Digital Therapy Models for Clinical Decision Support

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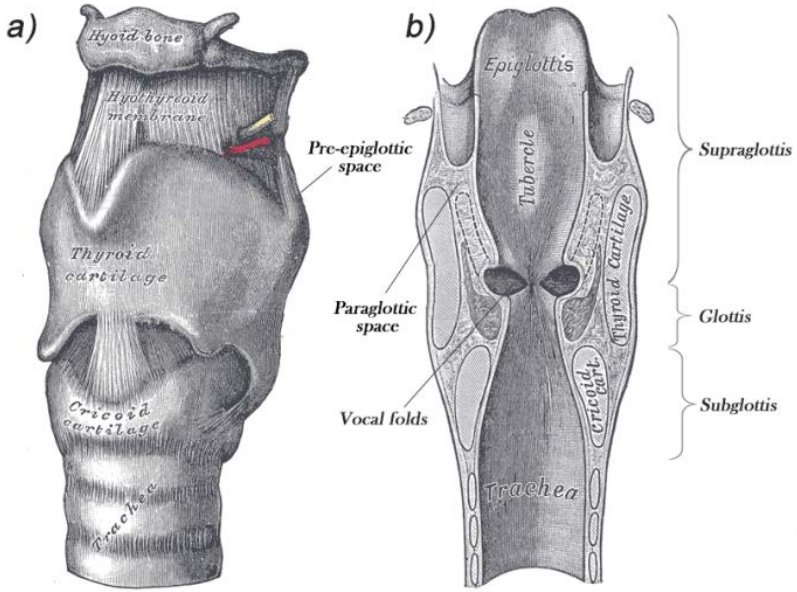
Outline

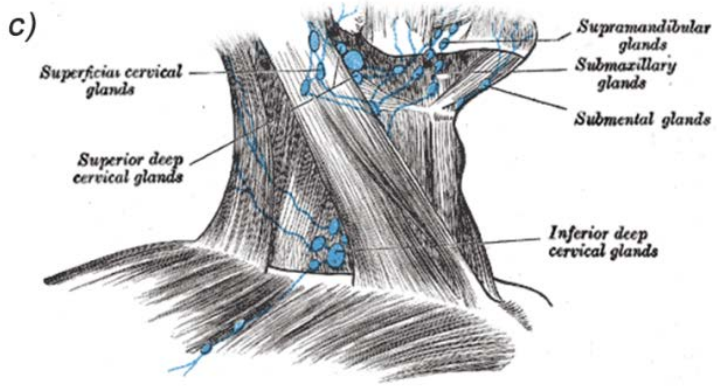
- **Decision support scenario**
- **Competing approaches**
- **The DPM approach**
- **Deployment in the clinic**

Slide acknowledgements: Mario A. Cypko

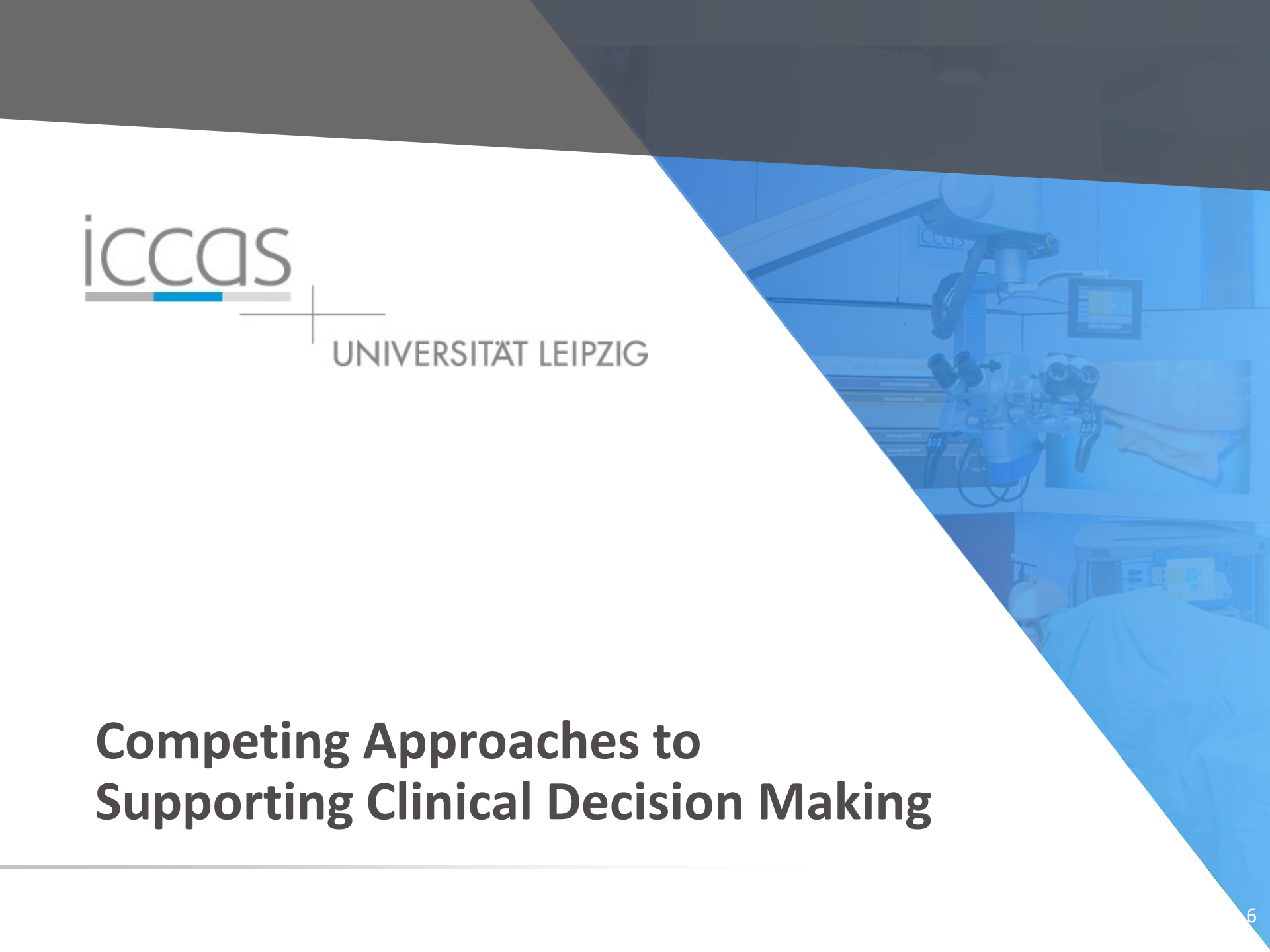
Decision Support Scenario

Scenario: Laryngeal Cancer Treatment





Tumor Board Meetings for Clinical Decision Making in Laryngeal Cancer Treatment



Competing Approaches to Supporting Clinical Decision Making

Competing Approaches

Data-driven Learning

- Integration of ML, NLP, information retrieval, knowledge representation, and automated reasoning
- Require huge amounts of high-quality (patient) data
- Reasoning of algorithms hard to understand
- Example: IBM Watson for Oncology [IBM2018]

Knowledge-driven Modelling

- Explicit organization, modelling and integration of available knowledge from various sources
- Require expert modelers and update mechanisms
- Reasoning of algorithms is easy to understand
- Example: Warfarin therapy [Yet2013]

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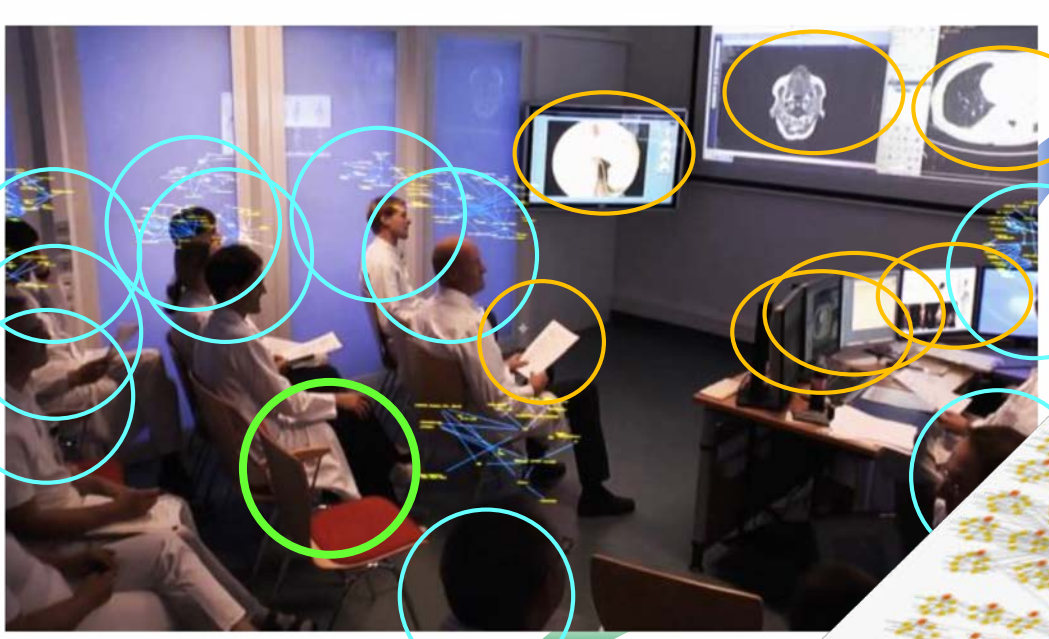
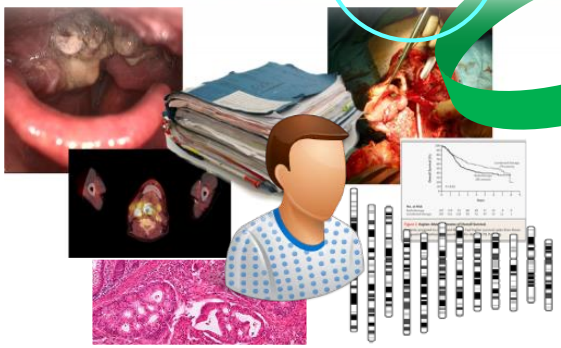
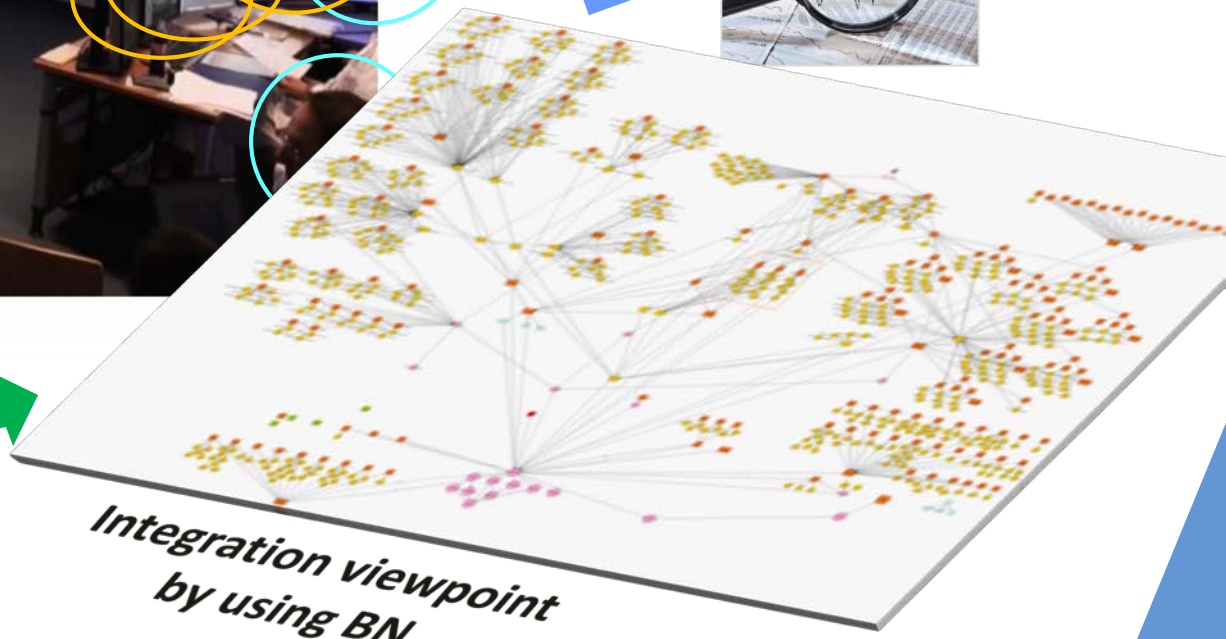
The DPM Approach: Knowledge-Driven Bayesian Network Modelling

The DPM Approach: Bayesian Network Modelling



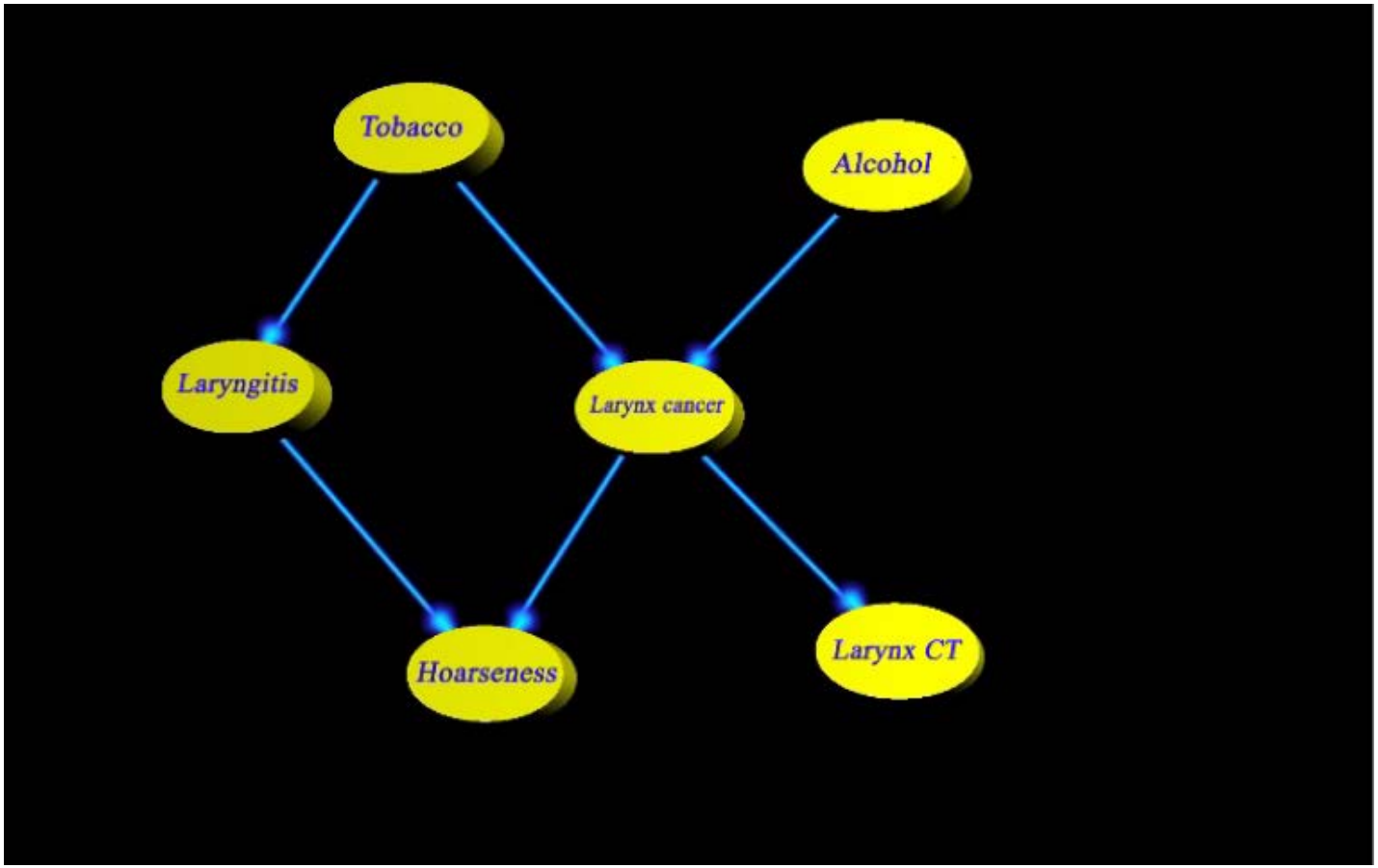




Integration viewpoint by using BN

Bayesian Network in a Nutshell

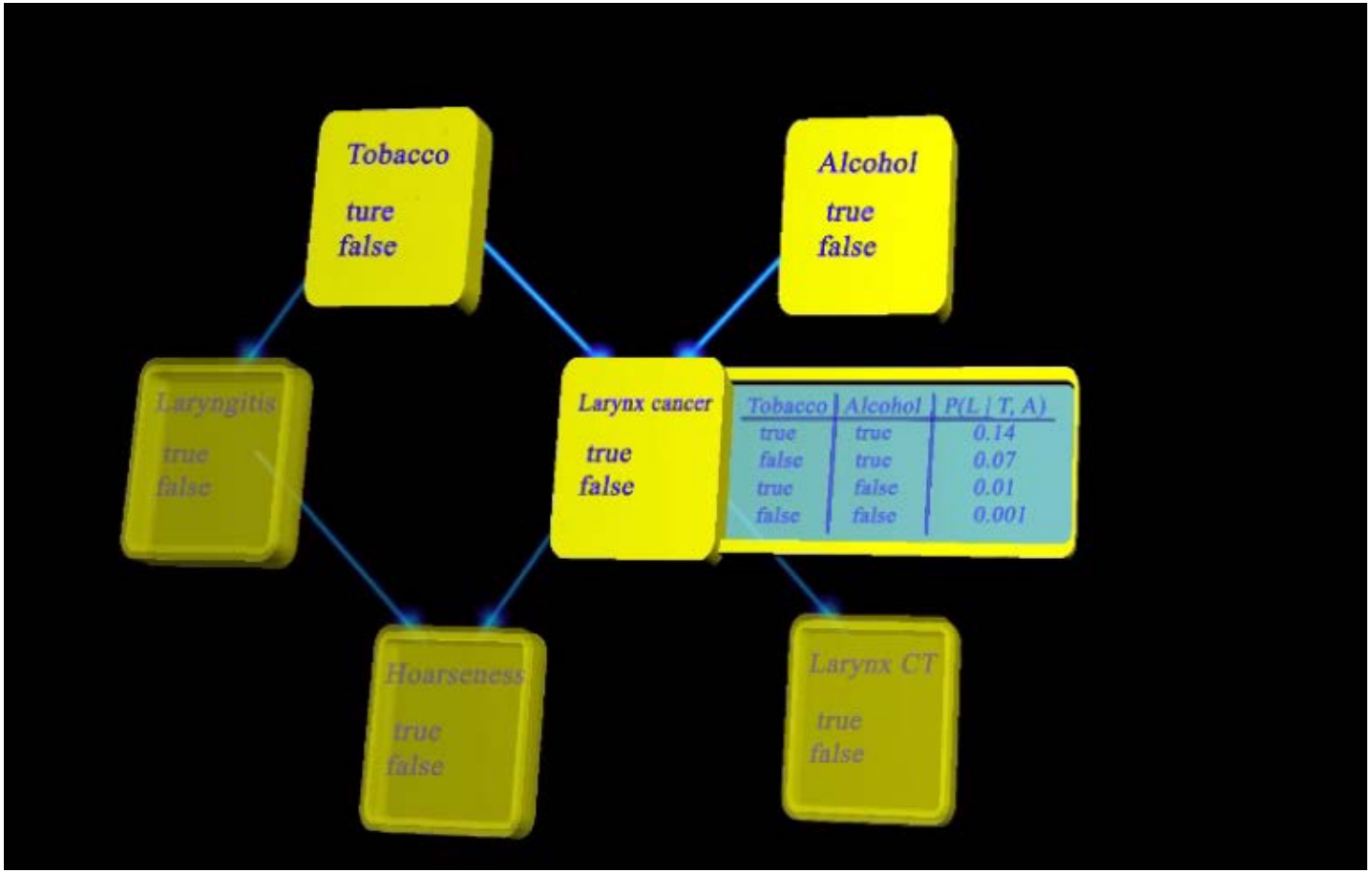
Graphical Modelling example of laryngeal cancer



Source: https://www.youtube.com/watch?v=FI2tlwSoNuY

Bayesian Network in a Nutshell

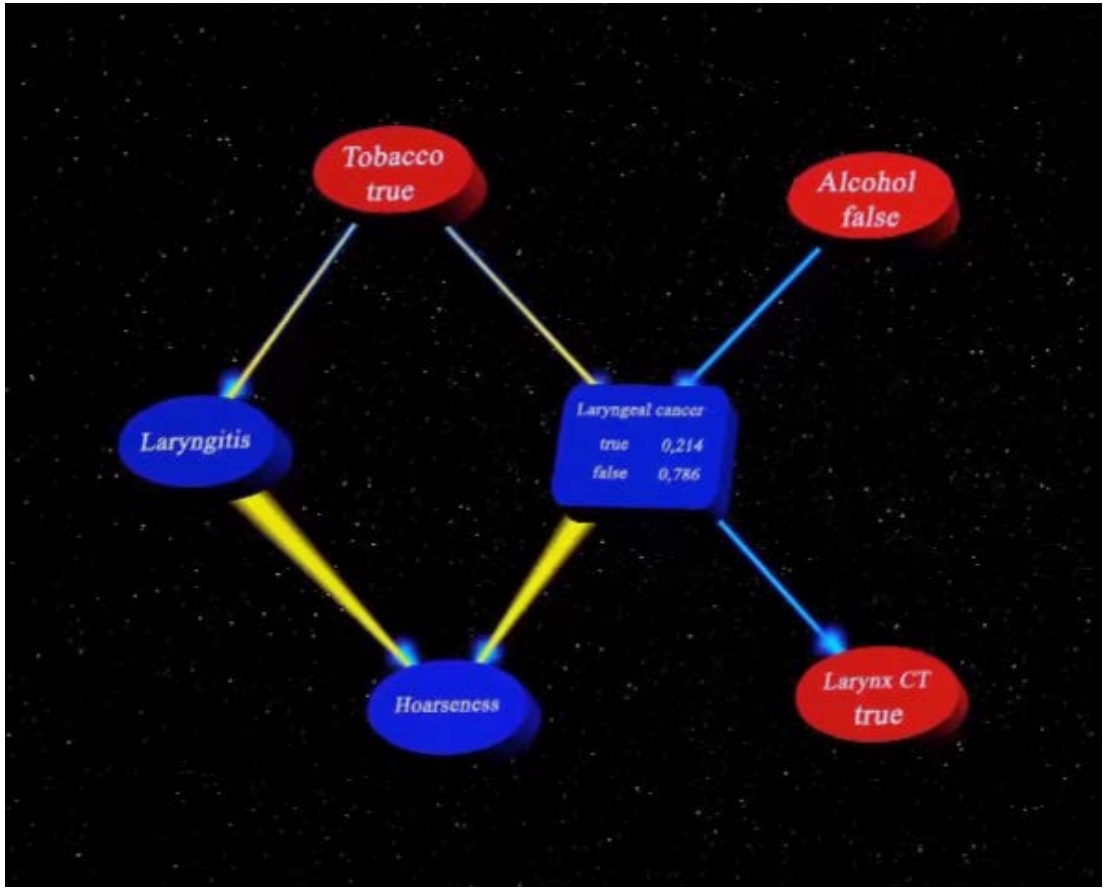
Probabilistic Modelling example of laryngeal cancer

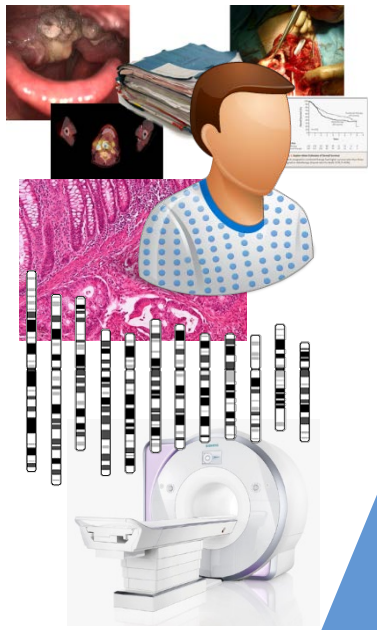


Source: https://www.youtube.com/watch?v=FI2tlwSoNuY

Bayesian Network in a Nutshell

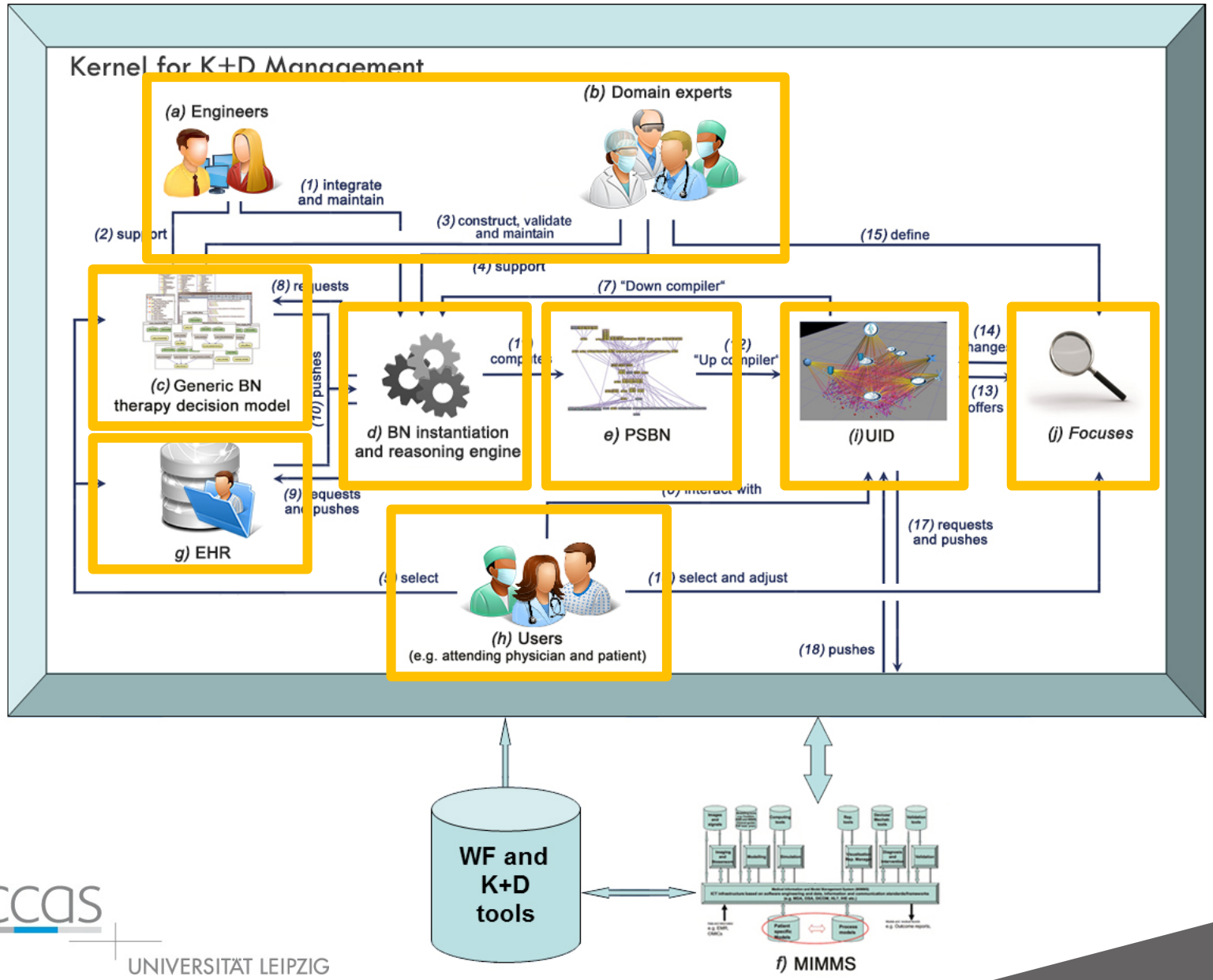
Inferencing



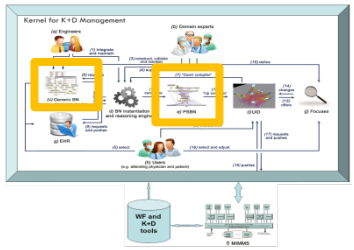


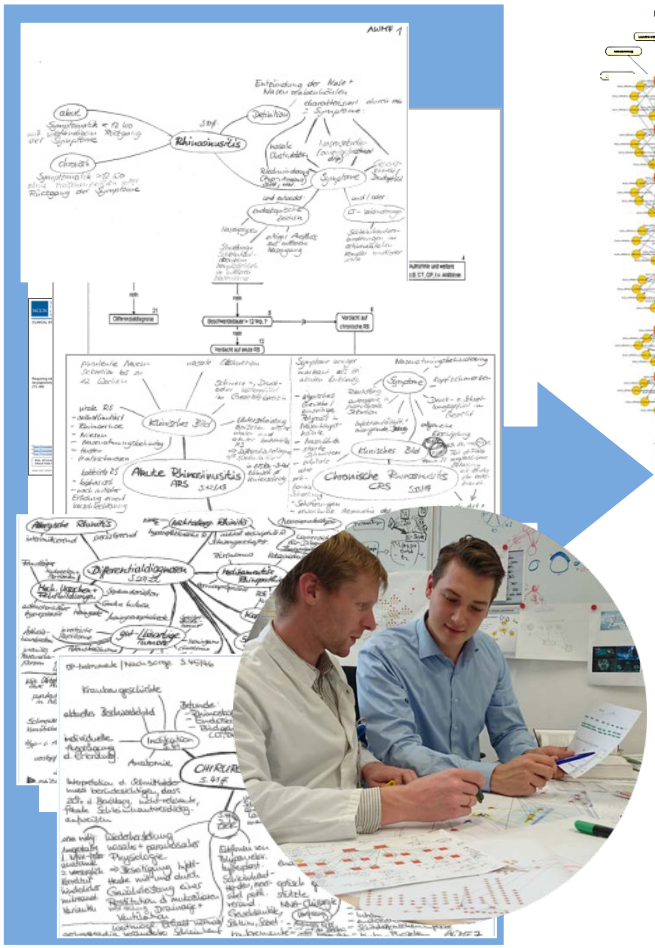
Source: https://www.youtube.com/watch?v=FI2tlwSoNuY

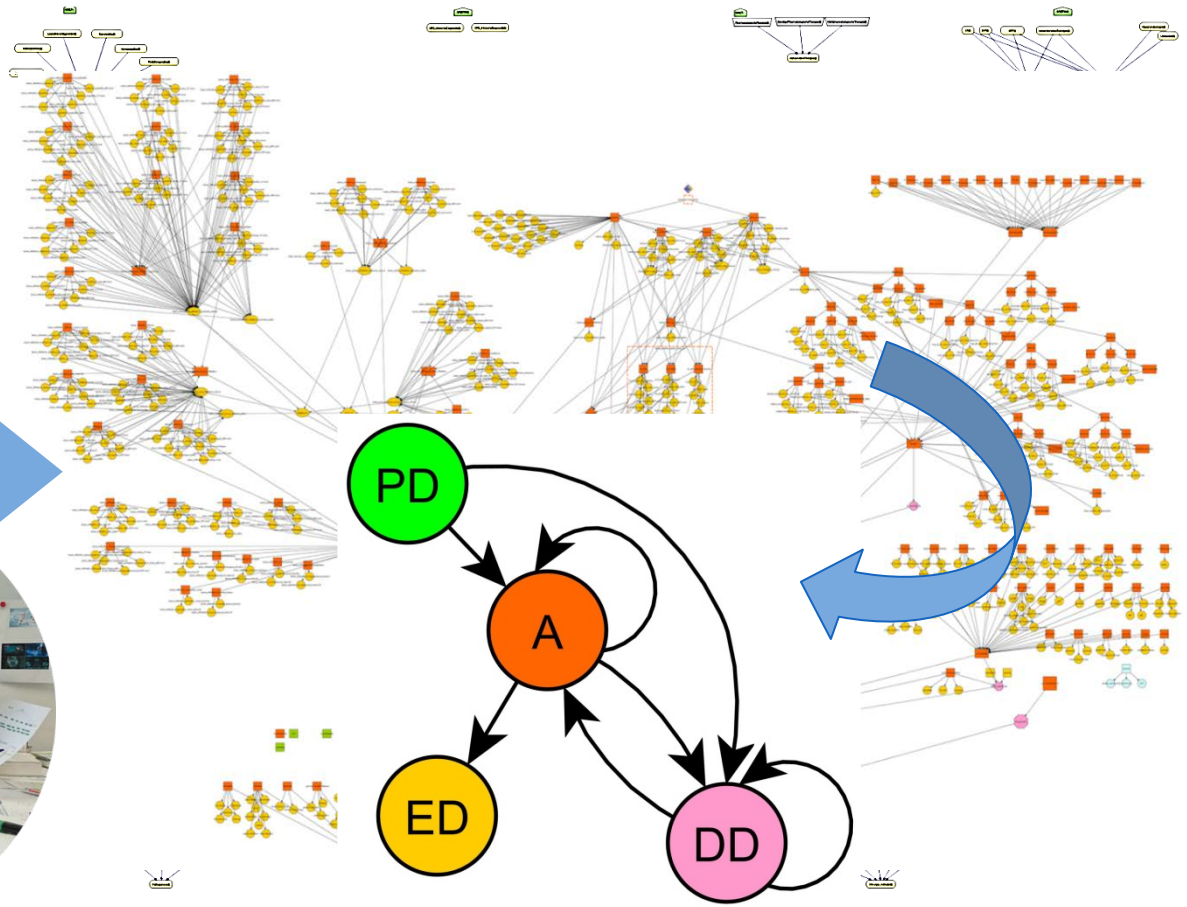
Concept of a CDSS using BN



Modeling BN Structure







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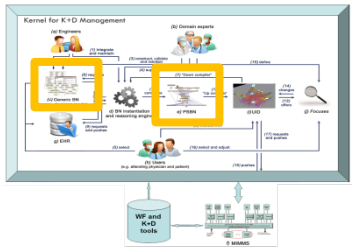
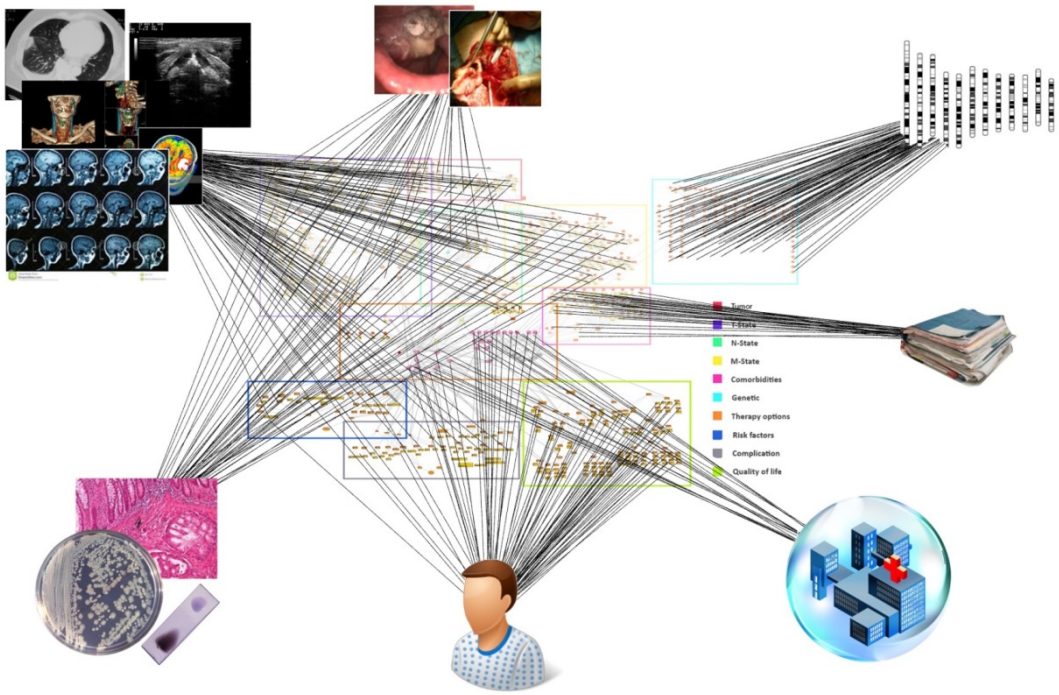
Treatment Decision Model for Laryngeal Cancer [Stoehr2014]





Three years of teamwork of one clinician and one engineer (+ expert meetings):

First year, every day full time, second year, twice a week for four hours, third year, once a week for four hours

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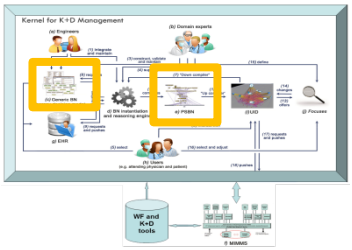
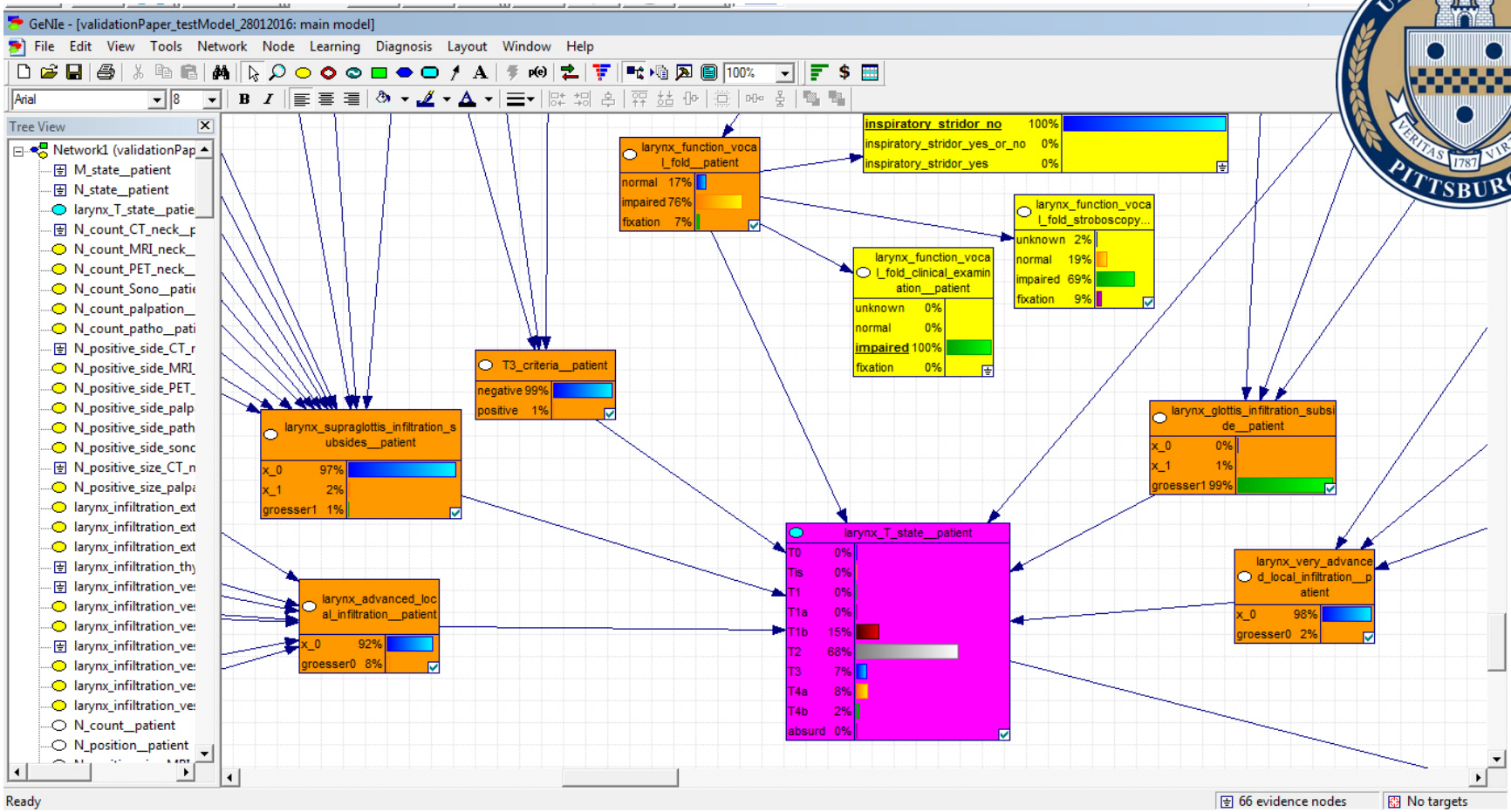
Modelling and Analysis Software

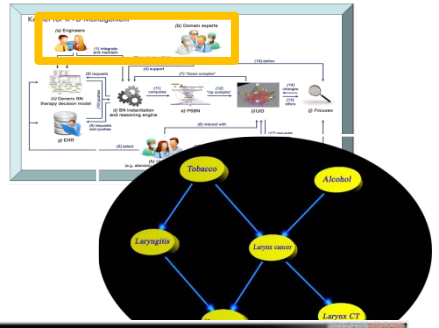


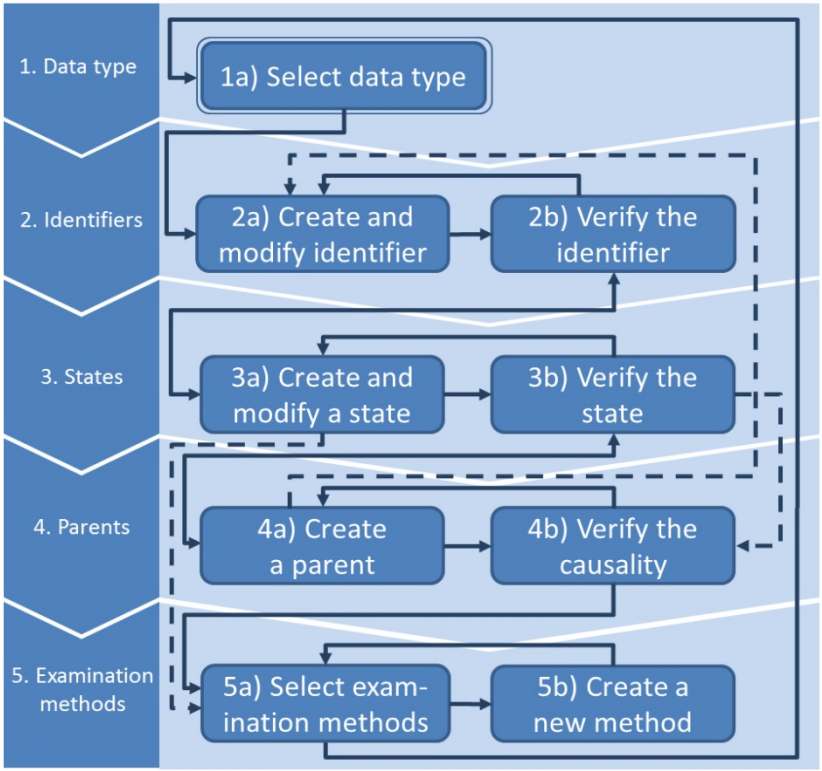
GeNIe [Druzdzel1999]



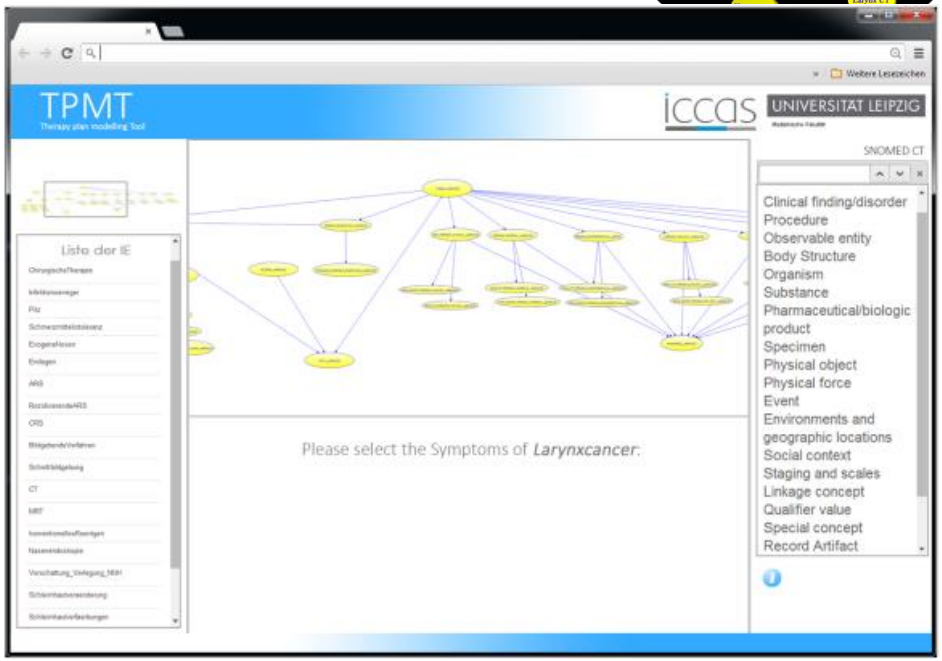
Expert-Friendly Structure Modeling

[Cypko2017c]





Modelling workflow



Development of a web-based tool for BN graph modeling

In collaboration with:

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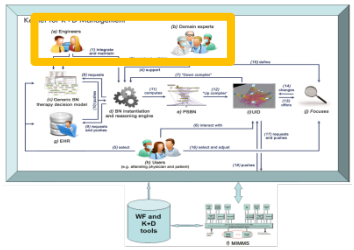
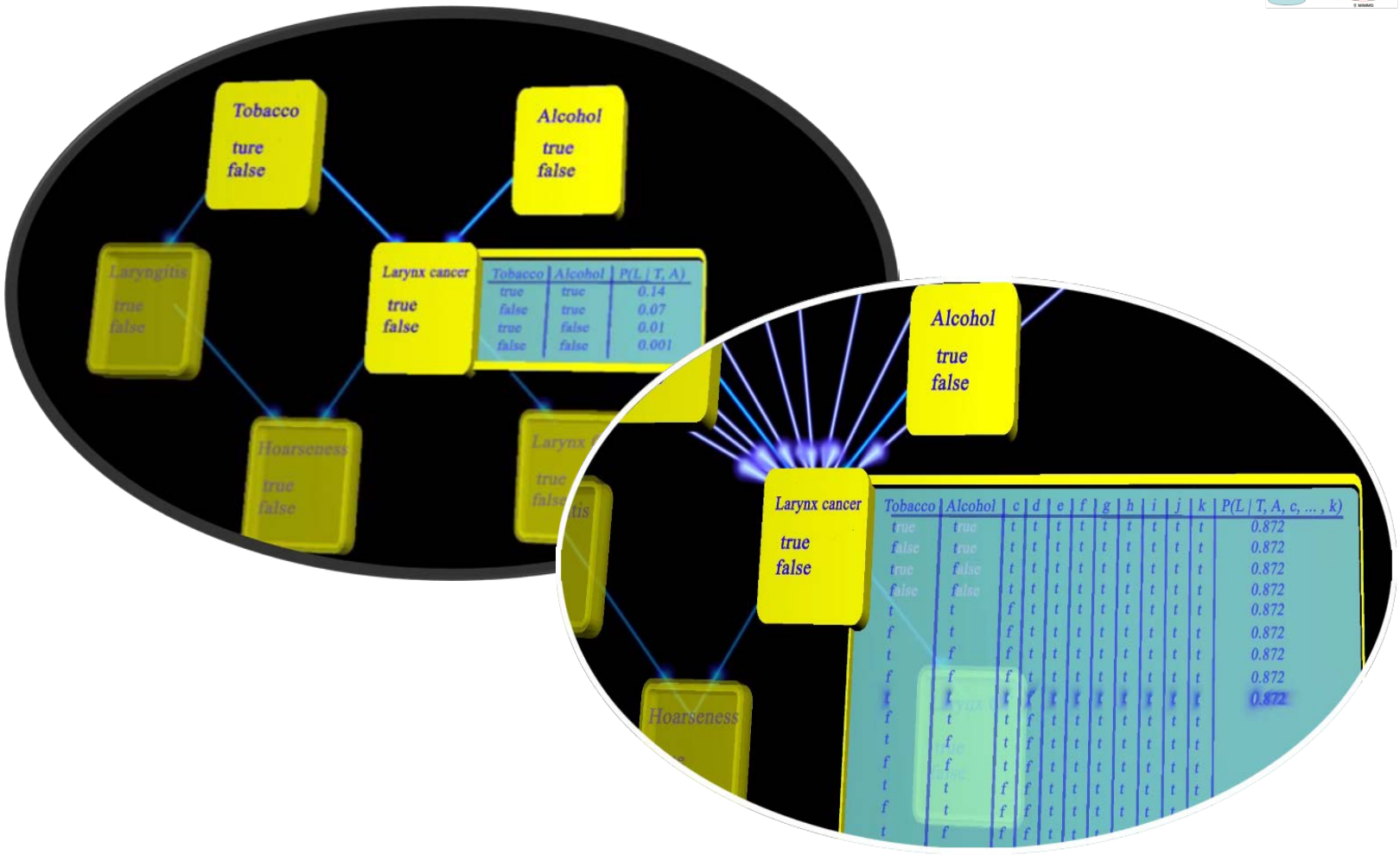
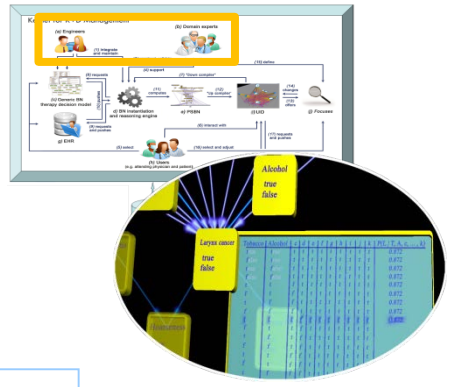
Freie Universität Berlin

Modeling BN Parameters

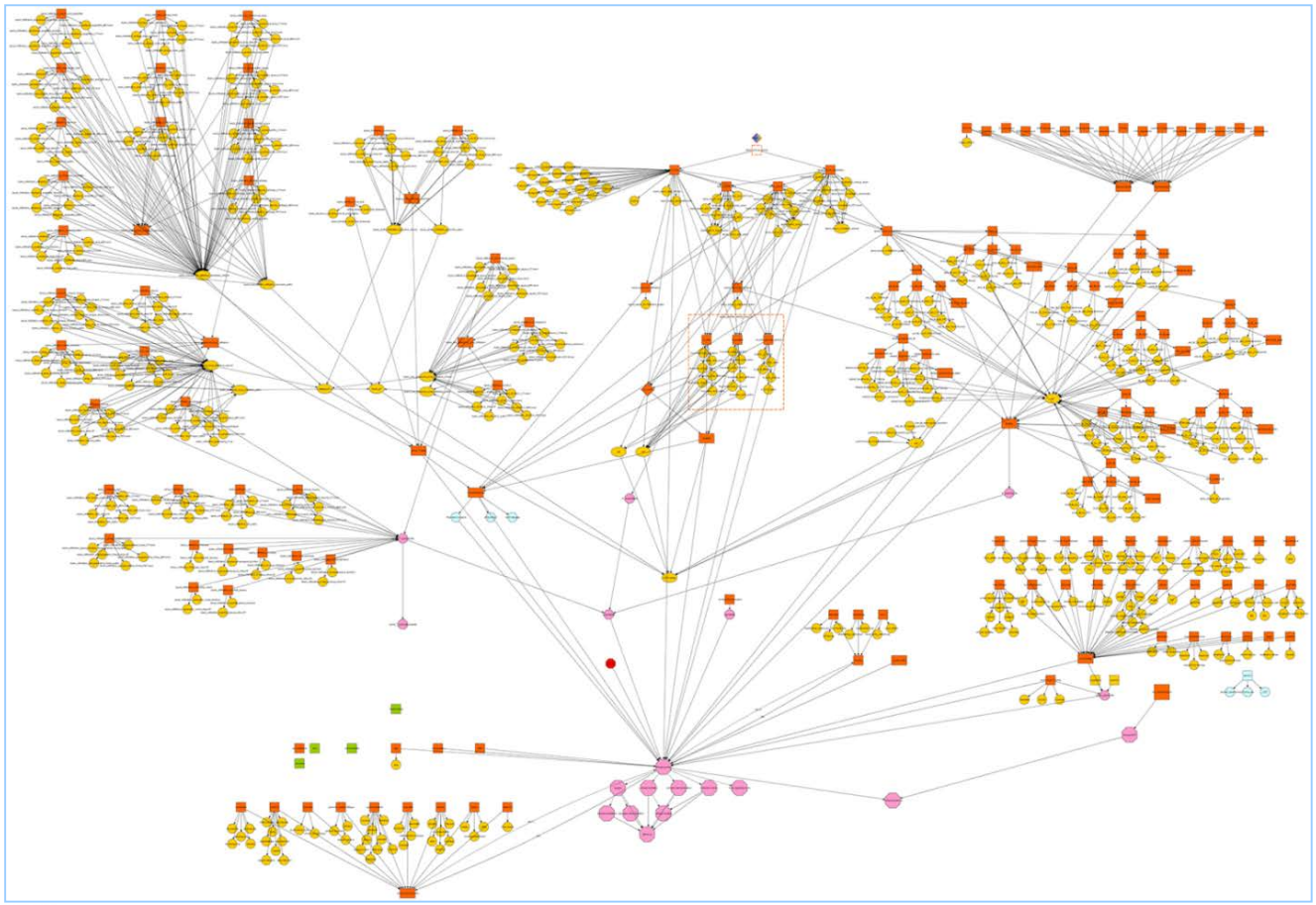




BN Parameters in Large Networks



TNM-Staging Model
Over 78,000 parameters/probabilities



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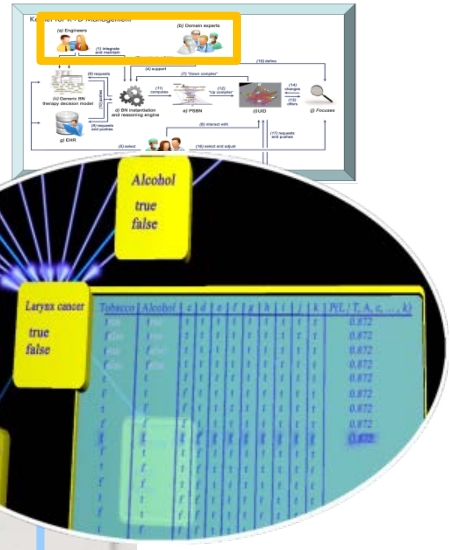
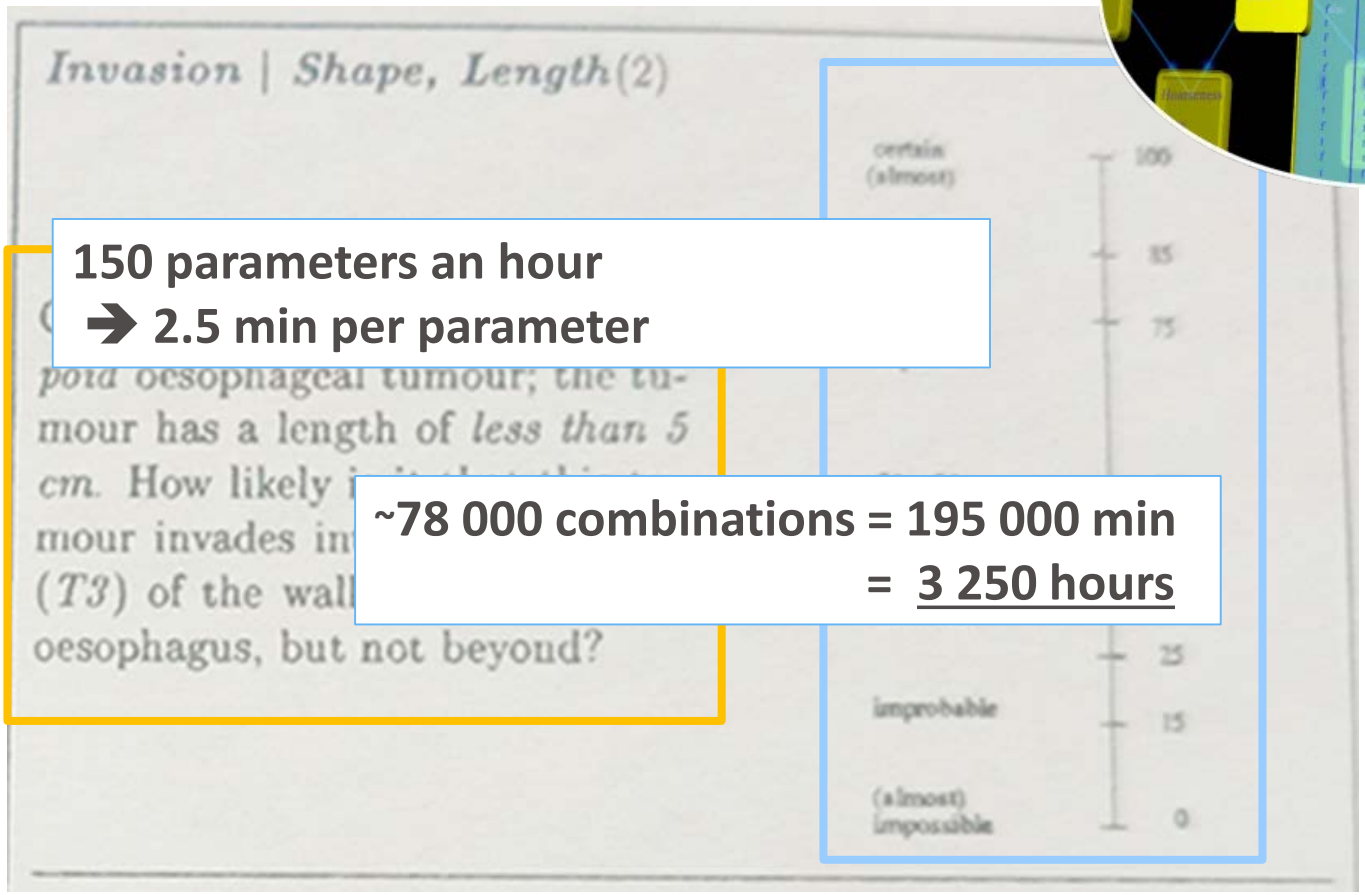
Expert-Friendly Parameter Modeling





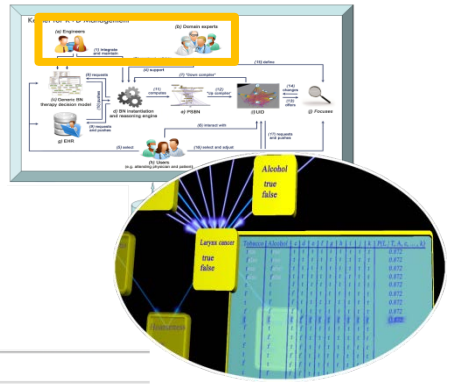
150 parameters an hour
➔ 2.5 min per parameter

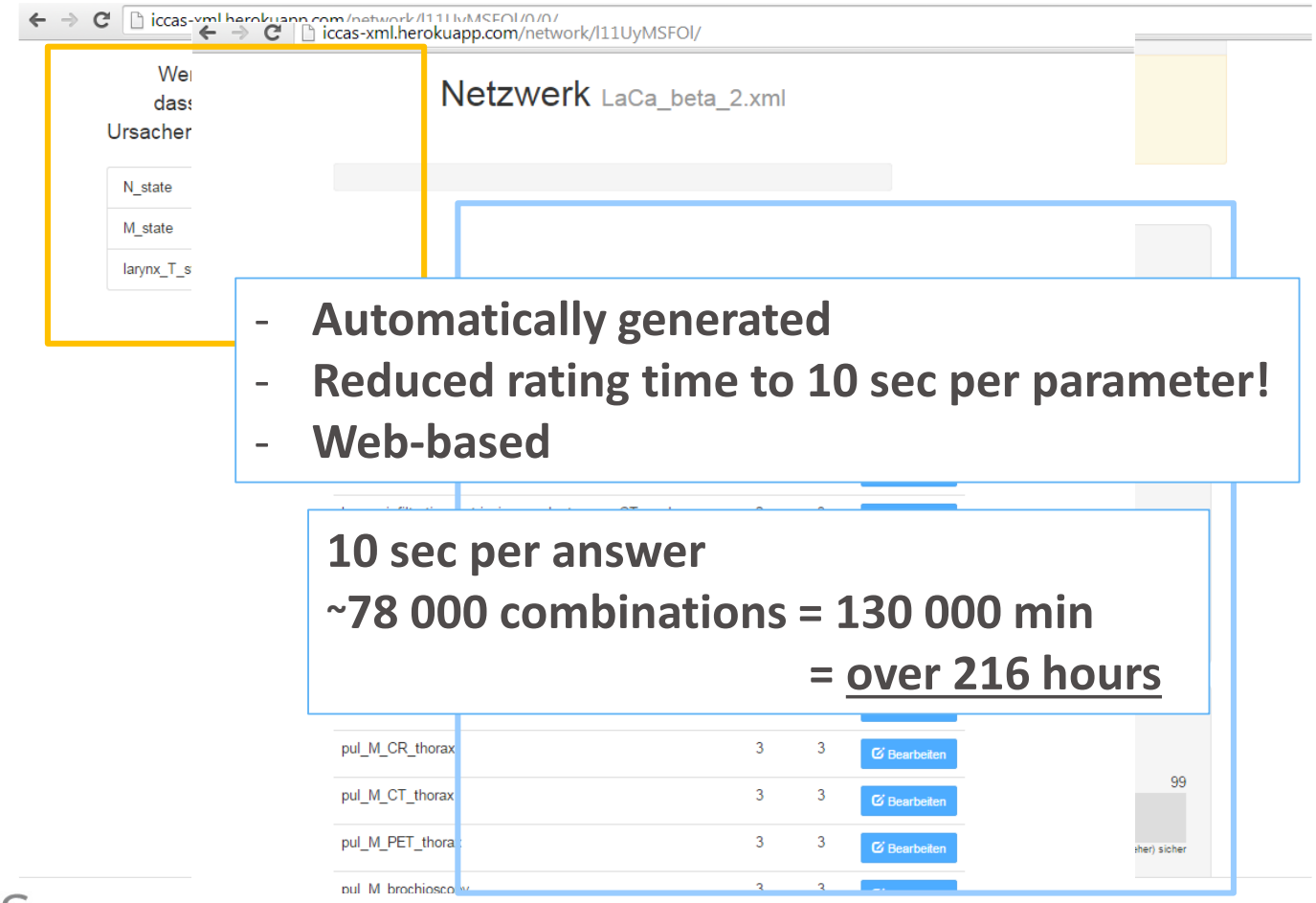
~78 000 combinations = 195 000 min
= 3 250 hours

[van der Gaag2002]

Expert-Friendly Parameter Modeling

[Cypko2015]

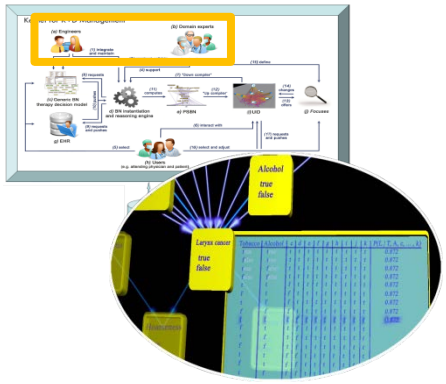




- Automatically generated
- Reduced rating time to 10 sec per parameter!
- Web-based

10 sec per answer
~78 000 combinations = 130 000 min
= over 216 hours

Expert-Friendly Parameter Modeling



40%

larynx_T_resectability

Decisive event combinations

Are there any influential events that would decide over all the events for **larynx_T_resectability**.

Please, select combinations of events starting with the most influential.

larynx_infiltration_Nvagus	larynx_infiltration_Naccessorius
no 1	no
yes 2 3	yes
larynx_infiltration_Nglossopharynxgeus	**larynx_infiltration_skin**
no	yes
yes	
[illegible] 3	**larynx_infiltration_pterygopalatine_fossa**
	no 2
	yes

78 000 combinations = in under 6 hours!

How likely is it, that **larynx_T_resectability** is **true**?

1 — 15 — 25 — 50 — 75 — 85 — 99

28 %

(almost) impossible | improbable | uncertain | fifty-fifty | expected | probable | (almost) certain

How certain are you?

unsure | rather unsure | rather sure | sure

Continue →

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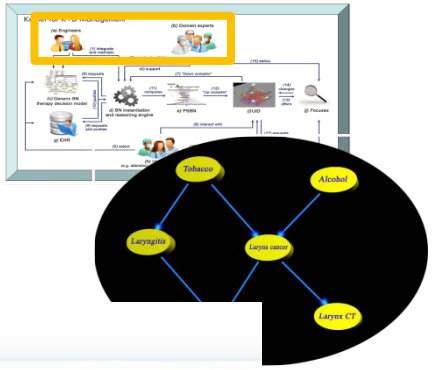
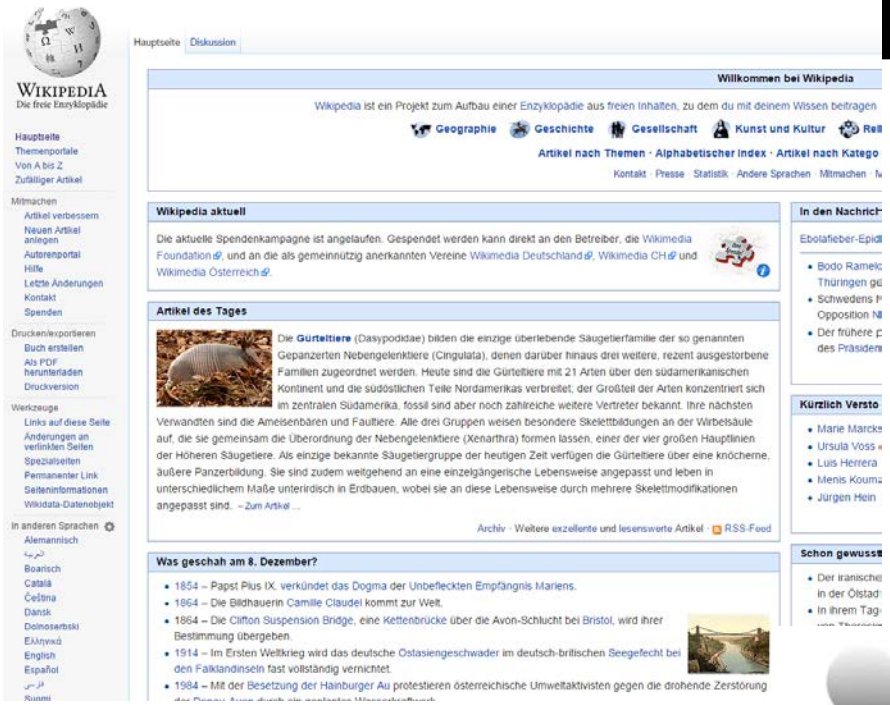
How to build faster and how to decrease modeler bias?



WIKIPEDIA
Die freie Enzyklopädie



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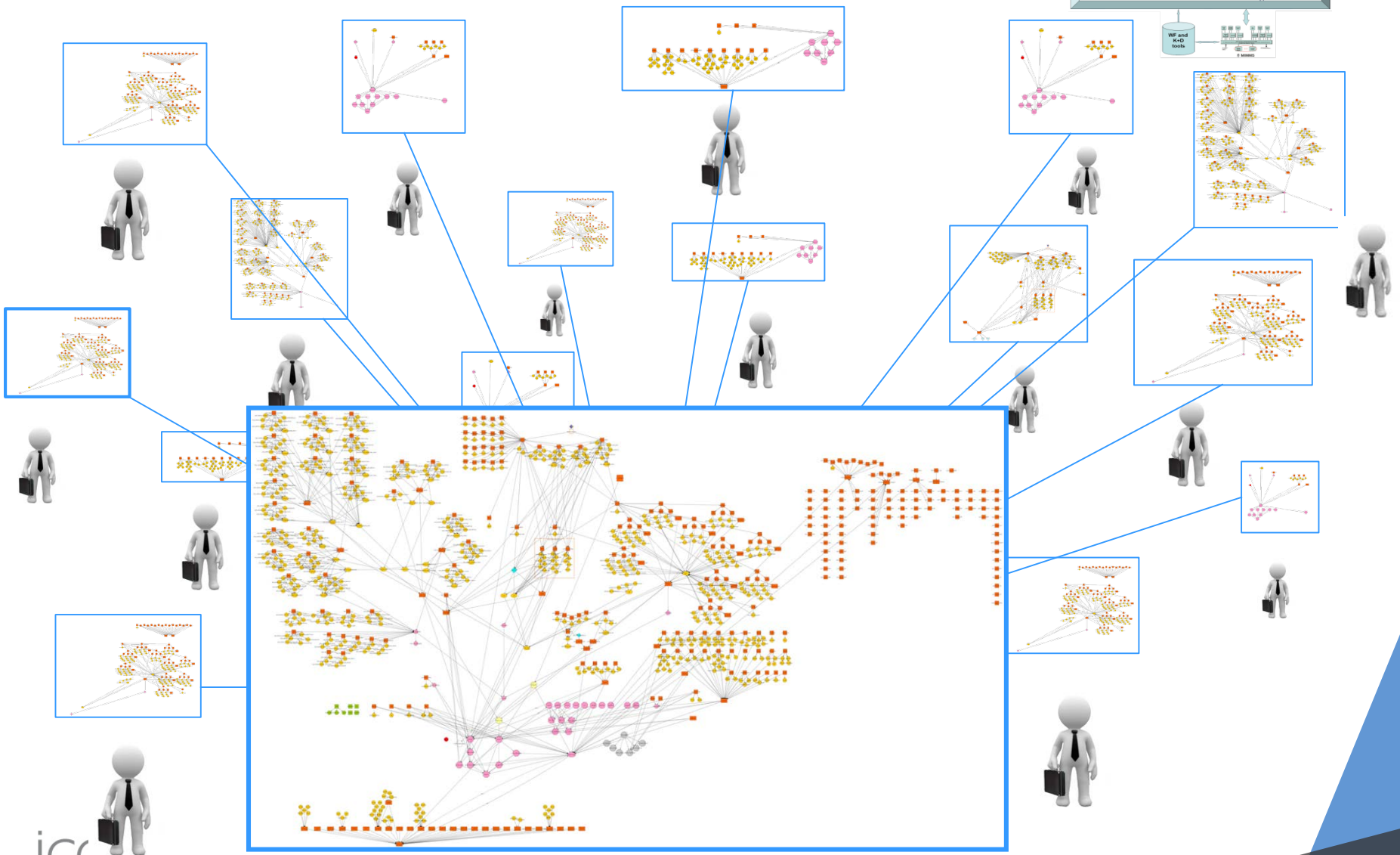
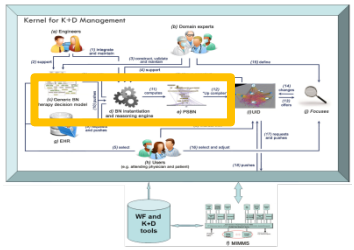
Collaborative Modeling

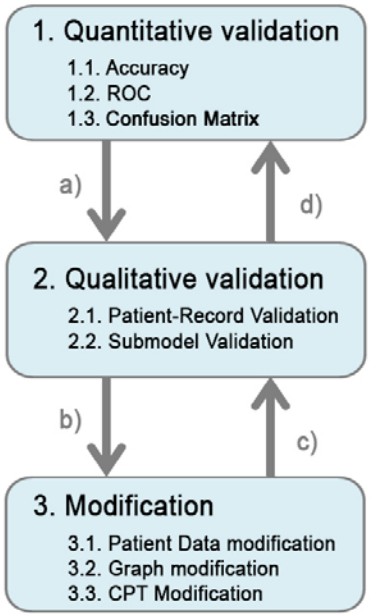


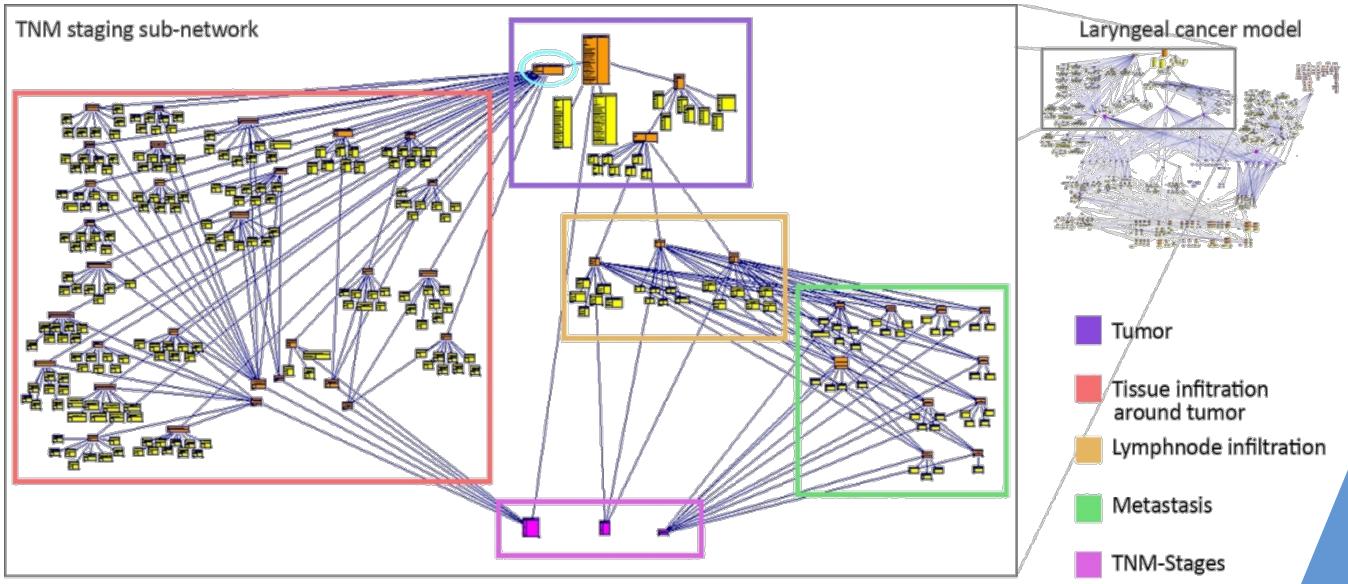
Semi-automatic Model Validation



Example of the TNM staging model

- has sufficient complexity (303 variables and 334 dependencies)
- is relatively well described by clinical guidelines
- has an adequate evidence base
- highly impacts the patient-specific treatment decision





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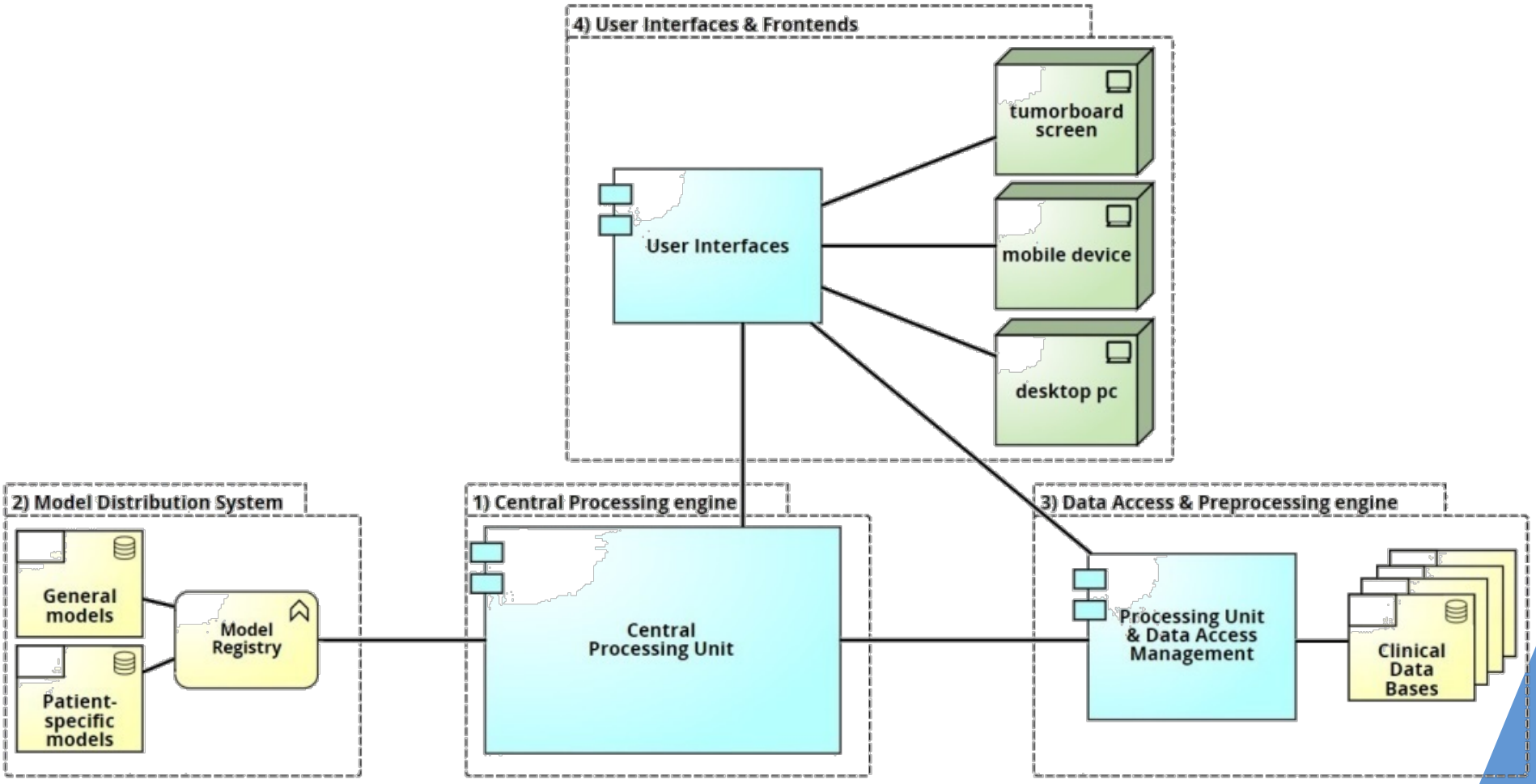
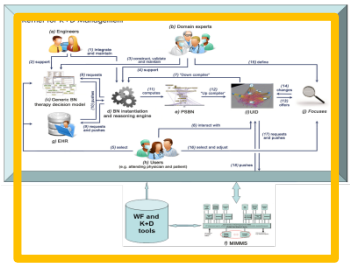
Deployment in the Clinic

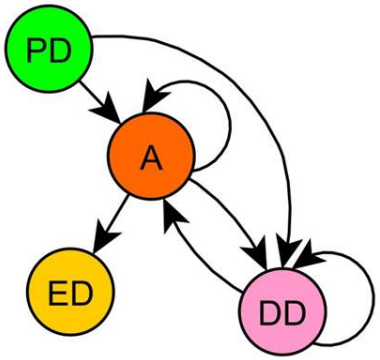
Modular Architecture [Gaebel2018]



Standards



Predefined structure and M&V workflows



Established file formats and cross sharing

HL7® FHIR®

Established medical knowledge

z.B. SNOMED CT
The global language of healthcare

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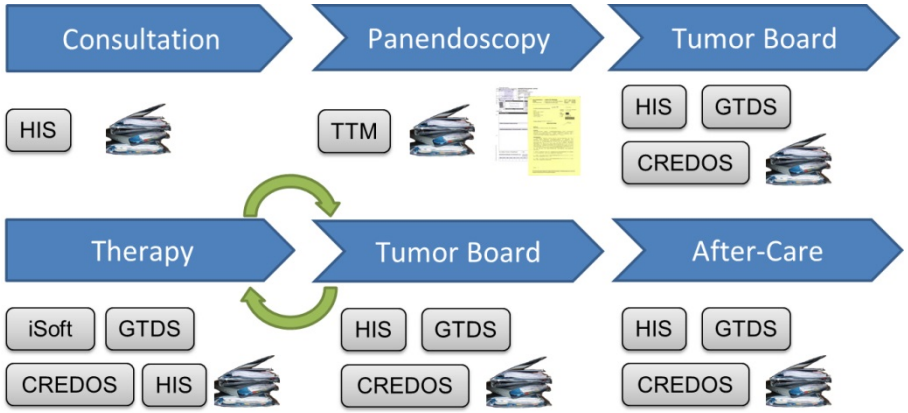
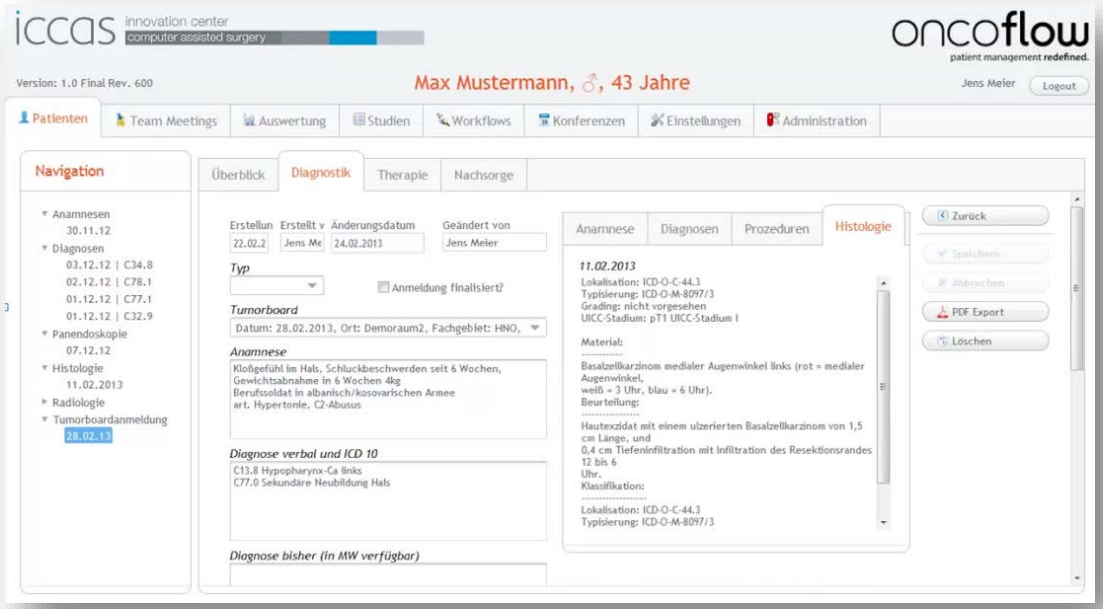
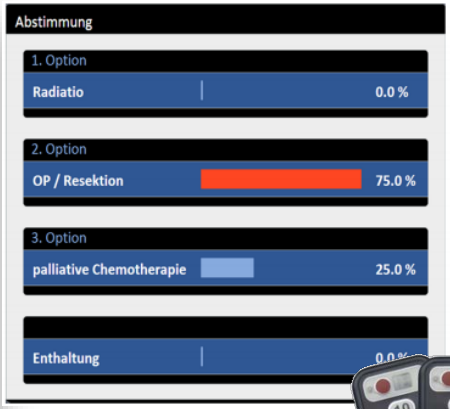
Oncoflow – Interactive Tumorboard [Meier2014]

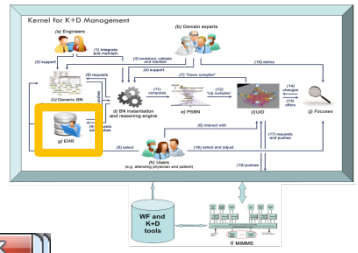






Structured, Model-Based Data Input

[Unger2018]



Patient Data Tool

File Help

Selected region: Neck

Number of existing patients: 1 currently viewing: 1 Date: 20.04.2017

Examination Details

CT

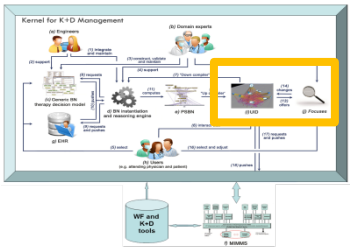
larynx_infiltration_extrinsic_muscle_tongue_function__patient		-
larynx_infiltration_extrinsic_muscle_tongue_CT_neck__patient		-
larynx_infiltration_ACI_ACC_CT_neck__patient	yes	99% - very sure
larynx_infiltration_pre_epiglottic_space_function__patient		-
larynx_infiltration_pre_epiglottic_space_CT_neck__patient		-
larynx_infiltration_prevertebral_space_function__patient	yes	85% - sure
larynx_infiltration_prevertebral_space_CT_neck__patient		-
larynx_infiltration_thyroid_CT_neck__patient		-
larynx_infiltration_thyroid_function__patient	no	15% - unsure
larynx_infiltration_trachea_CT_neck__patient		-
larynx_infiltration_trachea_function__patient		-
larynx_infiltration_pyriform_sinus_CT_neck__patient		-

Patient-ID: 34300 Jump to next examination... OK Cancel

< Previous Print Next >

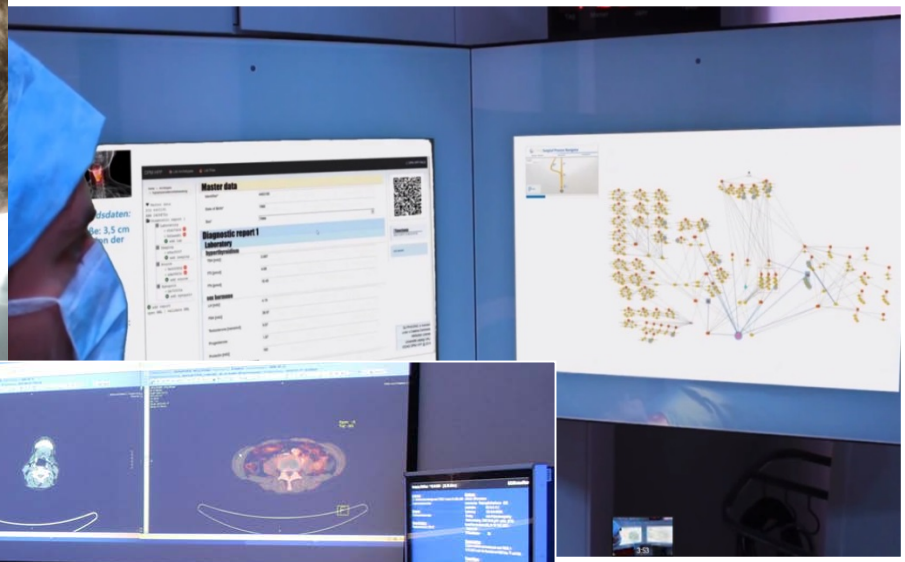
Patient ID: 34300 Name: Date of birth:

User Interface Designs



Tumor board preparation

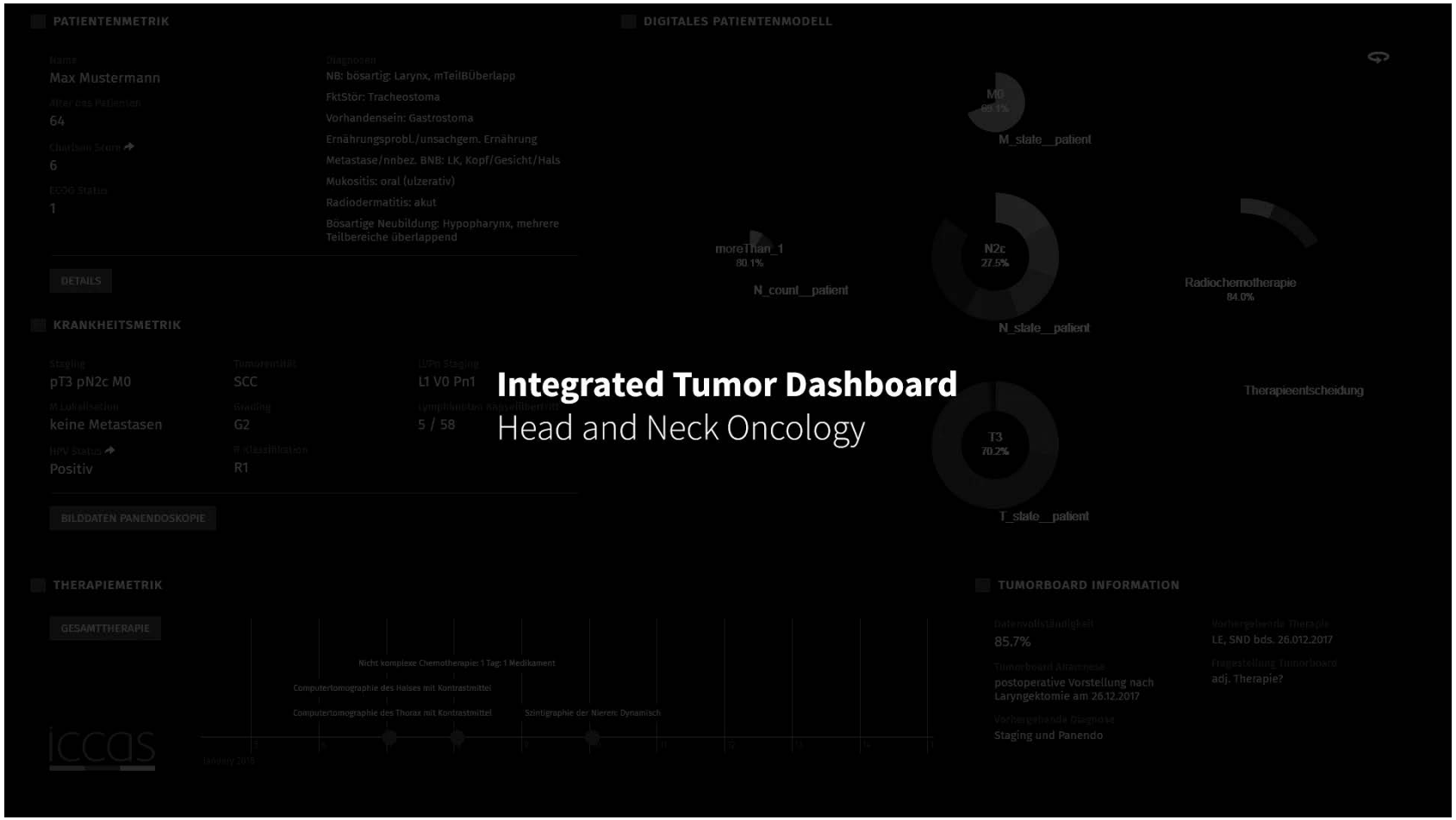
During intervention



In the tumor board

Patient-Specific Tumor Board Dashboard

[Oeser2018]



Conclusion and Outlook

- Knowledge-driven modelling approach
- BN-based treatment model for laryngeal cancer
- Expert-friendly modelling approaches
- Partially validated model
- Deployment in the clinic

Outlook:

- Finalization of the model and validation
- Collaborative modelling and update mechanisms
- Deployment in the ENT department

DPM-Group

Prof. Dr. A. Dietz

Dr. M. Stöhr

Thank you!

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UNTERNEHMEN REGION
Die BMBF-Innovationsinitiative Neue Länder

Questions?

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Literature

- Cypko, M. A., Stoehr, M., Kozniewski, M., Druzdzel, M. J., Dietz, A., Berliner, L., & Lemke, H. U. (2017a). Validation workflow for a clinical Bayesian network model in multidisciplinary decision making in head and neck oncology treatment. International journal of computer assisted radiology and surgery, 12(11), 1959-1970.
- Cypko, M.A., Wojdziak, J., Stoehr, M., Kirchner, B., Preim, B., Dietz, A., Lemke, H. U. & Oeltze-Jafra, S. (2017b). Visual Verification of Cancer Staging for Therapy Decision Support. Computer Graphics Forum, 36(3), 109-120.
- Cypko, M.A., Stoehr, M., Oeltze-Jafra, S., Dietz, A. & Lemke, H. U. (2017c). Guided Expert Modeling of Clinical Bayesian Network Decision Graphs. In Proc. of CURAC, pp. 85-8.
- Cypko, M. A., Hirsch, D., Koch, L., Stoehr, M., Strauss, G., & Denecke, K. (2015). Web-tool to Support Medical Experts in Probabilistic Modelling Using Large Bayesian Networks With an Example of Hinosinusitis. Studies in health technology and informatics, 216, 259-263.
- Druzdzel, M. J. (1999, July). SMILE: Structural Modeling, Inference, and Learning Engine and GeNIe: a development environment for graphical decision-theoretic models. In Aaai/Iaai (pp. 902-903)
- Gaebel, J., Schreiber, E., Oeser, A., & Oeltze-Jafra, S. (2018). Modular Architecture for Integrated Model-Based Decision Support. Studies in health technology and informatics, 248, 108-115.
- IBM Watson for Oncology, https://www.ibm.com/us-en/marketplace/ibm-watson-for-oncology
- Meier, J., Boehm, A., Kielhorn, A., Dietz, A., Bohn, S. & Neumuth, T. (2014). Design and evaluation of a multimedia electronic patient record "oncoflow" with clinical workflow assistance for head and neck tumor therapy. Int J Comput Assist Radiol Surg., 9(6), 949-65.
- Oeser, A., Gaebel, J., Dietz, A., Wiegand, S., & Oeltze-Jafra, S. (2018). Information architecture for a patient-specific dashboard in head and neck tumor boards. Int J Comput Assist Radiol Surg., 13(8), 1283-90.
- Stoehr, M., Cypko, M.A., Denecke, K., Lemke, H.U. & Dietz, A. (2014). A model of the decision-making process: therapy of laryngeal cancer. Int J CARS 9(Suppl 1).
- Unger, C., Stoehr, M., Oeltze-Jafra, S. & Cypko, M.A. (2018). A Knowledge-based Data Entry Form for High Quality Clinical Data Collection. Extended abstract. In Computer Assisted Radiology and Surgery Congress, 2018.
- van der Gaag, L. C., Renooij, S., Witteman, C. L. M., Aleman, B. M., & Taal, B. G. (2002). Probabilities for a probabilistic network: a case study in oesophageal cancer. Artificial Intelligence in medicine, 25(2), 123-148.
- Yet, B., Bastani, K., Raharjo, H., Lifvergren, S., Marsh, W., & Bergman, B. (2013). Decision support system for Warfarin therapy management using Bayesian networks. Decision Support Systems, 55(2), 488-498.