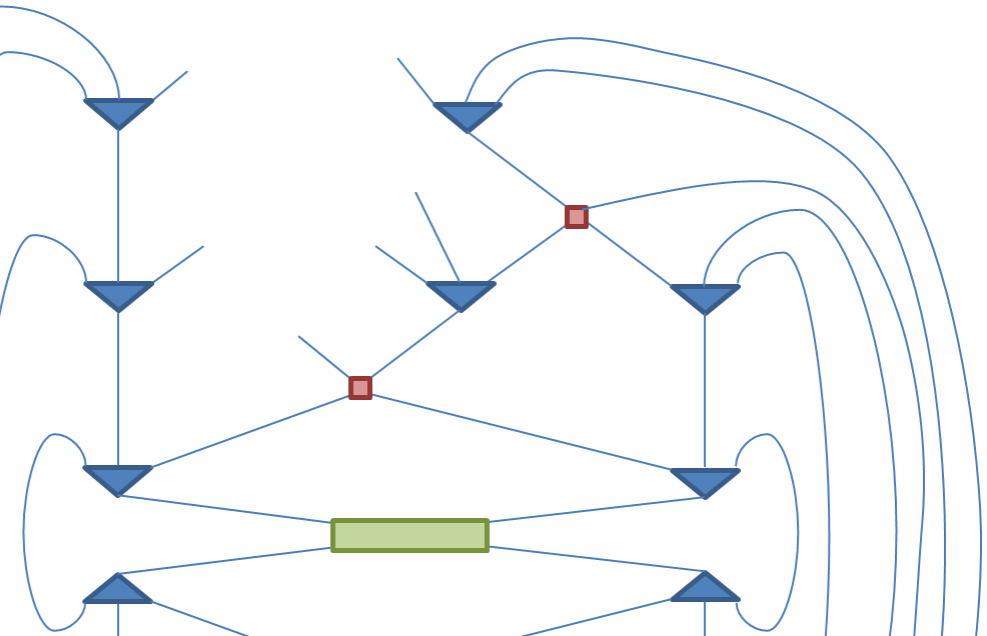
MATHEMATICA, TENSOR NETWORKS, MERA AND ENTANGLEMENT

TOWARDS HOLOGRAPHY FROM THE FIELD THEORY SIDE



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Mathematica School, PI, August 2015

OUTLINE

MERA, entanglement and AdS/MERA

- Tensor networks and contractions
- Entanglement on a slice of AdS?
- Goal: do MERA computations, and make AdS/MERA quantitative
  - →get simple MERA example + routines and do exercises

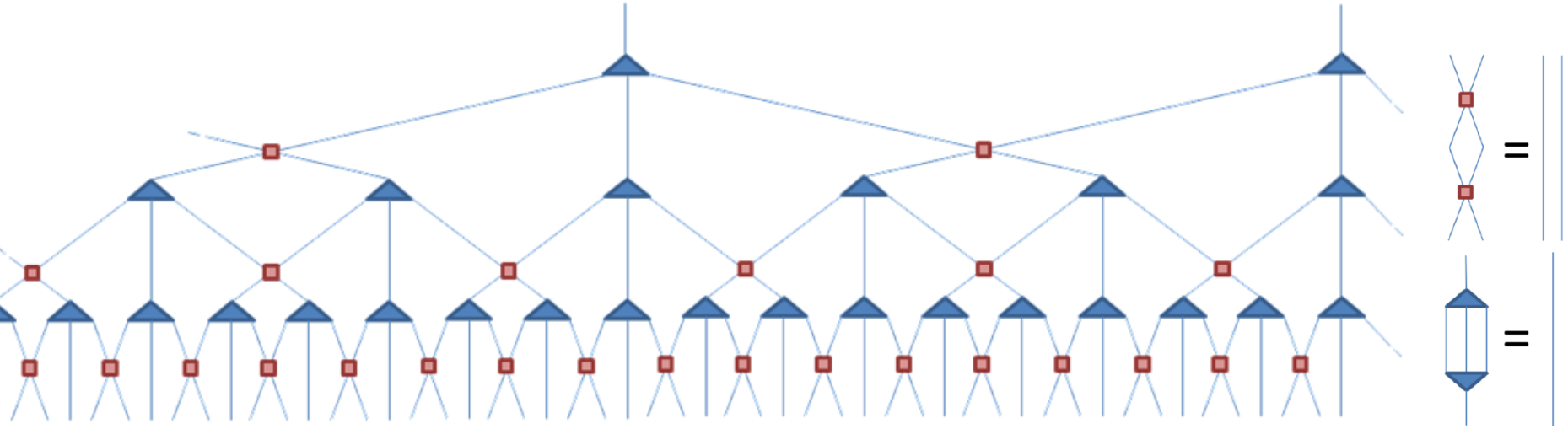
Frequently used *Mathematica*

- Making and using packages
- NDSolve and/or spectral methods
- Transforming functions/coordinate transformations

MULTISCALE ENTANGLEMENT RENORMALISATION ANSATZ (MERA)

MPS correlations/entanglement requires larger χ

Choose different *ansatz* to incorporate RG flow:



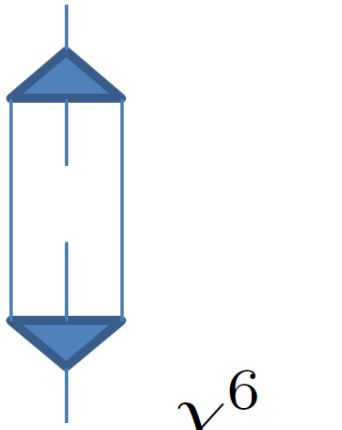
Disentanglers and coarse grainers (ternary)

Extra advantage: scale invariance is very natural!

G. Vidal, Entanglement Renormalization (2007)

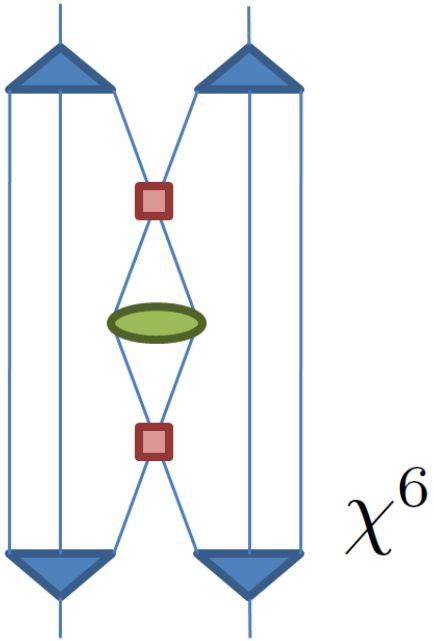
FUN FACT: TENSOR CONTRACTIONS NP COMPLETE

Algorithm depends crucially on `efficiently contractible'

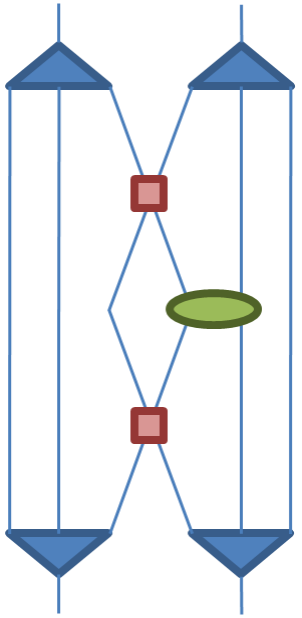


χ^6

$\sum_{i,j} w^a_{ibj} w^{c*}_{idj}$



χ^6



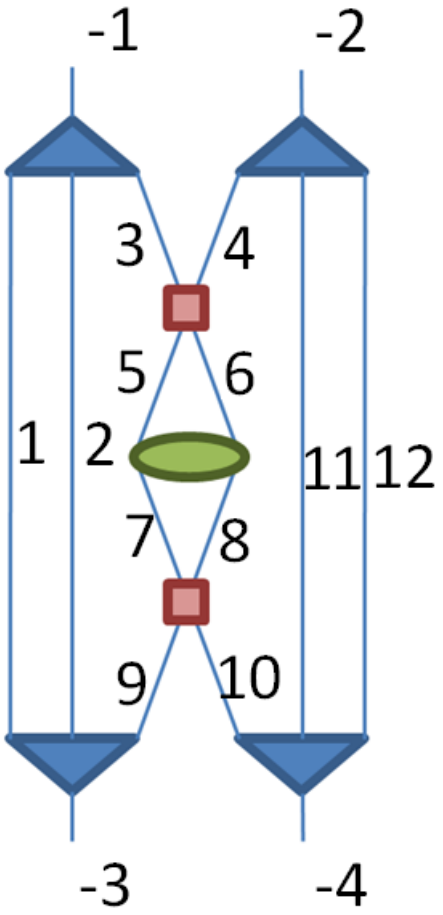
χ^8

Much harder for 2 dimensions (i.e. χ^{16} or χ^{23})

R.N.C. Pfeifer, J. Haegeman and F. Verstraete, Faster identification of optimal contraction sequences for tensor networks (2013)

NCON FUNCTION

Idea: contract sequentially, contracting two tensors at a time:

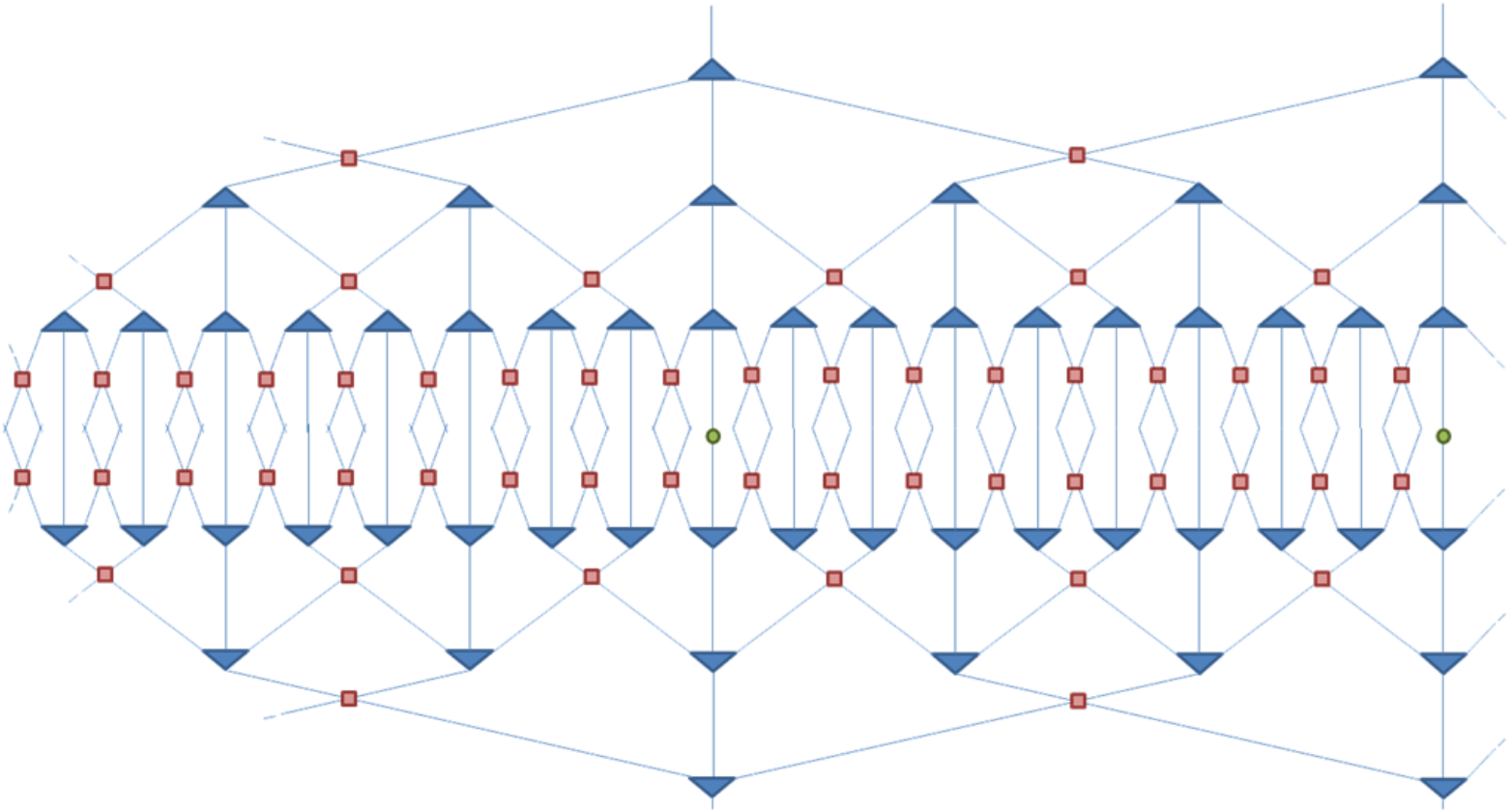


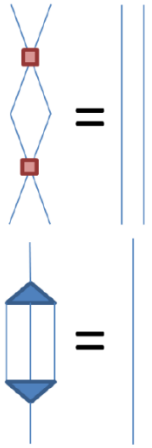

```
ncon[{w,w*,w,w*,u,u*,o},
{{-1,1,2,3},
 {-3,1,2,9},
 {-2,4,11,12},
 {-4,10,11,12},
 {3,4,5,6},
 {7,8,9,10},
 {5,6,7,8}},
??
]
```

R. N. C. Pfeifer, G. Evenbly, S. Singh, G. Vidal, NCON: A tensor network contractor for MATLAB (2014)

EXAMPLE: CORRELATORS IN MERA

Choose operators at smart locations





Simplify ☺

R.N.C. Pfeifer, G. Evenbly and G. Vidal, Entanglement renormalization, scale invariance, and quantum criticality (2009)

EXAMPLE: CORRELATORS IN MERA

Add reduced density matrix (green)