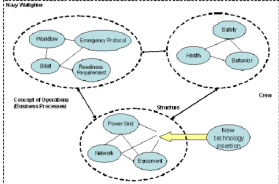




Systems of Systems



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Systems-of-Systems (SoS)

◆ Conway's Conjecture (1968)

◆ *Any system of consequence is constructed from smaller subsystems, which are interconnected.*

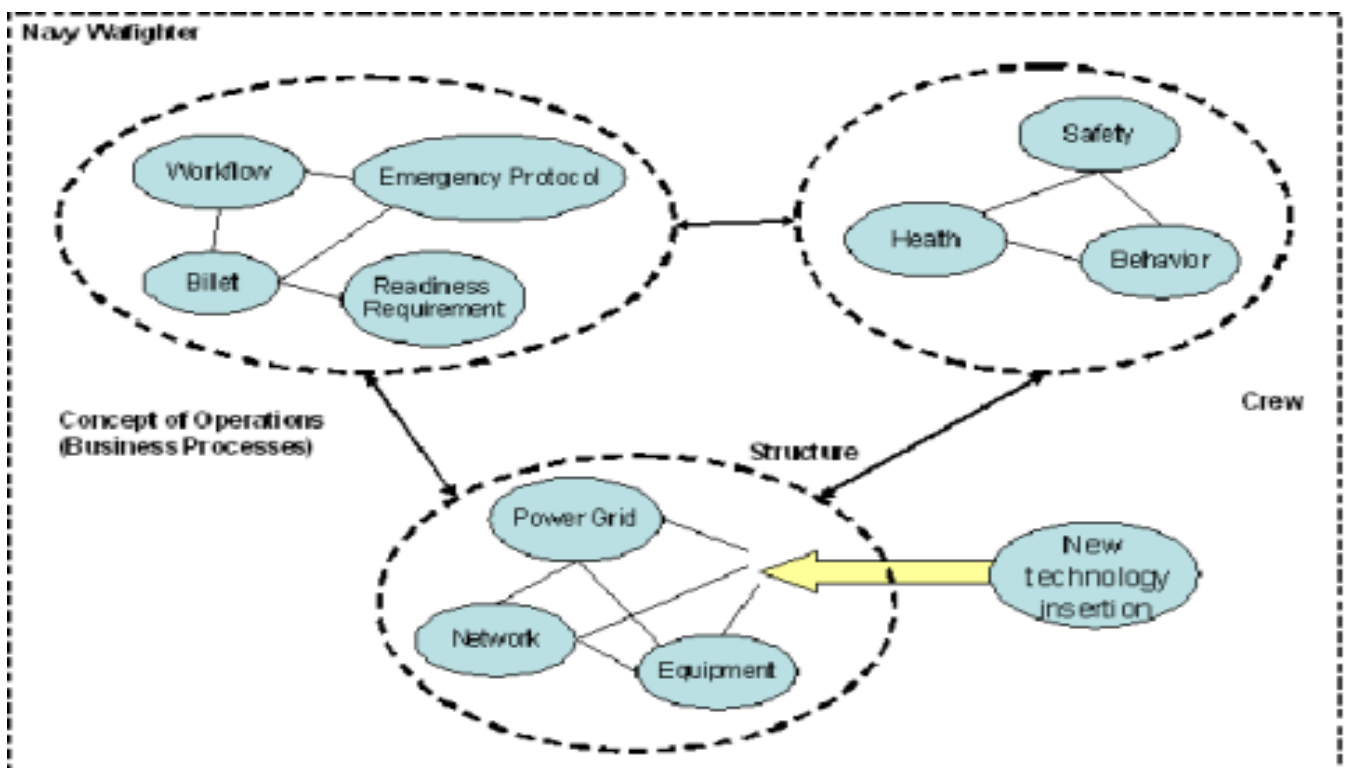
◆ **Early concept about the complexity in systems and**

◆ **Emergent behavior**

◆ **EU-H2020 Dictum:** Systems-of-Systems (SoS) describe the large scale integration of many independent self-contained IT systems to satisfy global needs from citizens, taking into account multi-system requests.



Sample Systems-of-Systems (SoS)

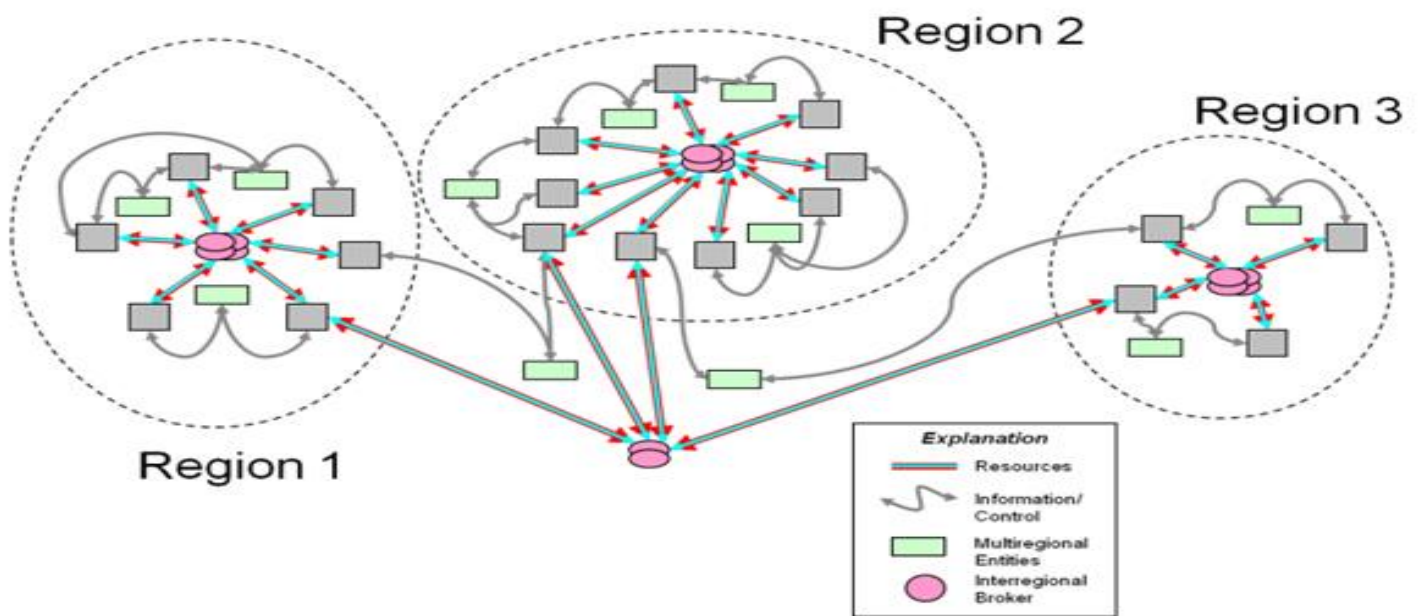


Sample Systems-of-Systems (SoS)



Sample Systems-of-Systems (SoS)

Global System of Systems



Agenda – Systems of Systems (SoS)

◆ **Why SoS?**

- ◆ *Complexity*
- ◆ *Interoperability*
- ◆ *Emergence*

◆ **What are SoS?**

- ◆ *Properties*
- ◆ *Learning Support as SoS*

◆ **How?**

- ◆ *Conceptualization*
- ◆ *Operation*

◆ **Conclusion**

- ◆ *Learnings from Learning Support Systems of Systems*
- ◆ *Further Developments*

Why Systems of Systems (SoS)?

◆ **Decomposition due to**

◆ **Complexity**

- ◆ *understanding of the parts, however,*
- ◆ *they do not predict the whole*

◆ **Heterogeneity (i.e. quest for interoperability)**

- ◆ *A specific problem but*
- ◆ *different ways, self-contained apps or devices to adjust for problem solving*

◆ **Emergence**

- ◆ *but we cannot predict the what, and*
- ◆ *we cannot predict the how*

◆ **Need for scale**

- ◆ *in a logical rather than physical sense, since*
- ◆ *a SoS can be a local entity with co-located sub systems*

Systems of Systems (SoS)

◆ *What are SoS?*

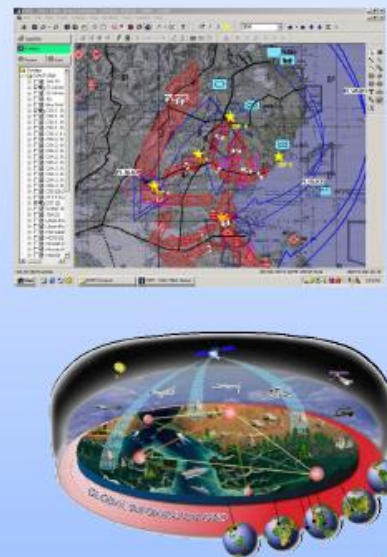
A collaboration among technical systems and organizational (people) systems...



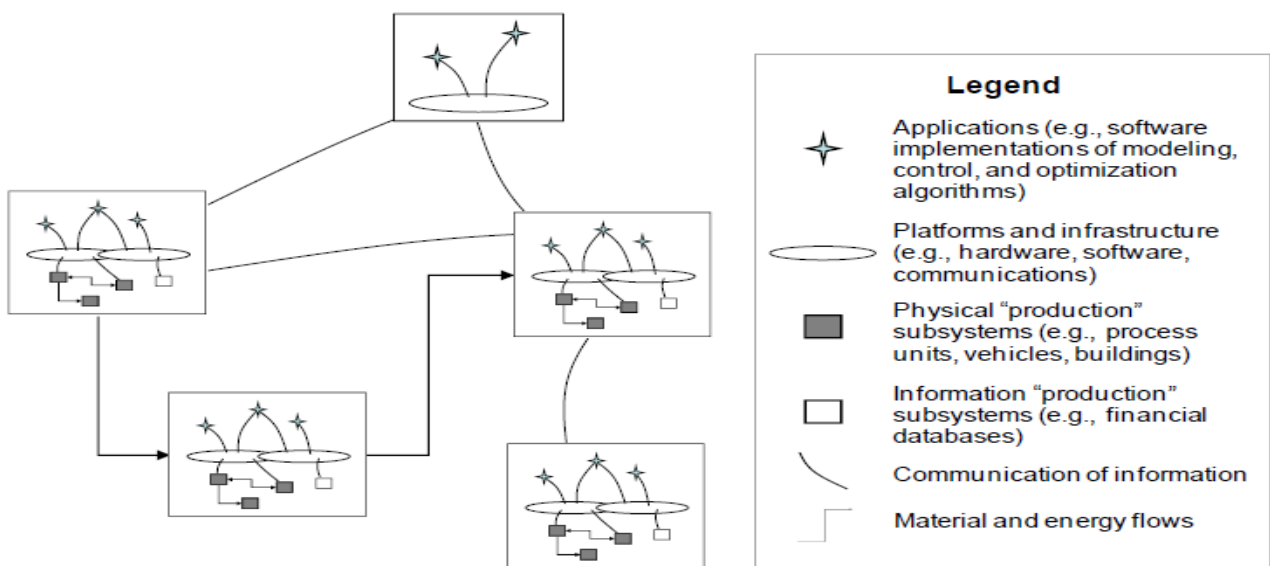
...in relation to some use



...within a changing, unpredictable context



Systems of Systems (SoS)



Samad et al., 2011: schematic representation of a system of systems. Each component system may consist of applications, platforms, and "production" elements, the last of which can be physical systems or information systems—dynamics are very different in the two cases. Component systems may be integrated through information and/or material/energy interconnections. Additional component systems may be employed for coordination and control (the top system), and coordination can also occur among production systems.

Systems of Systems (SoS)

◆ **What are SoS?**

- ◆ *Principles include*
 - *operational and managerial independence of individual systems as well as*
 - *geographic distribution*
 - *evolutionary development, and*
 - *emergent behavior*

- ◆ *Characteristics encompass*
 - *Autonomy*
 - *Belonging*
 - *Connectivity*
 - *Diversity of individual systems*

Systems of Systems (SoS)

◆ **Properties (Boardman&Sauer, 2006)**

- ◆ **Autonomy.** *Individual systems are autonomous with respect to their operation. This includes both the operational as well as the managerial independence of those systems.*
- ◆ **Belonging.** *Based on their needs (e.g., functionality), individual systems independently decide on whether they want to be part of a SoS or not.*
- ◆ **Connectivity.** *Individual systems have the ability to team up with other systems in order to enhance the overall capability of a SoS. Decentralization in terms of distributed system design is therefore possible.*
- ◆ **Diversity.** *Individual systems are heterogeneous by nature. ``Increase diversity in SoS capability achieve by release autonomy, committed belonging, and open connectivity'' [p.4]*
- ◆ **Emergence.** *The interaction of individual systems and their evolutionary developments enable the formation of novel properties. These properties cannot be ascribed to a single system.*

Learning Support as Systems of Systems (SoS)

Knowledge society requires

- ◆ *doing knowledge* as ‚life style‘ beyond work, in spiral movements
- ◆ flexible feedback procedures – adaptive & context-sensitive
- ◆ self-regulation
- ◆ continuous quality management (Rahmstorf, 1999)

Education and learning transforms to Knowledge ‚Osmosis‘ (Nolda, 1996)

- ➔ Dynamic development of knowledge needs to be reflected by learning support
- ➔ Transfer of knowledge is replaced by permanent exchange of individual expertise and organized knowledge management (Alheit et al., 2002)



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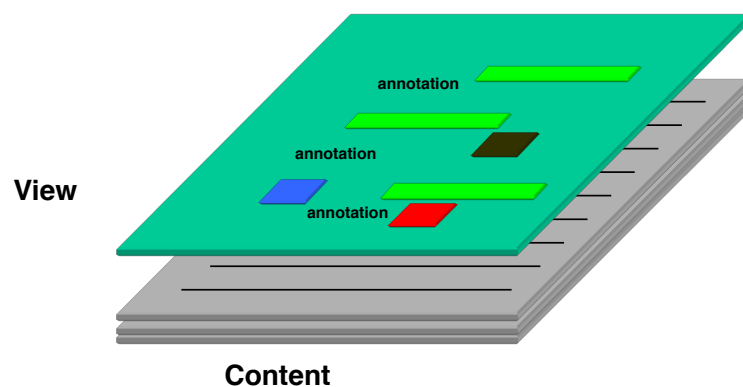
Systems of Systems (SoS)

◆ **Learning Support Systems**

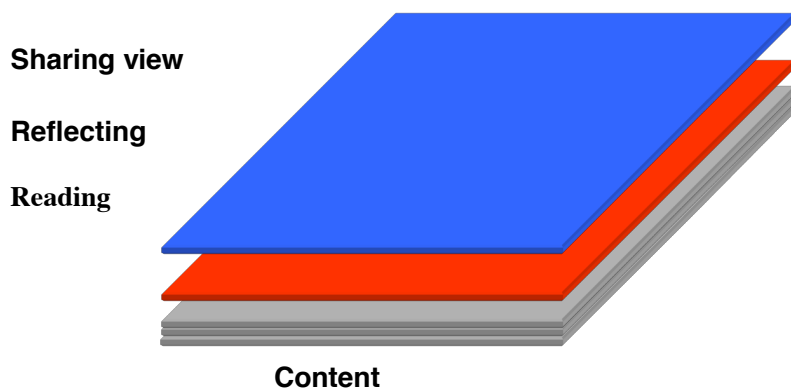
- ◆ *Content Management*
 - *Provision of Learning Material, more or less tagged according to its didactic relevance*
- ◆ *Social Media*
 - *Social interaction is part of learning, either when organizing learning tasks or when requiring orientation or peer perspective*
- ◆ *Intertwining Content & Social Interaction (cf. Lave & Wenger, 1991)*
 - *From Content to Social Interaction*
 - *From Social Interaction to Content*
 - *Situated Cognition*
 - *Annotation generation / creation of perspective*
 - *Sharing of annotated material /exchange of perspectives*

Individualization and Collaboration

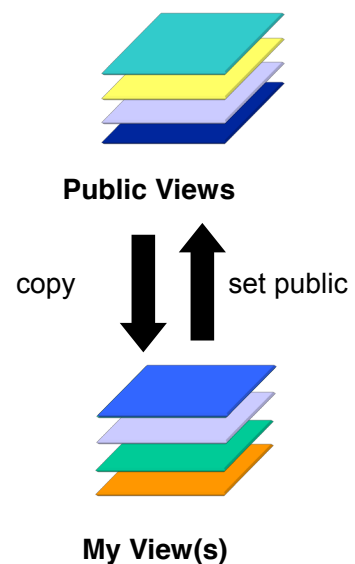
Developing a perspective on content corresponds to generating shared content



Individualization und Collaboration = Taking and Giving Perspectives



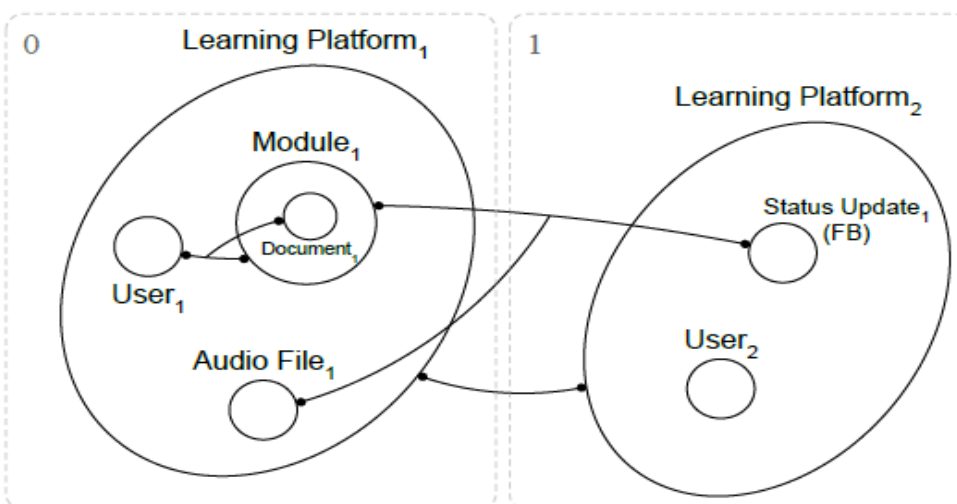
Integrating cognitive and social processes



Learning Support Systems as Systems of Systems

◆ **Bigraphs for Formal Specification**

- ◆ *SoS as meta-systems that are themselves comprised of multiple autonomous (embedded) (complex) systems that can be diverse in technology, context, operation, geography, and conceptual frame (cf. Keating et al., 2003)*

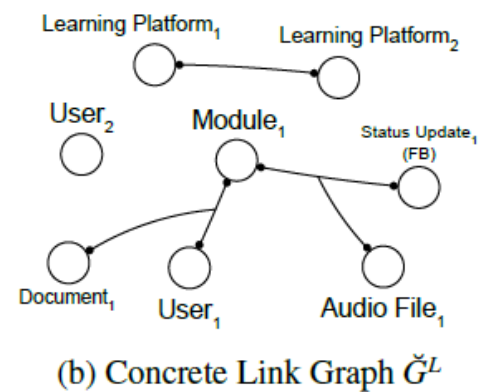
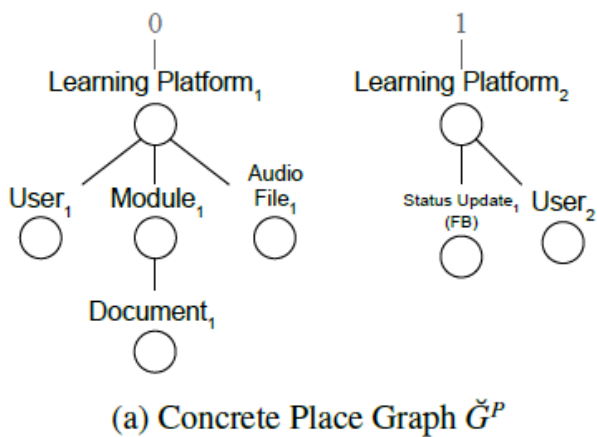


A concrete Bigraph

(Wachholder&Stary, 2015,
Stary&Wachholder, in press)

Learning Support Systems as Systems of Systems

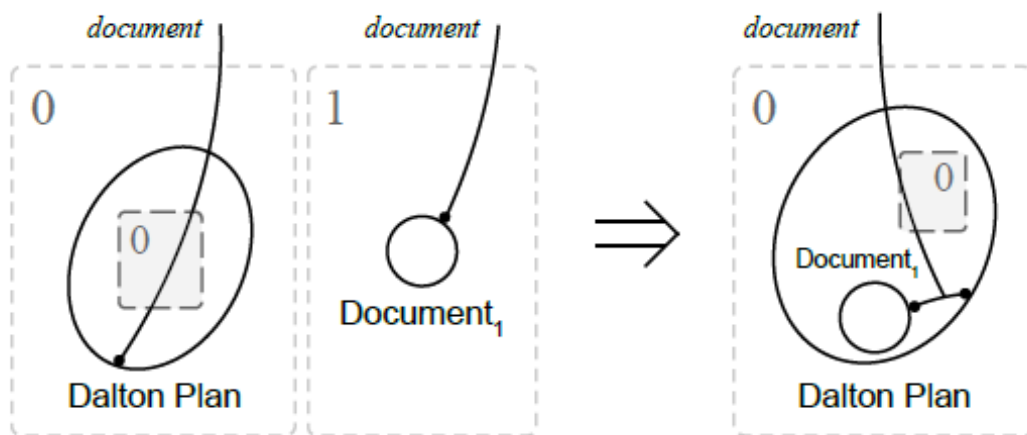
◆ Bigraph Specification – Dual Structuring



(Wachholder&Stary, 2015,
Stary&Wachholder, in press)

Learning Support Systems as Systems of Systems

◆ Bigraph Specification – Rule-based Dynamics



Reaction Rule

(Wachholder&Stary, 2015,
Stary&Wachholder, in press)

PKM Vorlesung
This is a short project description.

Project News Feed

Recent activities in the context of the project (also includes activities from other platforms, such as Facebook)

Use posting (inkl comments) as baseline for further project work (e.g., include it in documents as content element)



Dominik Wachholder
Posted on Sep 23, 2015

Document icon | Comment icon | Like icon

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum.



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Sep 23, 2015

Activities

Dominik Wachholder
published a post on Facebook
23.09.2015 18:07

Dominik Wachholder
joined the project
23.09.2015 18:07

Dominik Wachholder
edited a document
23.09.2015 18:07

Dominik Wachholder
created a document
23.09.2015 18:07

Dominik Wachholder
likes a post on Facebook
23.09.2015 18:07

Dominik Wachholder
annotated a document
23.09.2015 18:07

Conclusion

- ◆ Diversity and complexity increase in system development
- ◆ Systems of Systems (SoS) understanding enables abstraction from structure & behavior
- ➔ Variability of elements and relationships in Learning Support System design
 - ◆ Content
 - ◆ Interaction
 - ◆ Intertwining
- ➔ Dynamics & emergence
 - Perspectives
 - Sharing

Conclusion – Learning Support Systems-of-Systems

