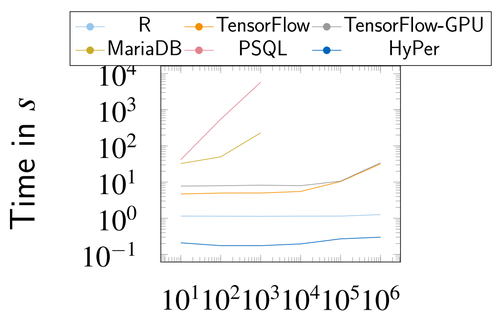


\+ Precomputes weights in pipelines

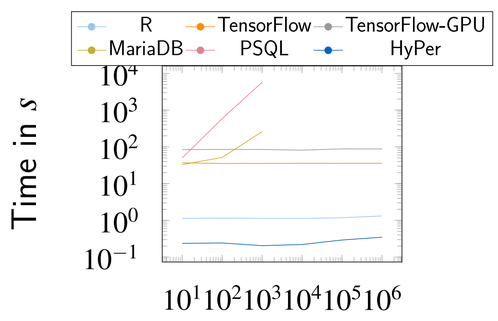
– Little performance gains

Evaluation

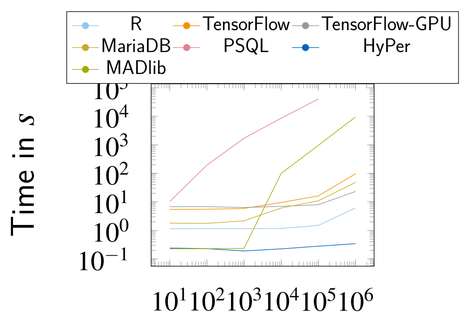
Linear Regression



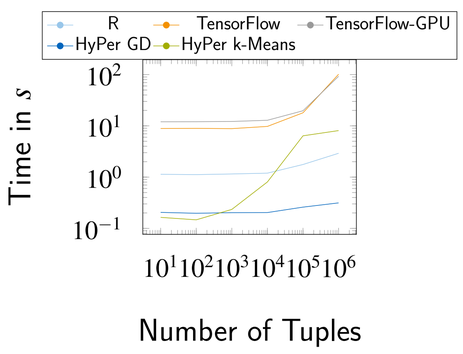
Multiple Linear Regression



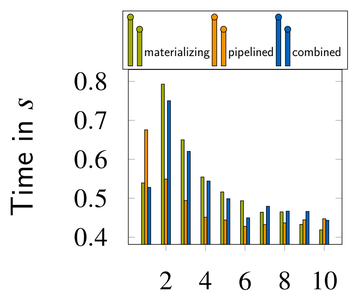
Logistic Regression



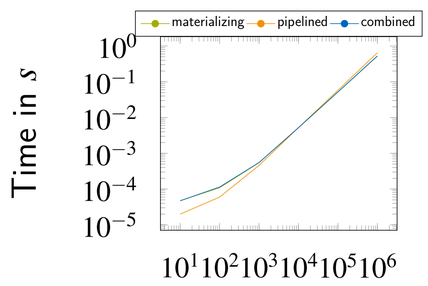
k-Means



Number of Tuples



Number of Tuples



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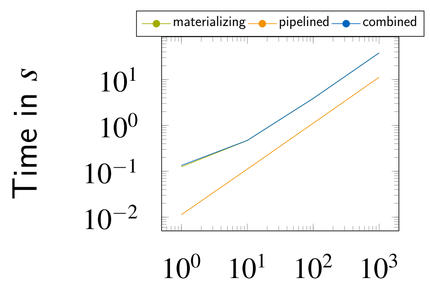

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