Series-parallel posets having a near-unanimity polymorphism

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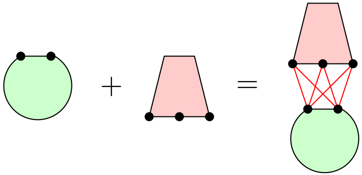
All posets are finite.

If $\mathbf{P}, \mathbf{Q}$ are posets, then $\mathbf{P} + \mathbf{Q}$ is their **ordinal sum**:



$\mathbf{P} \mathbin{\dot\cup} \mathbf{Q}$ is their disjoint union.

$\mathbf{1} \;=\; \bullet$ $\qquad$ $\mathbf{1} \mathbin{\dot\cup} \mathbf{1} \;=\; \bullet\;\bullet \;=\; \mathbf{2}$ $\qquad$ $\mathbf{1} + \mathbf{1} \;=$ 

Definition. Let **P** be a poset.

A function $f : P^n \to P$ is a **near unanimity (NU) polymorphism** of **P** if

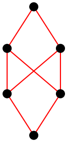
- $n \geq 3$.
- $\forall\ 1 \leq i \leq n,\ \ \forall\ a, b \in P,$

$$f(a, a, \ldots, a, \underset{\substack{\uparrow \\ i}}{b}, a, \ldots, a) \;=\; a$$

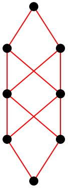
- f is monotone in each variable.

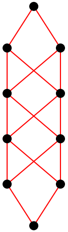
Clone theorists (last century) and CSPers (this century) care about which posets have an NU polymorphism.

Key examples

$\mathbf{T}_2 =$ 

$= \mathbf{1} + \mathbf{2} + \mathbf{2} + \mathbf{1}$

$\mathbf{T}_3 =$ 

$\mathbf{T}_4 =$ 

Facts

Every lattice-ordered poset has an NU polymorphism of arity 3.

$\mathbf{T}_2$: Has an NU polymorphism of arity 5 (Demetrovics et al, 1984).

$\mathbf{T}_3$: Does not have an NU polymorphism. (Demetrovics et al, 1984)
Does have “weaker” (Taylor) polymorphisms (McKenzie, 1990).

$\mathbf{T}_4$: Does not even have “weaker” polymorphisms (Dem. & Rónyai, 1989).

$\mathbf{T}_2, \mathbf{T}_3, \mathbf{T}_4, \ldots$ are examples of **series-parallel posets**.

Definition

A poset is **series-parallel** if it can be constructed from (copies of) $\mathbf{1}$ by finitely many applications of $+$ and $\dot\cup$.

Equivalently (Valdes, Tarjan, Lawler 1982), a poset is series-parallel iff

 does not embed into it.

Dalmau, Krokhin, Larose (2008) characterized those series-parallel posets which have “weaker” (Taylor) polymorphisms:

- By “forbidden retracts” (list of 5, including $\mathbf{T}_4$, $\mathbf{2}+\mathbf{2}$, and $\mathbf{2}+\mathbf{2}+\mathbf{2}$).
- By an internal characterization, easily checkable in polynomial time.

Our main result: We can do something similar for NU polymorphisms.

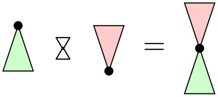
New operations: **P** ⧖ **Q**, **P** △ **Q**, **P** ▽ **Q**, and **P** ◊ **Q**

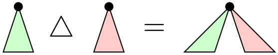
P ⧖ **Q** : defined when **P** has 1 and **Q** has 0.

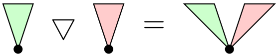
P △ **Q** : defined when both **P** and **Q** have 1.

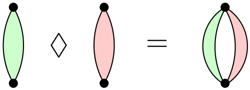
P ▽ **Q** : defined when both **P** and **Q** have 0.

P ◊ **Q** : defined when both **P** and **Q** have $1 \neq 0$.









Here is our result.

Theorem

Let $\mathbf{P}$ *be a series-parallel poset. TFAE:*

1. $\mathbf{P}$ *has an NU polymorphism.*
2. $\mathbf{P}$ *does not retract onto* $\mathbf{2}+\mathbf{2}$, $\mathbf{2}+\mathbf{2}+\mathbf{1}$ *or its dual, or* $\mathbf{T}_3$.
3. *Each connected component of* $\mathbf{P}$ *having more than one element is in the closure of* $\{\mathbf{1}+\mathbf{1}\}$ *under* $+, \between, \triangle, \bigtriangledown, \Diamond$.

About the proof:

1. Hardest part is showing that $\mathbf{P}$ being in the closure of $\{\mathbf{1}+\mathbf{1}\}$ under $+, \between, \triangle, \bigtriangledown, \Diamond$ implies $\mathbf{P}$ has an NU polymorphism.
2. Use a complicated induction on the construction of $\mathbf{P}$.
3. Do not actually construct an NU; instead, use criterion for existence due to Kun and Szabó (2001).

Thus we have no control over (and know nothing about) the NU's arity.

Problem

For fixed $k \geq 3$, characterize the series-parallel posets which have a k-ary NU polymorphism.

Added post-lecture: the above problem is solved by Corollary 3.3 of L. Zádori, Series parallel posets with nonfinitely generated clones, *Order* **10** (1993), 305–316.