Improvement on the Acceptance of a Conflict Resolution System by Air Traffic Controllers

R. Flicker, Technical University Berlin

Outline

1. Background
    1. Multi-Sector-Planning
2. Development of Conflict Resolution Assistance
    1. Hypotheses for conflict resolution
    2. First survey to acquire controllers' strategies
    3. Model implementation
3. Evaluation of Conflict Resolution Assistance
    1. Description of experimental design
    2. Measurements and results
4. Model Improvement
5. Conclusion and Outlook

Introduction / Multi-Sector-Planning

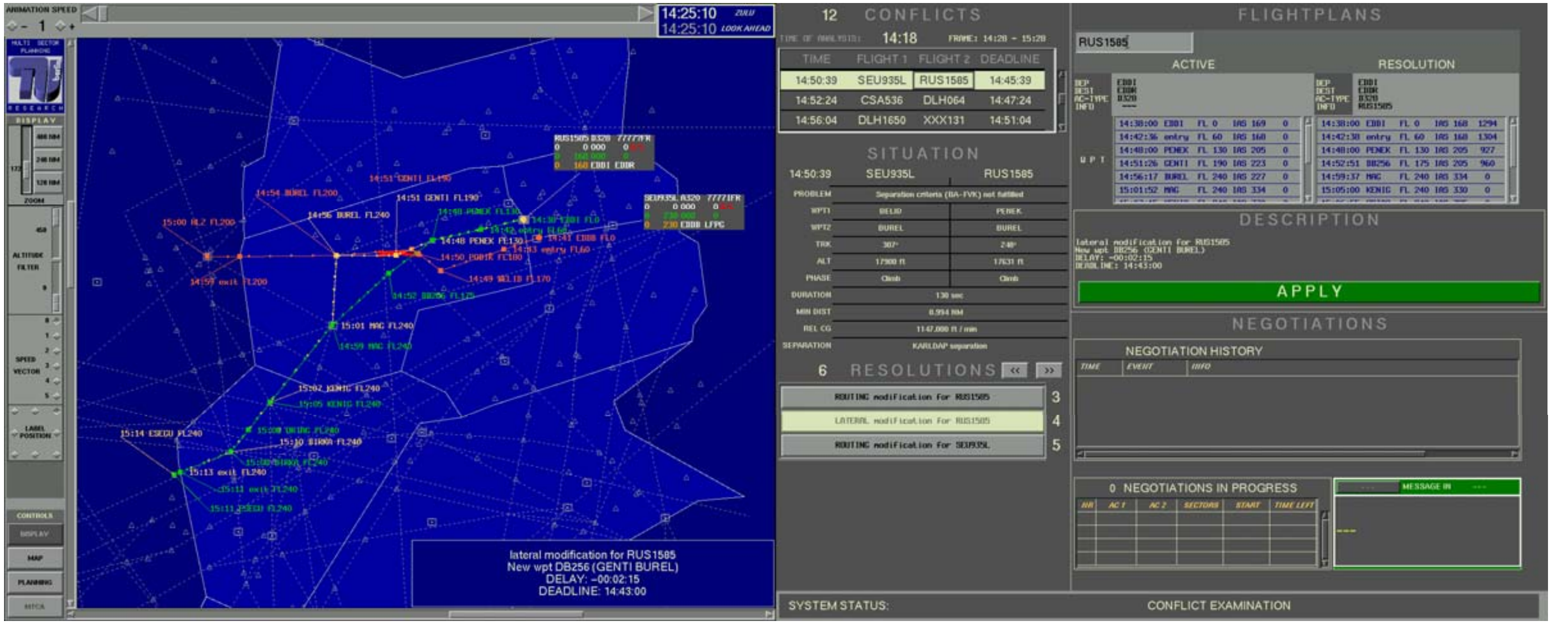
- ⇨ New ATM concepts to increase air space capacity
- ⇨ Airspace temporally and spatially enlarged
- ⇨ Exceeds cognitive capabilities of air traffic controllers
- ↳ Controller needs support by conflict detection and resolution

Multi-Sector Planning:

- ⇨ Medium-term traffic flow planning
- ⇨ Optimizes traffic flow beyond existing sector boundaries
- ⇨ Reduces conflict density
- ⇨ Relieves sector controller
- ⇨ Offers conflict solutions

Multi-Sector-Planner

- ⇨ Working position for one controller (MSP-Controller) with two screens:
  - Air Situation Display
  - Negotiation Window
- ⇨ 10 min up to 1 hour look ahead time exceeds the mental planning capacity of a controller
- ↳ Controller needs support for conflict detection and resolution by an assistance system



Conflict Resolution Assistance

⇨ Low acceptance of conflict resolutions generated by mathematical search methods:

- Less comprehensible solutions
- Contradictory to controllers' experiences

↳ Include controller knowledge to increase plausibility and acceptance of the system

⇨ Hybrid model (cube model) by Oliver Späth (2003) classifies conflicts and generates solutions with heuristic search methods

⇨ Essential criteria of the hybrid model:

- Conflict type (conflict classification by Eurocontrol)
- Distance to destination
- Aircraft flight performance
- Vertical distance to sector ceiling

Project Description

Project "Integration of controllers' strategies into a Medium Term Conflict Resolution System":

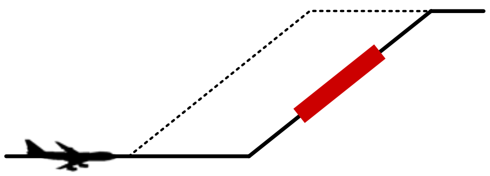
- ⇨ Supported by the German research foundation DFG (Deutsche Forschungsgemeinschaft)
- ⇨ Project duration: January 2003 to December 2005
- ⇨ Project team consists of a psychologist, an engineer and two students
- ⇨ Milestones:
  - ✓ Survey for data acquisition
  - ✓ Implementation of the acquired controllers' strategies into a conflict assistance system
  - ✓ Evaluation of the assistance system with the Multi-Sector-Planner
  - ▪ Evaluation of statistical and machine learning methods to adapt a model to air traffic controllers' behavior
  - ▪ Integration of the new model into the conflict assistance system and evaluation with the Multi-Sector-Planner

Hypotheses For Conflict Solution (1)

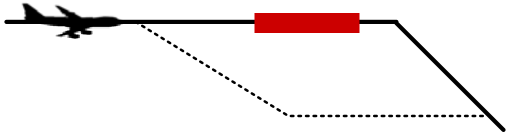
⇨ First indications from examinations of Späth's Hybrid/Cube Model and Eurocontrol CORA2

⇨ Hypotheses:

- If destination is far and climb is possible, then a climb is preferred

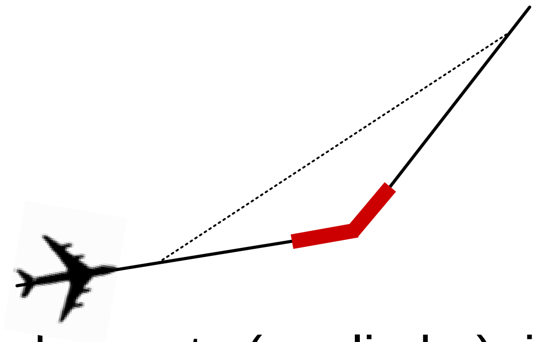


- If destination is near, then a descent is preferred

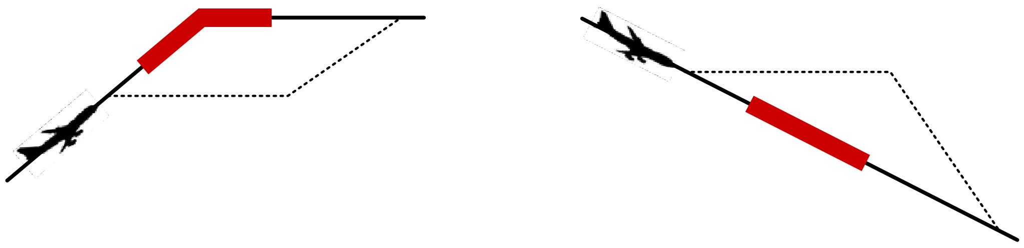


Hypotheses For Conflict Solution (2)

- If climb or descent is impossible, then a lateral solution is preferred



- When an airplane descents (or climbs), it will either continue or suspend the descent (or climb), but it will never fly contrary to the current flight phase



- The conflict type has no influence on the preferred solution

Model Parameter

Model Parameter:

⇨ Input Parameter:

- Distance to destination airport = {near, far}
- Flight phase = {climb, cruise, descent}
- Conflict type = {head-on, crossing, catch-up}
- Climb solution possible due to aircraft performance and distance to the sector ceiling = {yes, no}

⇨ Output Parameter:

- Solution category = {climb, descent, stop-climb, stop-descent, lateral}

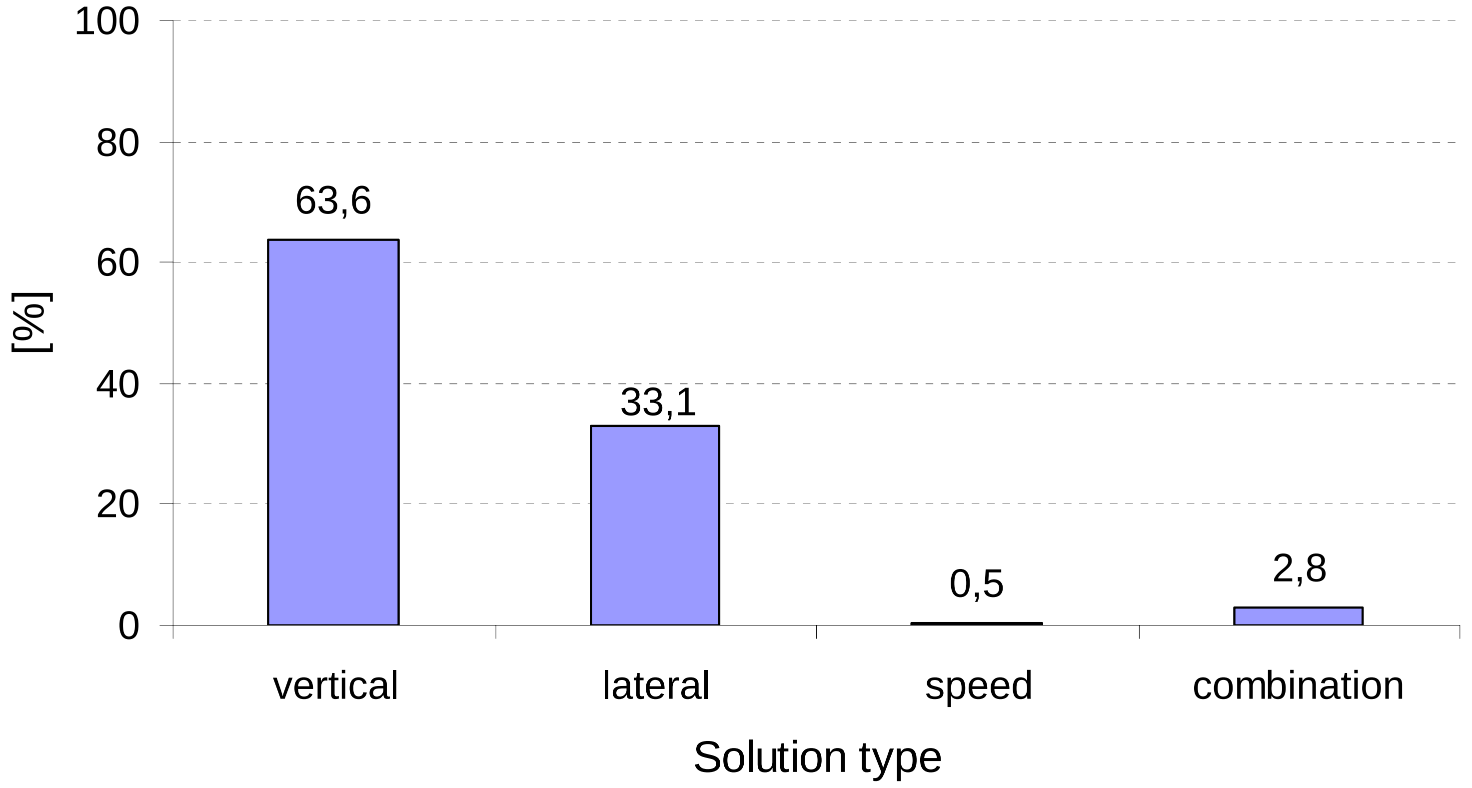
First Survey – Realization

⇨ 24 en-route controllers of the German Civil Air Navigation Service Provider (DFS)

	range
sex:	6 female 18 male
age:	22 to 51 years
work experience:	1 to 29 years

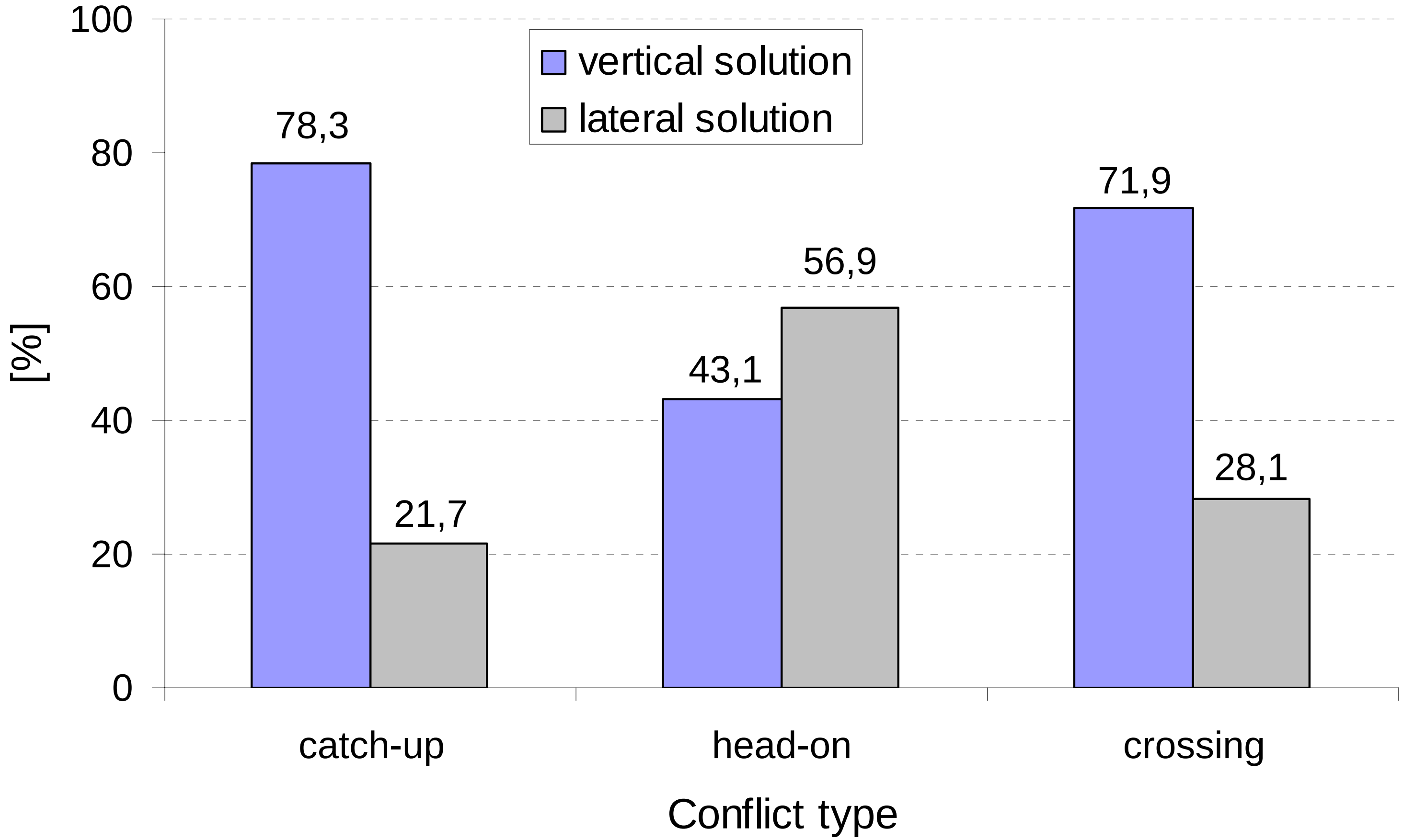
First Survey – Results - Resolution (1)

Results: preferred resolution over all criteria



First Survey – Results - Resolution (2)

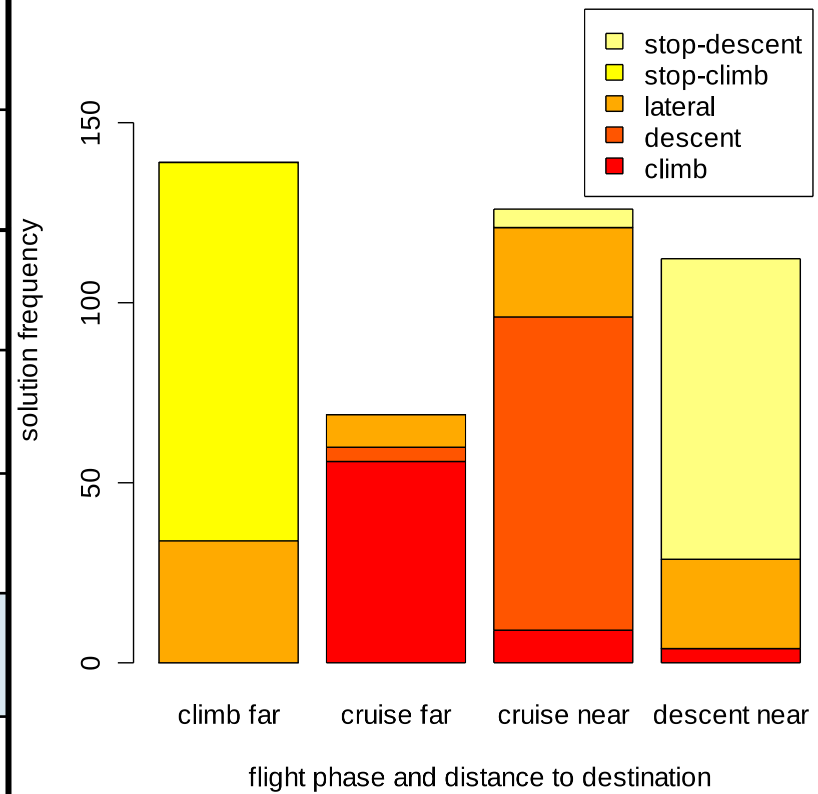
Results: preferred resolution depends on conflict type



First Survey – Results - Resolution (3)

⇨ Summarizing Results:

Flight phase	climb	cruise		descent
Distance to destination	far	far	near	near
Climb solution	0%	81.2%	7.1%	3.6%
Stop-Climb solution	75.5%	0%	0%	0%
Descent solution	0%	5.8%	69.1%	0%
Stop-Descent solution	0%	0%	4.0%	74.1%
Lateral solution	24.5%	13.0%	19.8%	22.3%



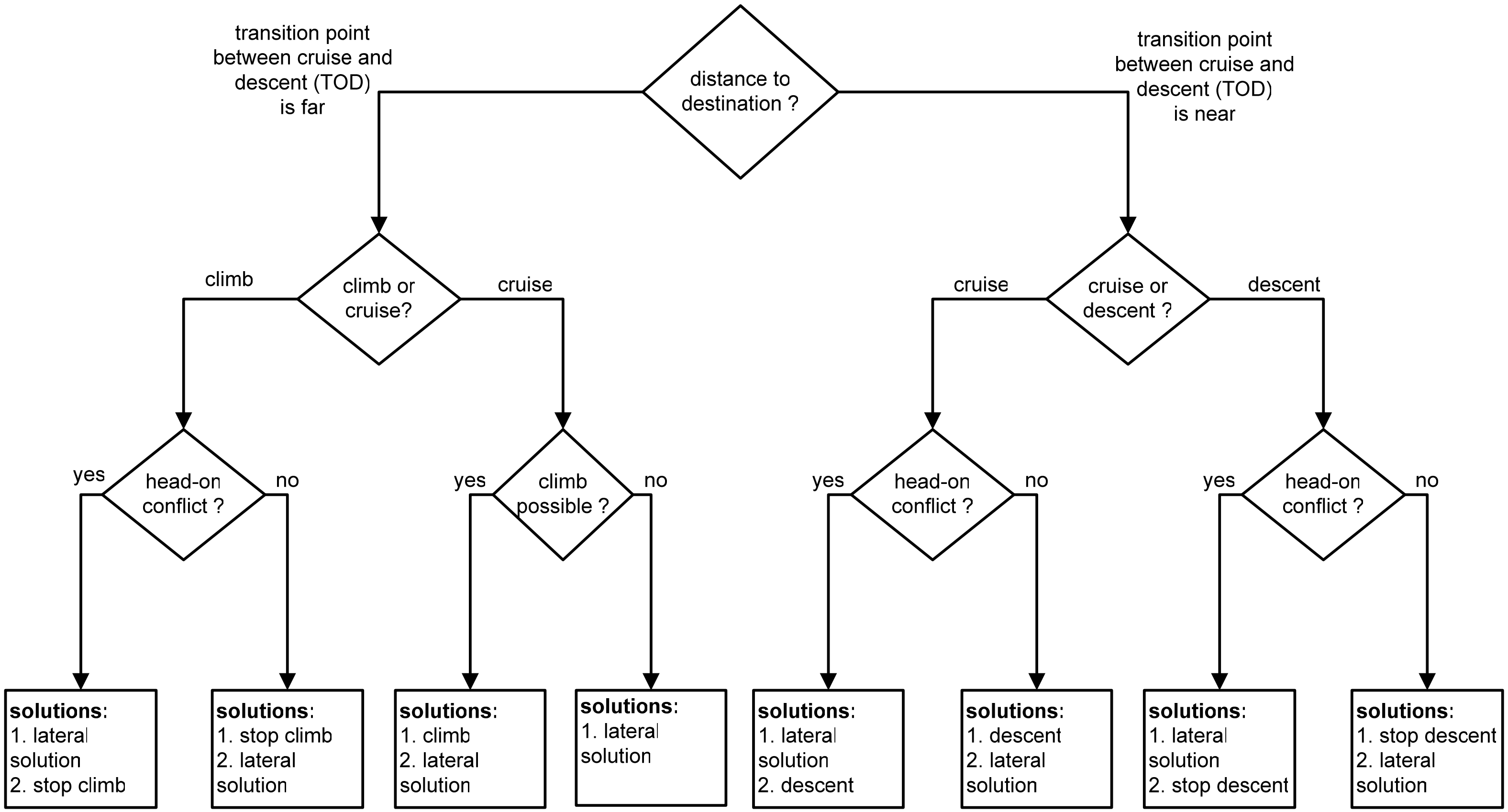
First Survey – Discussion

Results from the first survey:

- ⇨ Controllers preferred vertical solution
- ⇨ For aircrafts in cruise ATC instructs to climb when destination is far and to descent when destination is near
- ⇨ Aircrafts in climb or descent were instructed to interrupt their current flight phase
- ⇨ The preferred solution depends also on the conflict type (contradictory to the hypotheses)
- ⇨ Speed solutions are negligible for en-route control
- ⇨ Combined solutions were given as a service idea, but can be reduced to single solutions

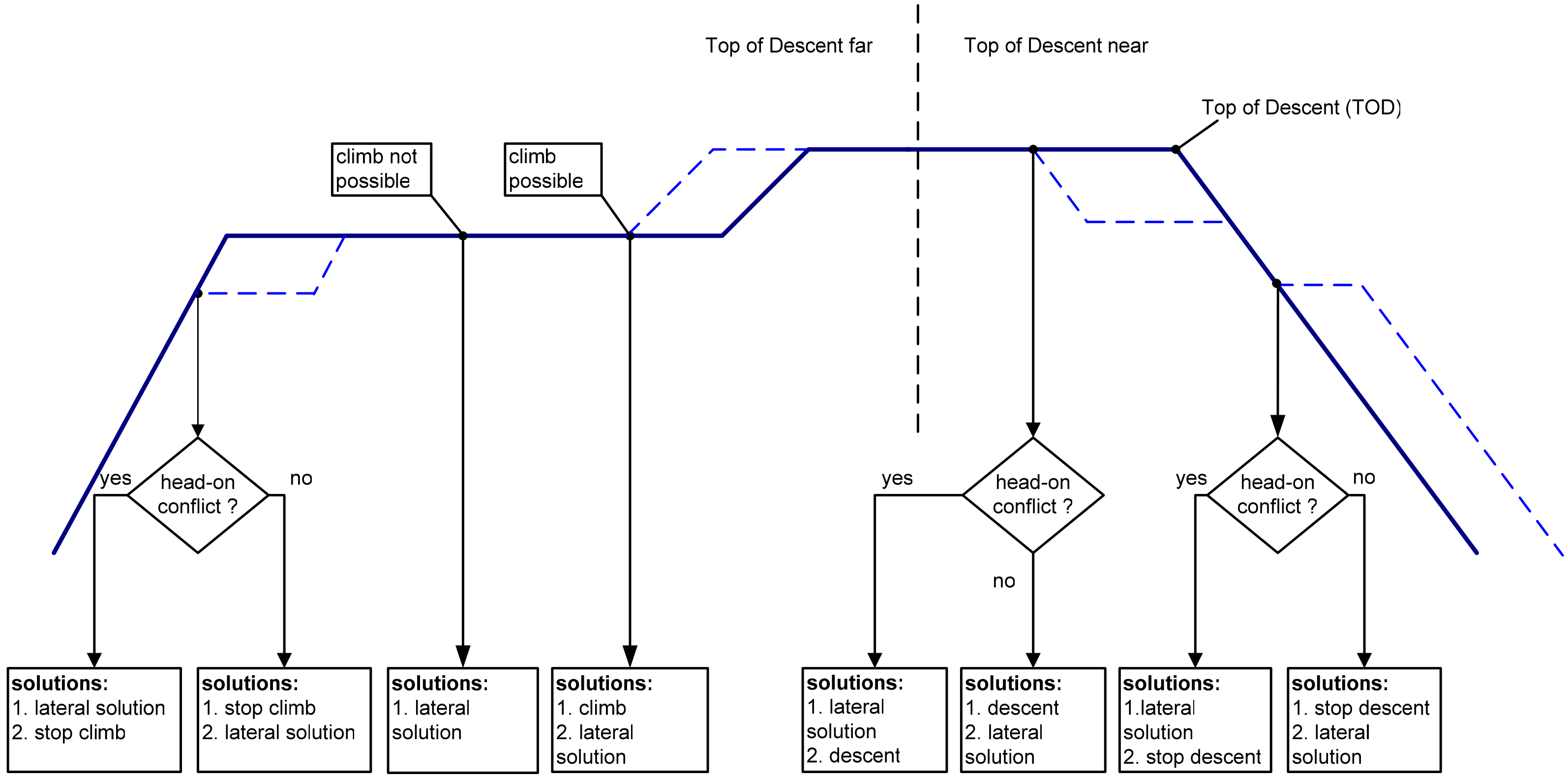
Conflict Resolution Assistance – Solution Choice (1)

Controllers' strategies are represented as decision tree:



Conflict Resolution Assistance – Solution Choice (2)

View of the vertical flight path with controllers' strategies:



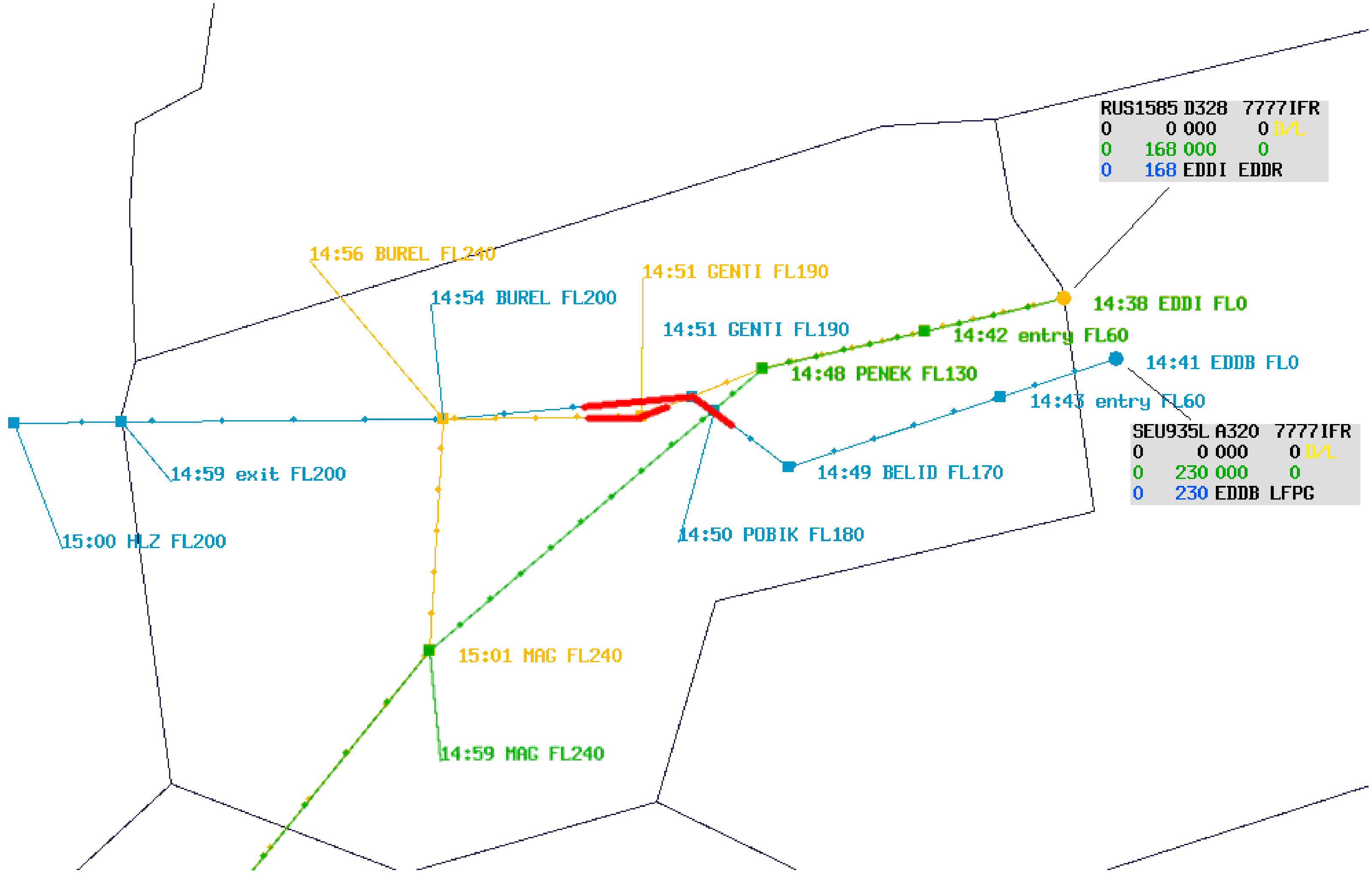
Model Implementation

- ⇨ Redesign of the existing assistance system “LOTEC” with highly sophisticated object orientated software engineering methods
- ⇨ COCOS (COntrollers’ strategies integrated into a COnflict resolution System)

COCOS:

- ⇨ Integration of the acquired controller strategies
- ⇨ Object orientated analysis and design with the Unified Modeling Language (UML)
- ⇨ Implemented in the programming language C++
- ⇨ Network based communication between MSP and the COCOS component

Example For a Conflict Situation



Second Survey – Evaluation

- ⇨ Evaluation with real-time simulation
- ⇨ Scenarios based on real traffic data
- ⇨ Measurement of:
  - subjective workload with questionnaires
  - behavior with system event logging
  - visual attention with an eye-tracking system
- ⇨ Three comparing conditions:
  - Baseline condition: To control the traffic with conflict detection and without conflict resolution
  - Prior system condition: To control the traffic with conflict detection and resolution without integrated controllers’ strategies
  - COCOS condition: To control the traffic with conflict detection and resolution with integrated controllers’ strategies

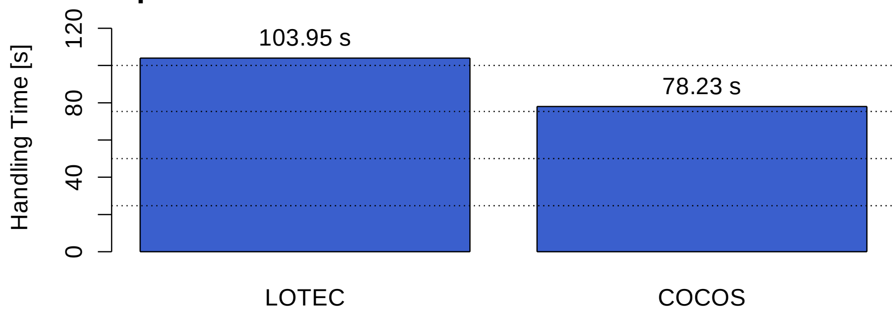
Second Survey – Realization

⇨ 27 en-route controllers of the German Civil Air Navigation Service Provider (DFS)

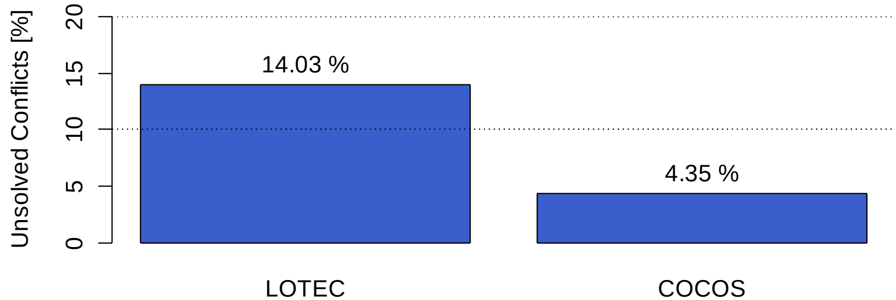
	range
sex:	3 female 24 male
age:	23 to 49 years
work experience:	0 to 24 years

Second Survey – Results (1)

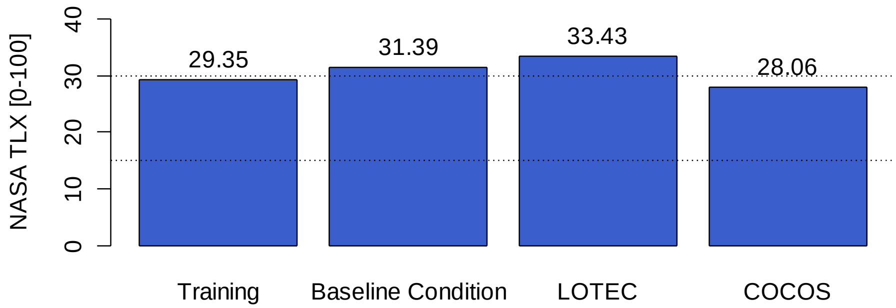
⇨ Handling Time per Conflict:



⇨ Unsolved Conflicts (Controller could not find suitable solution):



⇨ Workload (NASA Task Load Index (TLX)):



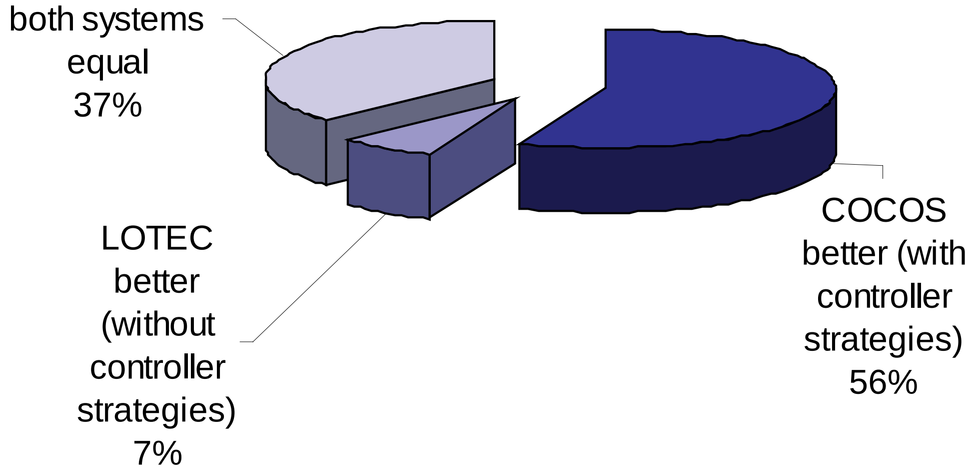
Second Survey – Results (2)

Evaluation showed:

⇨ Integration of air traffic controllers' knowledge leads to:

- Shorter handling times
- Less unsolved conflicts
- Better retrieval of the preferred solutions
- Higher subjective plausibility and acceptance

Acceptance of the solution system



Model Improvement (1)

Model improvement approach:

- ⇨ Infer probabilities for the conflict solutions from the input variables by induction from training examples
- ⇨ Show most probable solutions to the air traffic controller

Objective:

- ⇨ Set of examples E
  - Discrete input vector **x**
  - Discrete response variable y ∈ {climb, descent, stop-climb, stop-descent, lateral}
- ⇨ Infer hypotheses H from the examples E
- ⇨ Probability P for a value of the response variable y conditioned by the input vector x and hypotheses H is searched: P(y|**x**,**H**)

↳ Classification (Pattern Recognition)

Model Improvement (2)

Classification (pattern recognition):

⇨ Learning model consists of:

- Input vector x drawn from an unknown probability P(x)
- Output vector y corresponding to the input x, according to unknown conditional probability P(y|x)
- Learning machine with a set of functions $f(x,\alpha)$, where α is an element of a set of parameters

⇨ Objective: Choose a function from the function space which response to the output vector in the best possible way

- Discrepancy or loss between the response y to the input x can be measured by the loss function $L(y,f(x,\alpha))$
- Find a function which minimizes the risk functional $R(\alpha)$

$$R(\alpha) = \int L\left(y, f\left(x,\alpha\right)\right) dP(x,y)$$

- Learning model provides the statistical model $\hat{y} = f\left(x,\alpha\right)$, which is an estimate for the model y = f(x)

Model Improvement (3)

Problem:

- ⇨ Air traffic controllers assign different solution types to the same conflict situation
- ⇨ Using only the most probable solution in a conflict situation results in an lowest achievable error rate of about Err=0.194 (95% confidence interval: [0.168, 0.220])

Solution:

- ⇨ Using the smallest solution subset with the highest accumulated probabilities, which is greater equal a given threshold (e.g. θ=0,8)

Conclusion And Outlook

- ⇨ Acceptance of a conflict assistance system could be increased by integrating air traffic controllers' knowledge
- ⇨ Use of more than the four presented parameters will bring only a small increase in agreements between the model and controller's behavior
- ⇨ Presenting the most probable solution results in a residual value, which can be overcome by using a solution set of the most probable solutions

- ⇨ Evaluation of learning methods to solve the stated problem with Bayesian Belief Networks or Probabilistic Logic Learning

Thank you for your attention!

Questions ?

Comments ?

Interflug Controller Working Position 1990, Courtesy of DFS