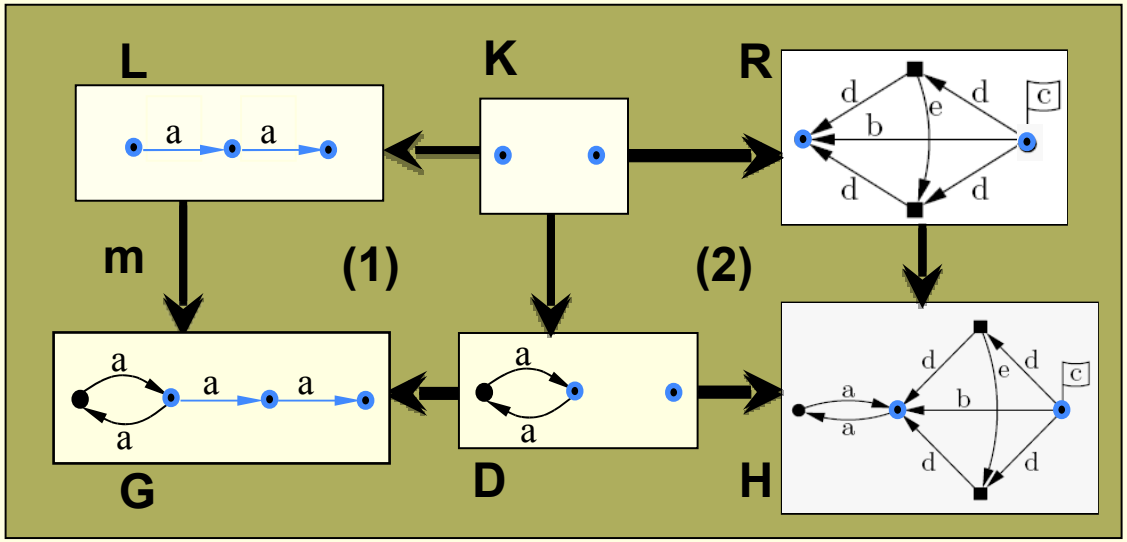
From Graph Transformation to Algebraic Specification and Back Again

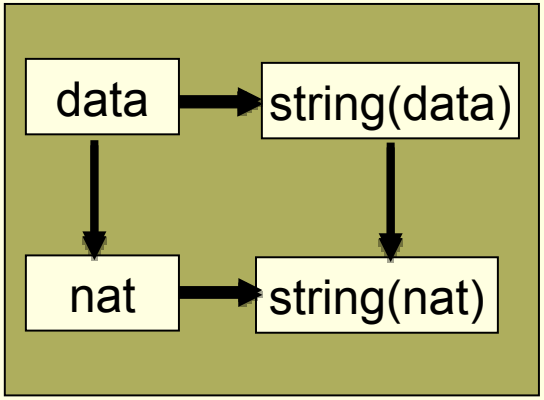
Dedicated to 60th Birthday of HJK

Bremen, Haus der Wissenschaften,
September 2009

Hartmut Ehrig, TU Berlin

What Came First ?

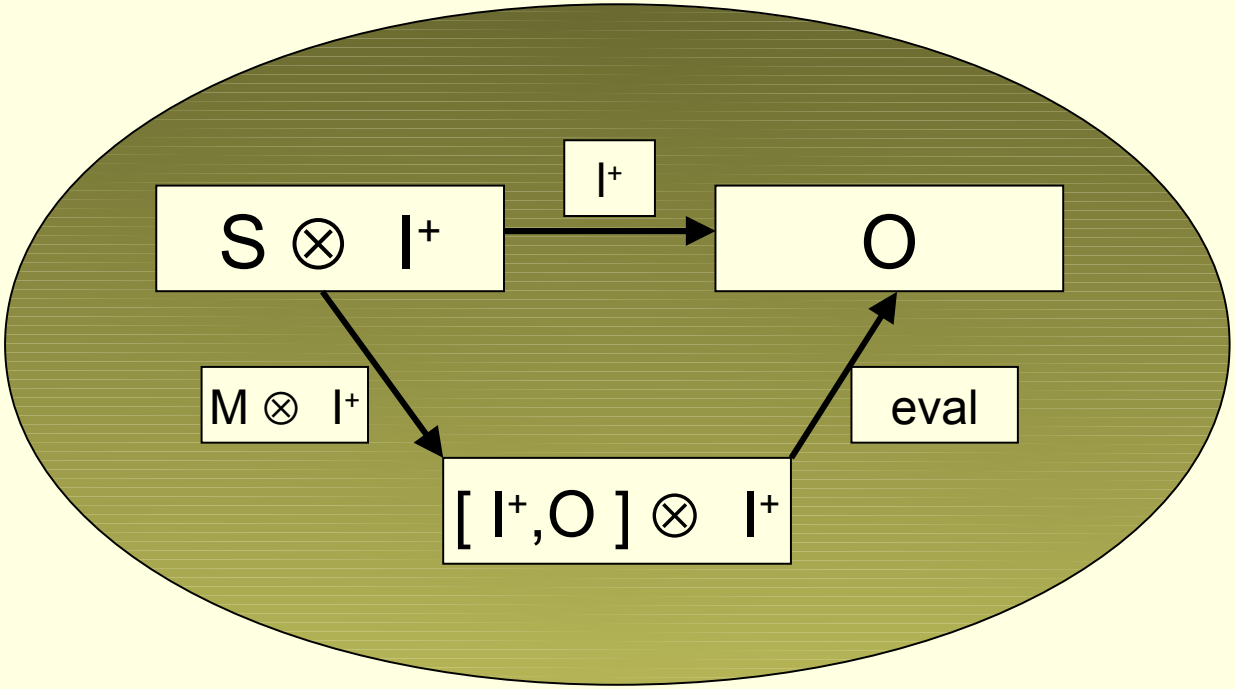




Double Pushout or Parameter Passing

GRA-GRA or ALG-SPEC ?

Neither GRA-GRA Nor ALG-SPEC



CAT–AUT Came First !

We are in 1970

- 2 years after student movement against establishment at universities

ORDINARIEN-UNIVERSITÄT

We are in 1970 at Math Dept

- **Seminar „Kategorien und Automaten“**
- **20 Students – 2 Assis – No Profs**
  - Main Questions
    - **What is a Category ?**
    - **What is an Automaton ?**
    - **What is the Category of Automata ?**

Students

HJK

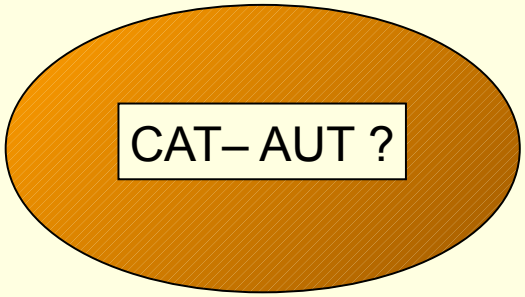
Teach

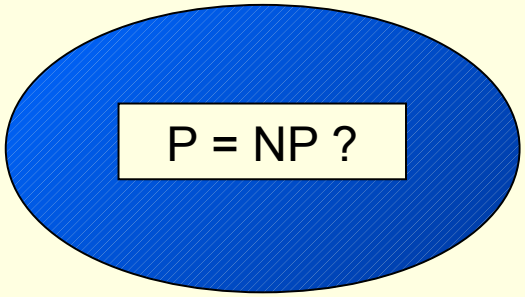
Assis

HE

Scientific Opinion in 1970

- Optimistic View
  - Category Theory is „Heart of Mathematics“
  - Automata Theory is „Soul of Computer Science“
- Pessimistic View
  - Category Theory is „Abstract Nonsense“
  - Automata Theory is „Dead“ (Hartmanis)





What is the Outcome in the 70ies ?

- **Students** receive **Seminar Certificates**
- **Students** and **Assis** become **Book Authors**
  - Kategorien und Automaten,de Gruyter 1971
  - Universal Theory of Automata,Teubner 1974
- Student **HJK** receives **Dipl. Math. Degree**
  - Theorie von Automaten in pseudoabgeschlossenen Kategorien

We are in 1978 at CS Dept of TUB

HJK submits his PhD thesis

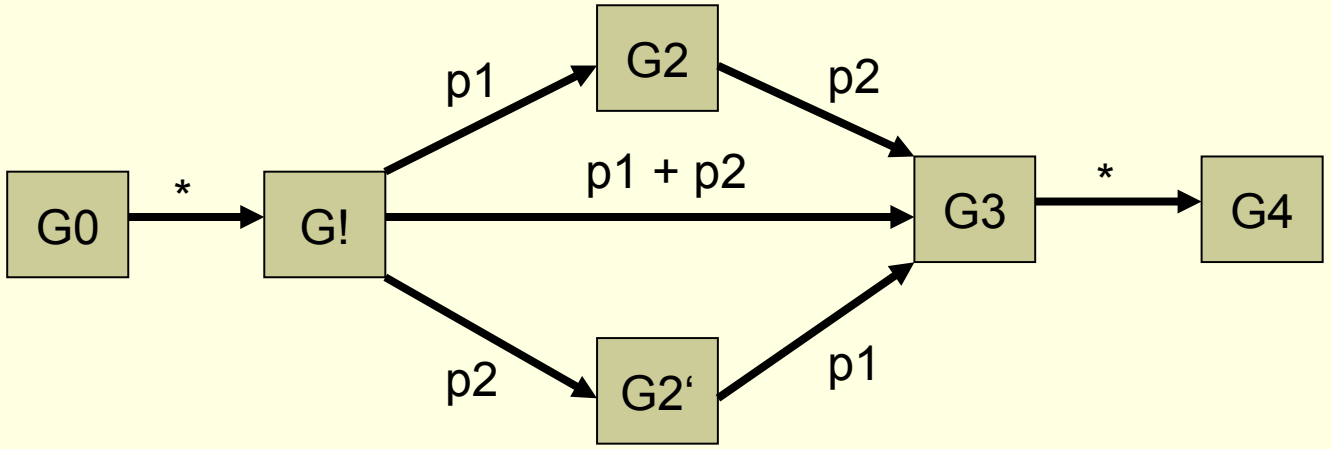
„Manipulationen von Graphmanipulationen“

- Very strange title !
- What does it mean ?
- Is it Mathematics or Computer Science ?

- Keywords :
  - Local Church-Rosser for Graph Transformation
  - Shift Equivalence of Parallel Deriv.Sequences
  - Canonical Derivation Sequences

What does it mean ?

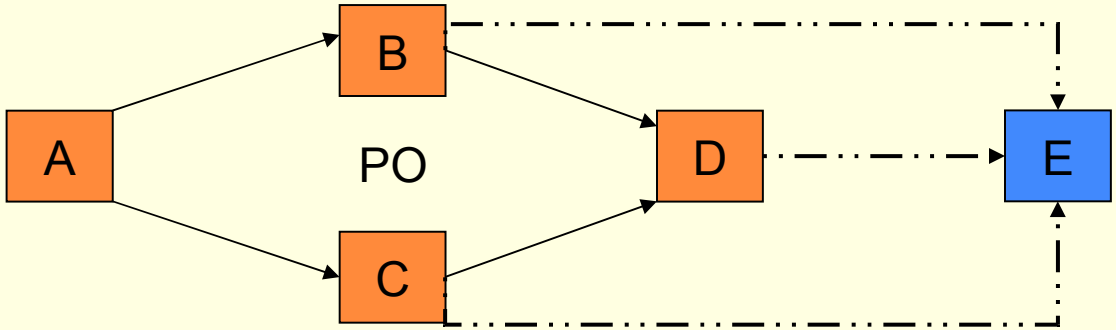
- Local Church-Rosser & Parallelism
  - Parallel and Sequential Independence
  - Switch & Shift Equivalence
- Existence & Uniqueness of Canonical Parallel Derivation Sequences



We are still in 1978

- *Problem*: Can HJK- PhD-thesis be accepted ?
  - Paper on Local CR was rejected by ICALP
  - Referee comment :

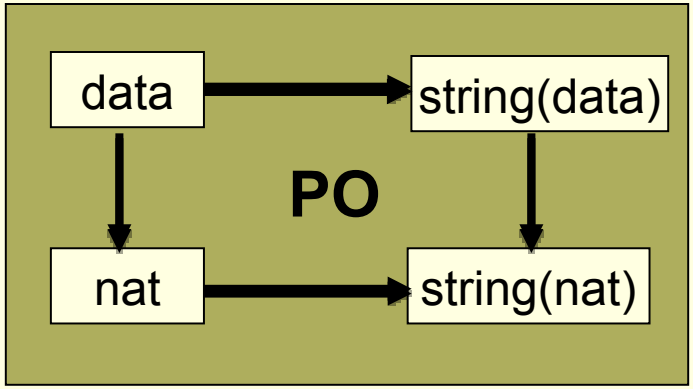
    Result obvious, proof only complicated by use of „strange notion of pushouts“
- *Solution*: Search for new referees
- *Result*: Acceptance of paper for MFCS & TCS
  & Acceptance of HJK-PhD-thesis at TUB



We are in 1982

- ACT-project of HE & HJK accepted by DFG

  Param.Spec in Initial Algebra Approach (ADJ et al.)
- Parameter Passing inspired by GRA-GRA (HDEhr)



- Alternatives
  - Final Algebra Approach (Guttag et al.)
  - Loose Semantics with Constraints (Reichel et al.)

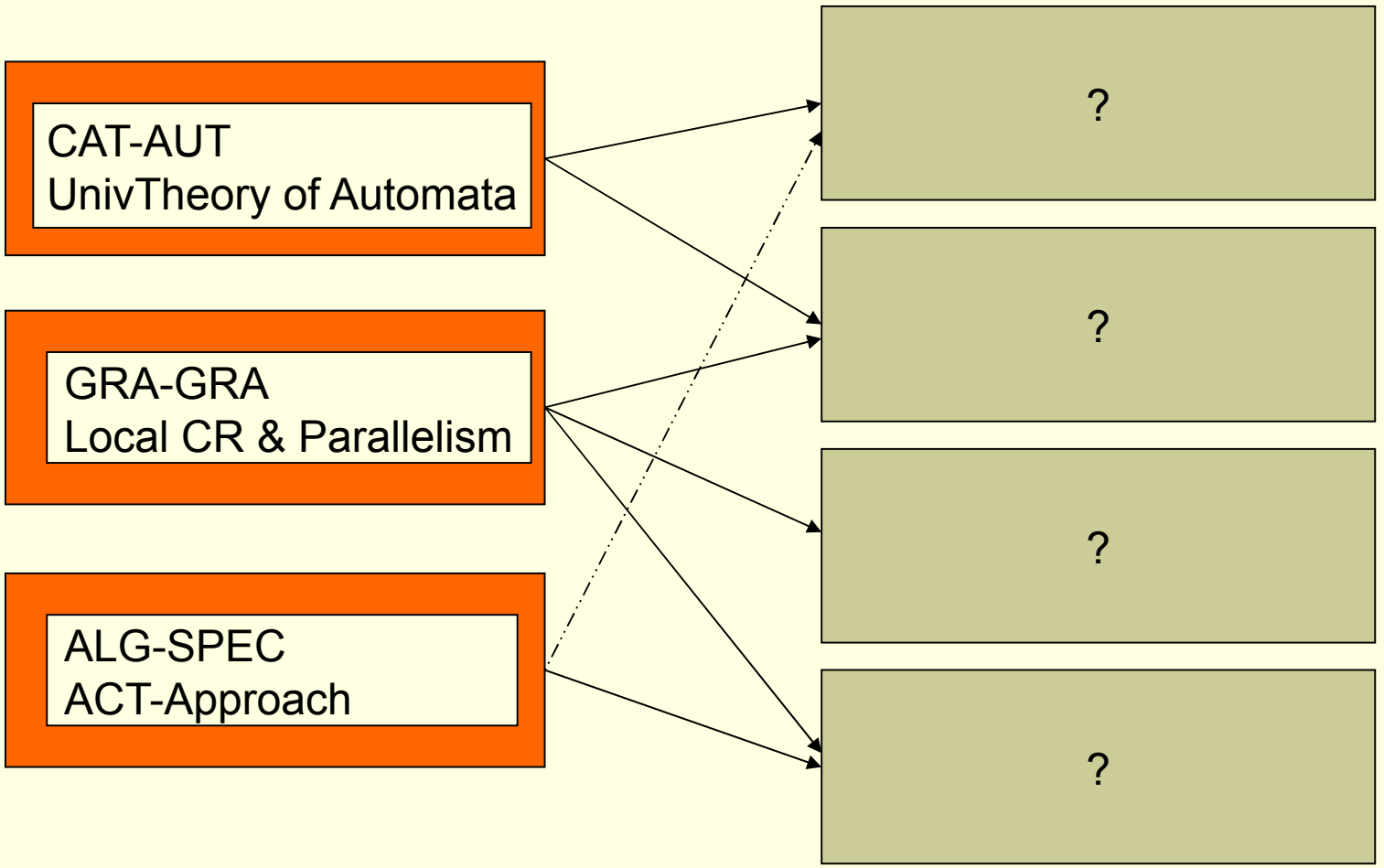
Algebraic Spec Languages in 1984

- **CLEAR** [BG 77 , San 81]
- **OBJ / OBJ 2** [GT 79 , FGJM 85]
- **CIP / CIP L** [CIP 81 , CIP 85]
- **ACT ONE / ACT TWO** [ACT 83, EM 85,EW 86]
- **ASL** [SW 83 , Wir 86]
- **LARCH** [GH 83]
- **PLUSS** [Gau 84]

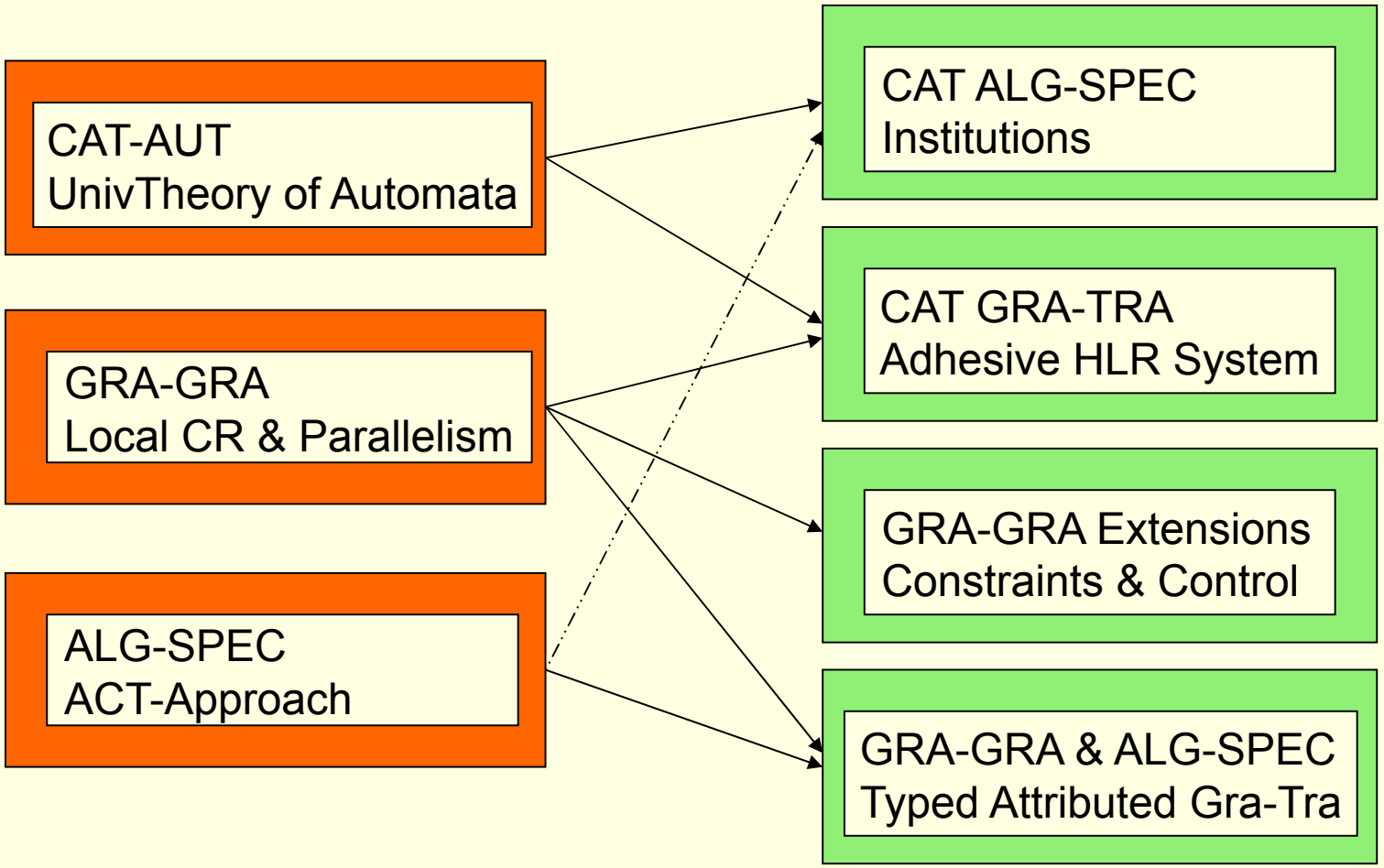
Algebraic Specification Community

- Since 1974 in USA [Zi 74 ,Gut 75 , ADJ 76]
- Since 1976 in Europe [GGM 76] MFCS'76
- Since 1978 in Germany [EKW 78] VLDB´78
  - [EL 79] GRA-GRA'78, [Rei80] MFCS'80, [BW80] CAAP'80
- *Problem*: ACT ONE rejected by ACTA INFORMATICA
  Referee : ACT ONE causes
  „headache because of 2 levels of semantics"
- *Solution*: ACT ONE published in EATCS Monographs [EM 85]
- HJK receives Professorship at Uni Bremen

10 – 25 Years Later ?



10 – 25 Years Later !



CAT ALG-SPEC

- Aim : Institution Independence of Approach
  - Institutions [BG 84]
  - Specification Frames [EM 90]
- Mod : $\underline{SPEC}^{op} \rightarrow \underline{CatCat}$ Model Functor
  - Mod(SPEC) = Category of Algebras/Models
  - Mod(f) = V_f = Forgetful Functor
  - Liberal Institution : Existence of Free Functor F_f
  - Amalgamation & Extension Lemma based on POs
- Main New ALG-SPEC Languages
  - MAUDE , SPECTRUM , CASL

CAT GRA-TRA

- High-Level Replacement Systems [EHKP91]
  - DPO-Approach based on HLR-Conditions
    - Graphs, Hypergraphs, Typed Attributed Graphs
    - Low & High-Level Petri Nets
  - Local CR, Parallelism, Concurency & Confluence
- Adhesive Categories [LS04]
  - Compatibility of POs & PBs in VK-cube
- Adhesive HLR Systems [EHPP04]
  - Categorical Theory of GRA-TRA

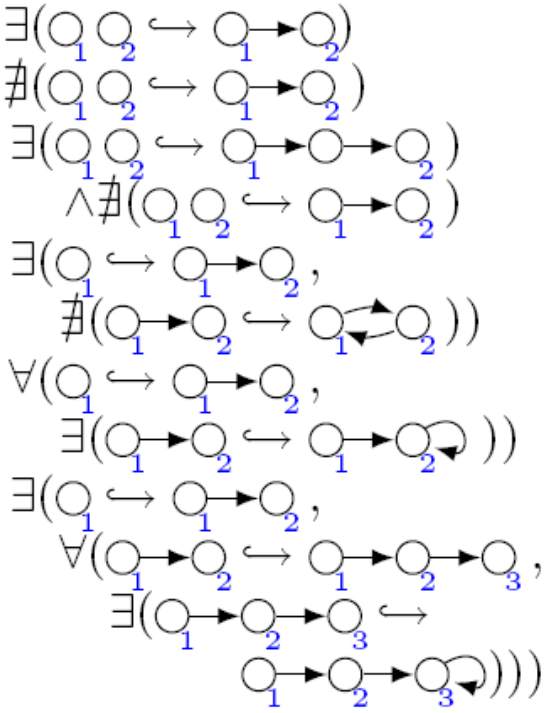
GRA-GRA EXTENSIONS

- Application Conditions [EH86]
  - Graph Constraints & Application Cond [LKW 95]
- Control by Transformation Units [KK96]
  - GRA-TRA with Clone & Graph Variables [Hof06]
  - GRA-TRA with NACs [HW95, Lam08/09]
  - GRA-TRA with Nested Application Cond [HP05]
    - FOL with Graph Variables
- Parallelism & Concurrency for Rules with Nested Application Conditions

  [EHL09, HJK-Festschrift]

Nested Application Conditions

List of Examples:



There is an edge from the image of 1 to the im. of 2.

There is no edge from the image of 1 to the im. of 2.

There is a directed path of length 2, but not of length 1, from the image of 1 to the image of 2.

There is a proper edge outgoing from the image of 1 without edge in converse direction.

For every proper edge outgoing from the image of 1, the target has a loop.

For the image of node 1, there exists an outgoing edge such that, for all edges outgoing from the target, the target has a loop.

GRA-GRA & ALG-SPEC

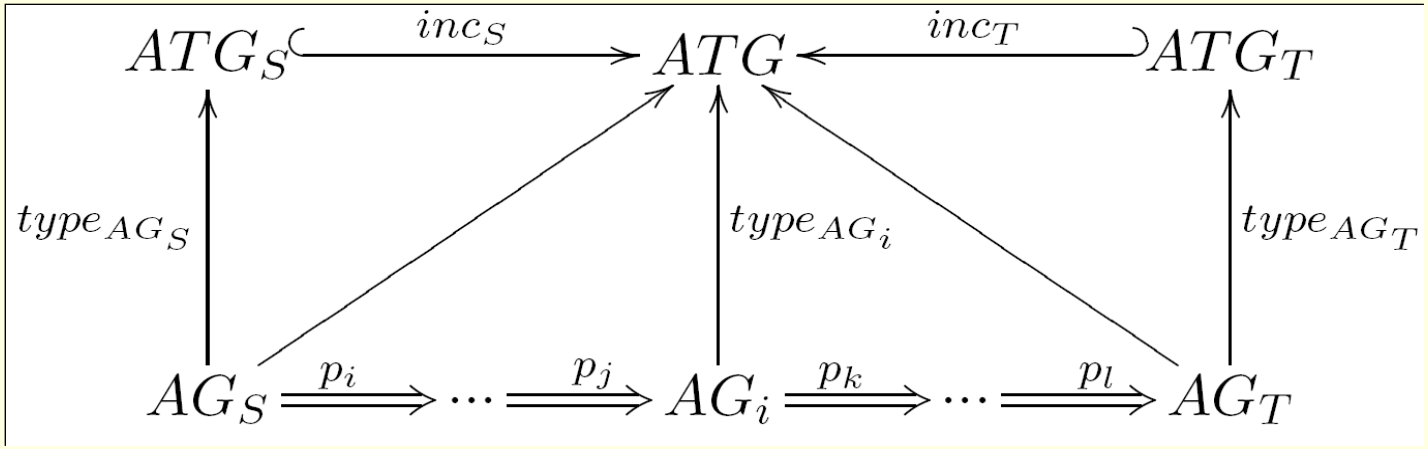
- Attributed Graphs [LKW93, HKT02]
  - Attributed Graph AG = (G, D)
    - G = E-Graph with Graph & Data Nodes
    - D = DSIG-Algebra with D-data = Data Nodes

- Typed Attr.Graphs = Adhesive HLR [EPT 04] $\Rightarrow$
  DPO-Approach for Typed Attr.Graphs [EEPT06]

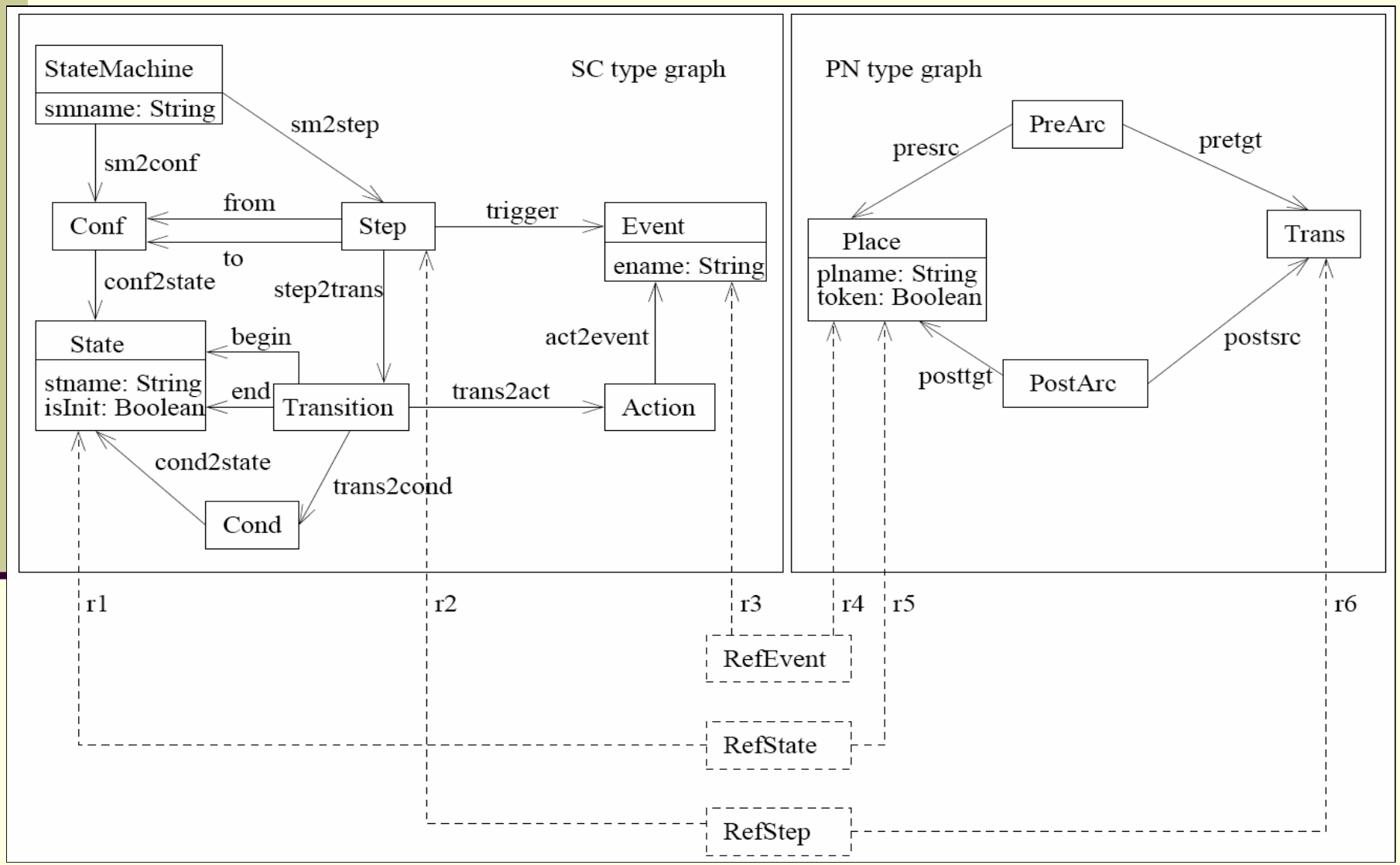
- Applications
  - Visual Modelling
  - Model Transformation

Model Transformation based on Graph Transformation

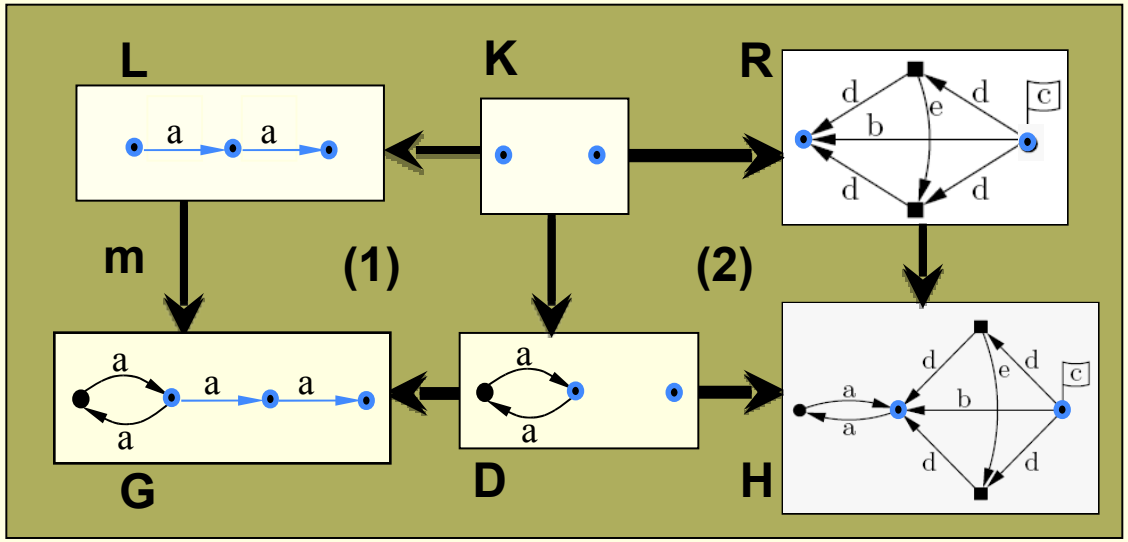
- Attributed graph transformation system
  - *AGTS=(ATG,Prod)*
  - *ATG*: attributed type graph
  - *Prod*: set of transformation productions
- Typing for model transformations



ModTrafo Typegraph `Statecharts to Petri Nets´

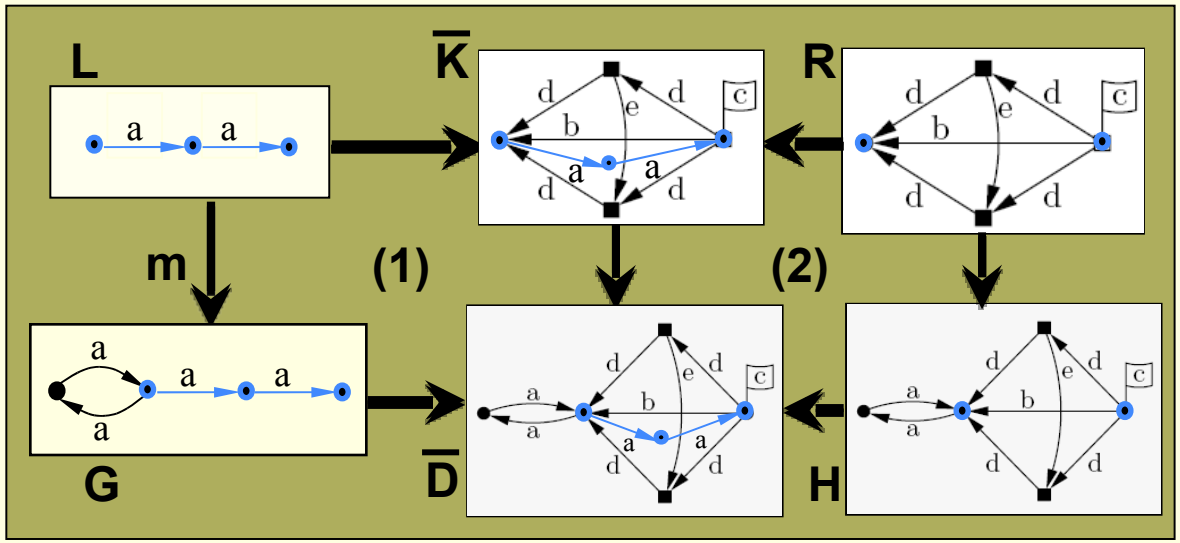


Alternatives for DPO-Approach



- NLC, Hyperedge, SPO, Logical, 2-Struct, Progr. Gra-Gra
  - Handbook of GRA-GRA [Roz 97]
- DPO, DPB, DPO-BC, SqPO, MPOC
  - (1) DELETE & (2) ADD
- **What about (1) ADD & (2) DELETE ?**

Cospan-DPO Rules & Trafos



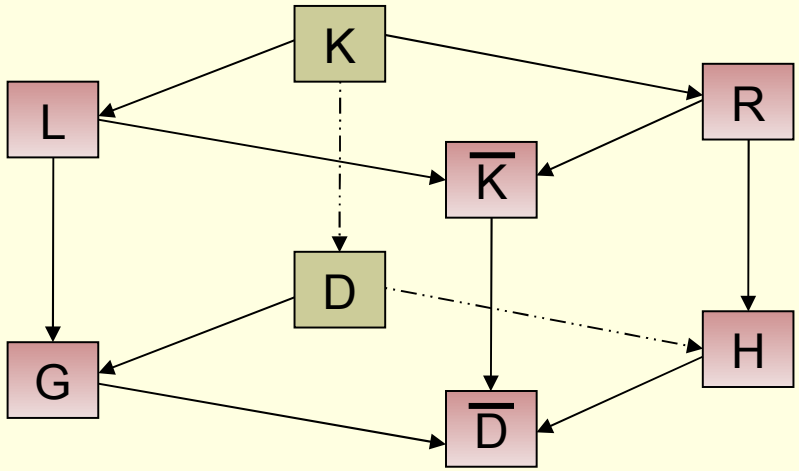
Cospan-DPO Trafo

G ≡ > H vi$\bar{a}$ (p,m)

- **Rules are Cospans $\bar{p}$ = (L → $\bar{K}$ ← R)**
  - DPO (1) = ADD & DPO (2) = DELETE
- **Application : Reconfigurable Petri Nets**
- **Problem : G ≡ > H vi$\bar{a}$ (p,m) as Cospan-DPO Trafo**

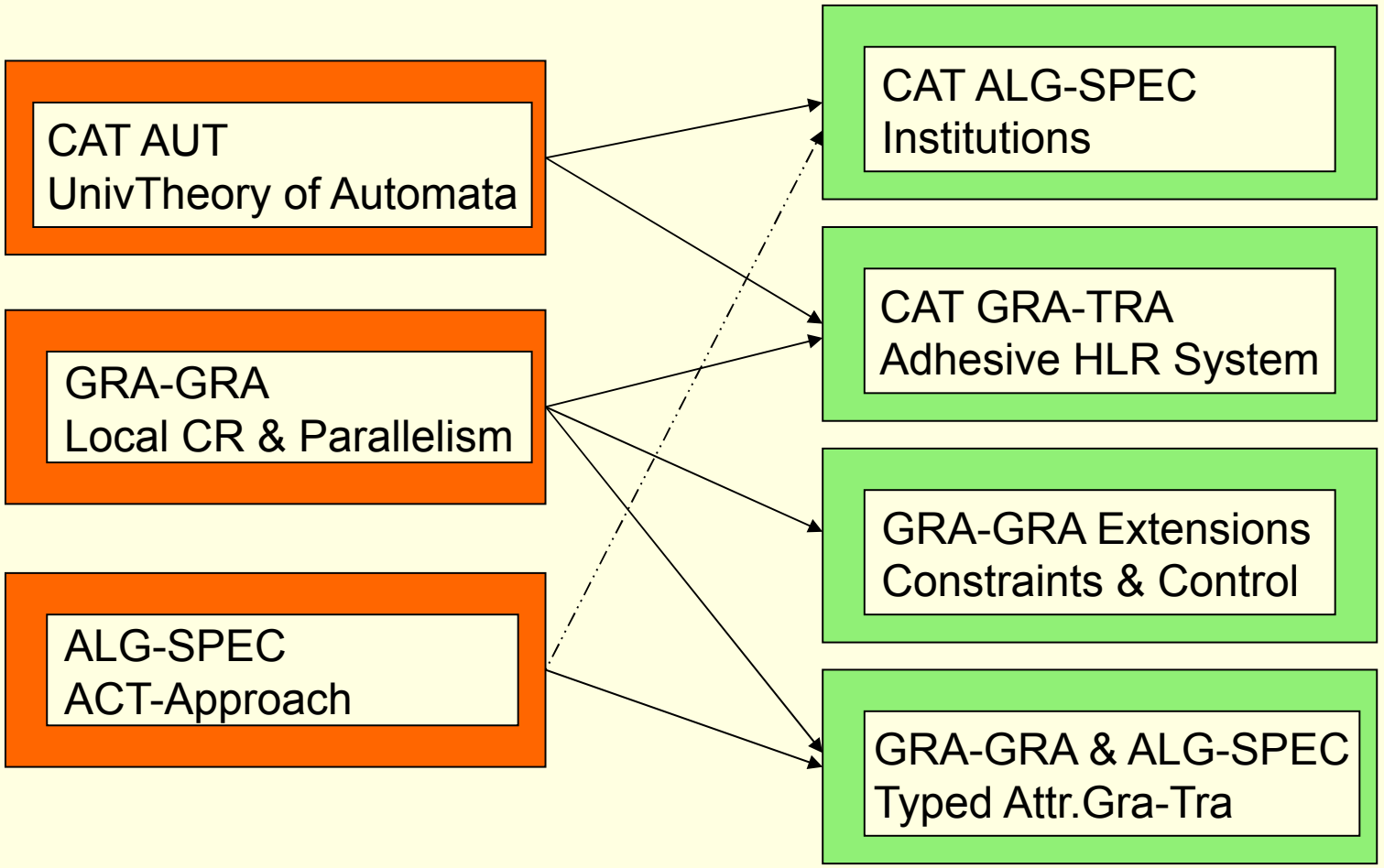
⇔ ? G ⇒ H via (p,m) as DPO Trafo

Proof of Equivalence



- **Top PO & PB by Relationship of p & $\overline{p}$**
- **Bottom PO & PB by Relationship of D & $\overline{D}$**
- **G ≡ > H via$\overline{a}$ (p,m) ⇔ Front Left & Right PO**
- **⇔ Back Left & Right PO ⇔ G ⇒ H via (p,m)**

CONCLUSION : From GRA-GRA to ALG-SPEC & Back Again



Joint History of HJK & HE

- **1968 – 1974 HJK Math Stud at TU Berlin**
- **1974 – 1983 HJK Ass / AssProf at CS-Dept TUB**
- **1983 – 2009 HJK Prof U Bremen**
- **1982 – 86 ACT-Project TUB / UB**
- **Since 1990 Joint European Projects**
  - **COMPASS**
  - **COMPUGRAPH**
  - **GETGRATS**
  - **APPLIGRAPH**
  - **SEGRAVIS**