From Graph Transformation to Algebraic Specification and Back Again

Dedicated to 60th Birthday of HJK
Bremen, Haus der Wissenschaften, September 2009
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What Came First?

Double Pushout or Parameter Passing

GRA-GRA or ALG-SPEC?

Diagram:

- L: Diagram with nodes labeled a, a, a, and m
- K: Diagram with nodes labeled a
- R: Diagram with nodes labeled d, b, e, d, and data
- G: Diagram with nodes labeled a, a, a, and a
- D: Diagram with nodes labeled a
- H: Diagram with nodes labeled a, b, d, e, d, and nat
- L to K via m
- K to R via string(data)
- R to G via string(nat)
- L to G via a
- K to D via a
- R to H via d

(a) (1) (2)
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?
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)

CAT – AUT ?

P = NP ?
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?

- CAT-AUT
  UnivTheory of Automata

- GRA-GRA
  Local CR & Parallelism

- ALG-SPEC
  ACT-Approach

? ? ? ?
10 – 25 Years Later!

- CAT-AUT
  UnivTheory of Automata

- GRA-GRA
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- CAT ALG-SPEC
  Institutions

- CAT GRA-TRA
  Adhesive HLR System

- GRA-GRA Extensions
  Constraints & Control

- GRA-GRA & ALG-SPEC
  Typed Attributed Gra-Tra
CAT ALG-SPEC

- **Aim**: Institution Independence of Approach
  - Institutions [BG 84]
  - Specification Frames [EM 90]

- **Mod**: $\text{SPEC}^{\text{op}} \rightarrow \text{CatCat}$ Model Functor
  - $\text{Mod}(\text{SPEC}) = \text{Category of Algebras/Models}$
  - $\text{Mod}(f) = V_f = \text{Forgetful Functor}$
  - 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, Concurrency & 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:

\[ \exists(\circ_1 \circ_2 \leftrightarrow \circ_1 \rightarrow \circ_2) \]
\[ \nexists(\circ_1 \circ_2 \leftrightarrow \circ_1 \rightarrow \circ_2) \]
\[ \exists(\circ_1 \circ_2 \leftrightarrow \circ_1 \rightarrow \circ_2) \]
\[ \land \nexists(\circ_1 \circ_2 \leftrightarrow \circ_1 \rightarrow \circ_2) \]
\[ \exists(\circ_1 \rightarrow \circ_2) \]
\[ \nexists(\circ_1 \circ_2 \leftrightarrow \circ_1 \rightarrow \circ_2) \]
\[ \forall(\circ_1 \rightarrow \circ_2 \rightarrow \circ_2) \]
\[ \exists(\circ_1 \rightarrow \circ_2 \rightarrow \circ_2) \]
\[ \forall(\circ_1 \rightarrow \circ_2 \rightarrow \circ_3) \]
\[ \exists(\circ_1 \rightarrow \circ_3 \rightarrow \circ_2) \] (im. of 2)

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

- **Rules are Cospan**s $\bar{p} = (L \rightarrow \bar{K} \leftarrow R)$
  - DPO (1) = ADD & DPO (2) = DELETE
- **Application** : Reconfigurable Petri Nets
- **Problem** : $G \equiv > H$ via $(p, m)$ as Cospan-DPO Trafo

$\iff ? G \Rightarrow H$ via $(p, m)$ as DPO Trafo
Proof of Equivalence

- Top PO & PB by Relationship of $p$ & $\bar{p}$
- Bottom PO & PB by Relationship of $D$ & $\bar{D}$
- $G \equiv > H \text{ via } (p,m) \iff \text{ Front Left & Right PO}$
- $\iff \text{ Back Left & Right PO} \iff G \Rightarrow H \text{ via } (p,m)$
CONCLUSION: From GRA-GRA to ALG-SPEC & Back Again

- CAT AUT
  UnivTheory of Automata

- GRA-GRA
  Local CR & Parallelism

- ALG-SPEC
  ACT-Approach

- CAT ALG-SPEC Institutions
- CAT GRA-TRA Adhesive HLR System
- GRA-GRA Extensions Constraints & Control
- GRA-GRA & ALG-SPEC Typed Attr.Gra-Tra
Joint History of HJK & HE

- 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