# Mesure de l'efficacité des réseaux radio-concentriques, urbains ou bio-inspirés, par deux métriques de la théorie des graphes : la rectitude et la centralité intermédiaire

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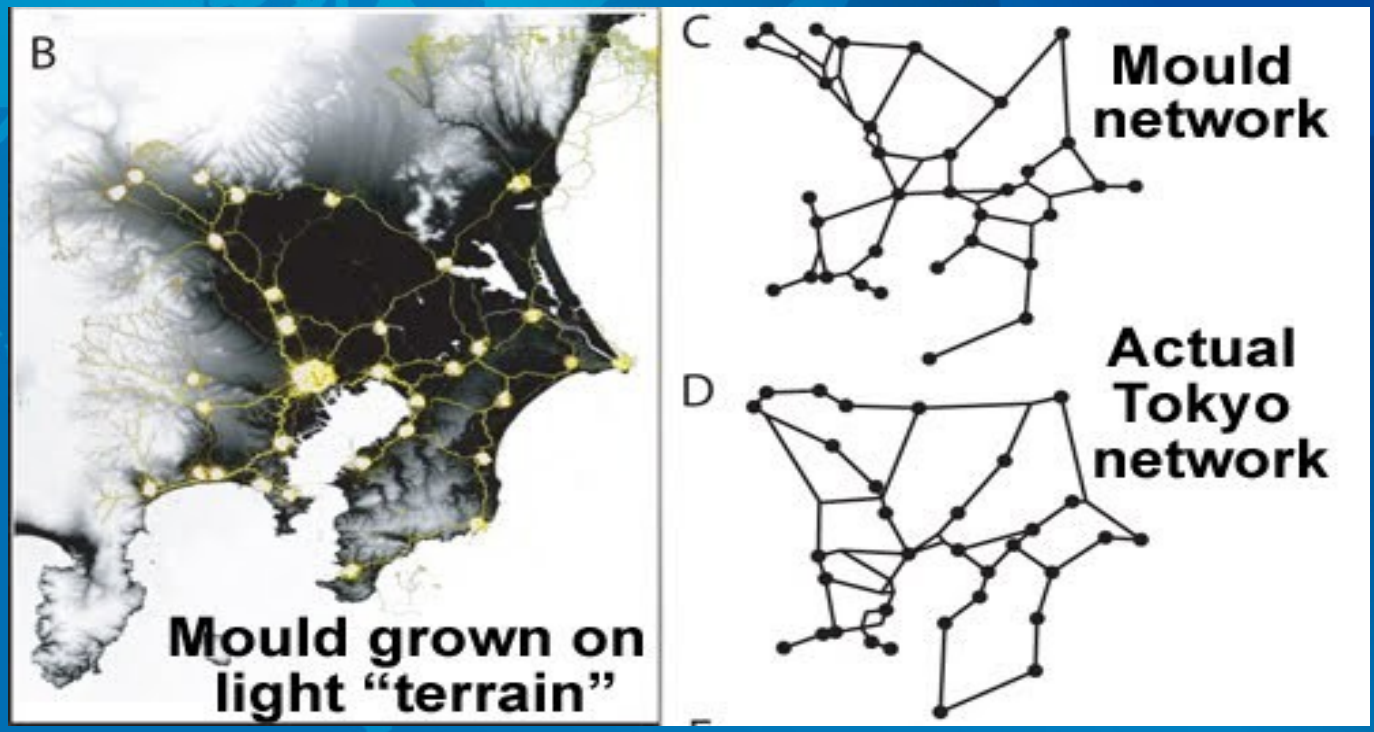
# RADIO-CONCENTRIC SHAPES

# Biomimicry and networks

- Example of the mould *Physarum plasmodium*




Nakagaki *et al.*, 2008

# Spider in Carboniferous era

Estimated size of a spider in Carboniferous

Harry Potter exagerates a little bit ;)

*Spider had time to improve its objective function...*

# Spider silk and music

**Shigeyoshi Osaki (Nara Medical University, Japon)**

*Spider silk : a bright and unique sound (Japanese patent)*

# Cloud nets in Nepal

*A structure close to layer web is efficient to keep humidity*

# Orbwebs

*Araneus diadematus*

Photos: Pasquet, 2011

# Some similarities between urban networks and orbwebs

Amsterdam

Avignon

Sfax

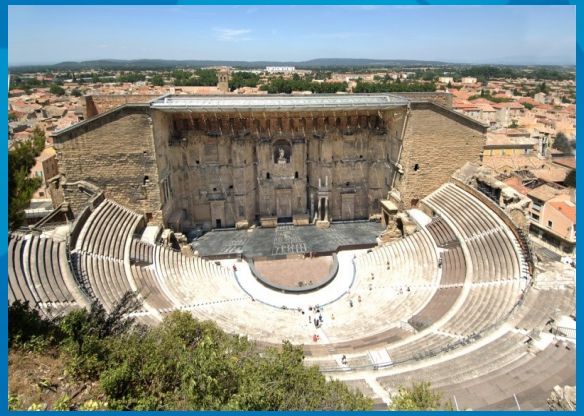
# Very regular structures

Sun city in USA (Arizona)

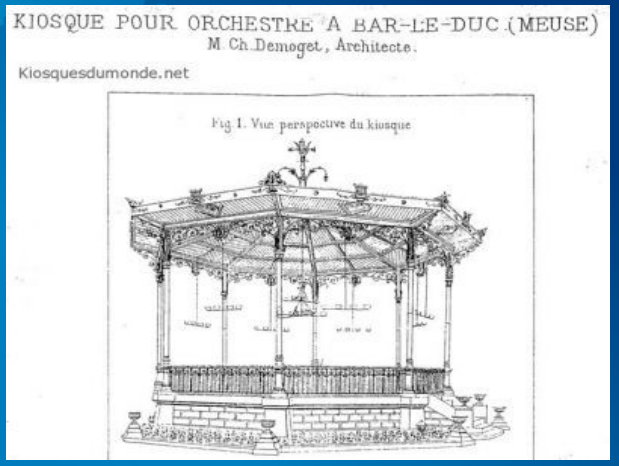
Palmanova (Italie)

Solar plant in USA

European Parliament (Strasbourg)



Antique theater (France)




Roof frame (France)

# Net, nenuphar or urchin ?

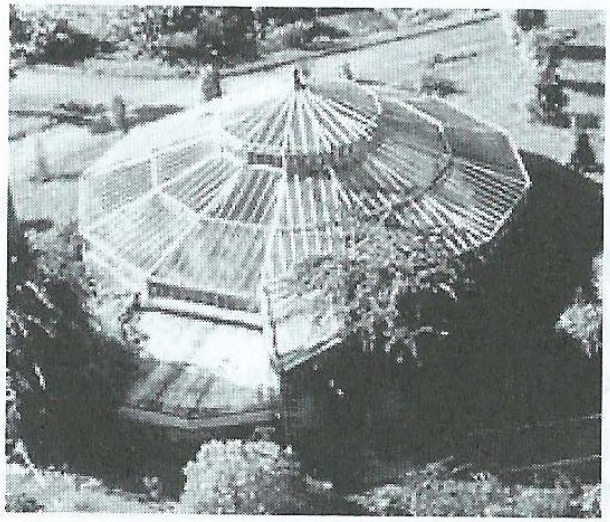


**Figure 2.2**
La « serre de Barry » du Jardin botanique de Strasbourg, dont l'armature est inspirée de la feuille du nénuphar *Victoria amazonica*.

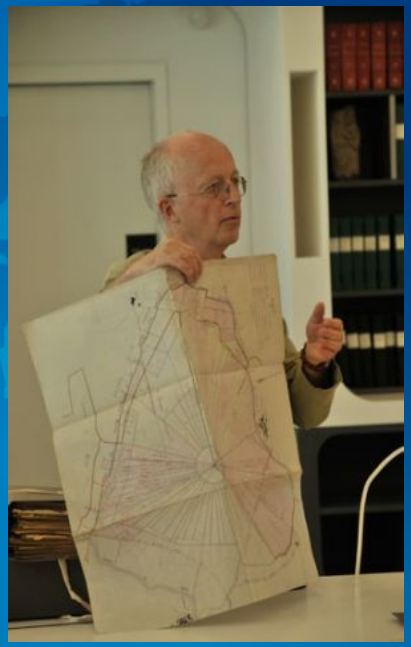
Guillot et Meiller, 2008

# Agricultural radio-concentric structures

Water canals (Marocco)

Montady pond (France)

*7th century b.JC*
*(Ensérune oppidum)*
*Association*
*70 owners (5 : 70%)*
*Network: 1300 m*

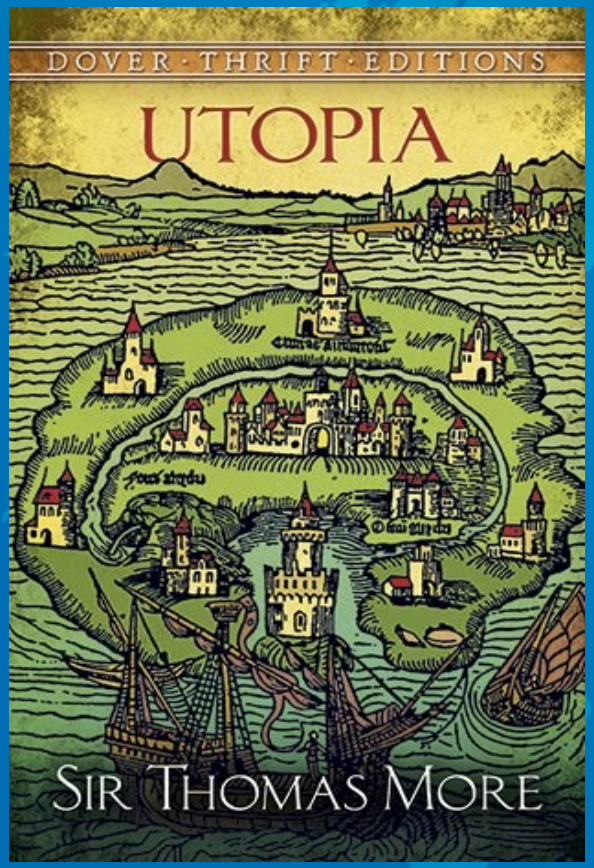


# “Sun city” in USA

40000 inhabitants, 40 km2
unincorporated area

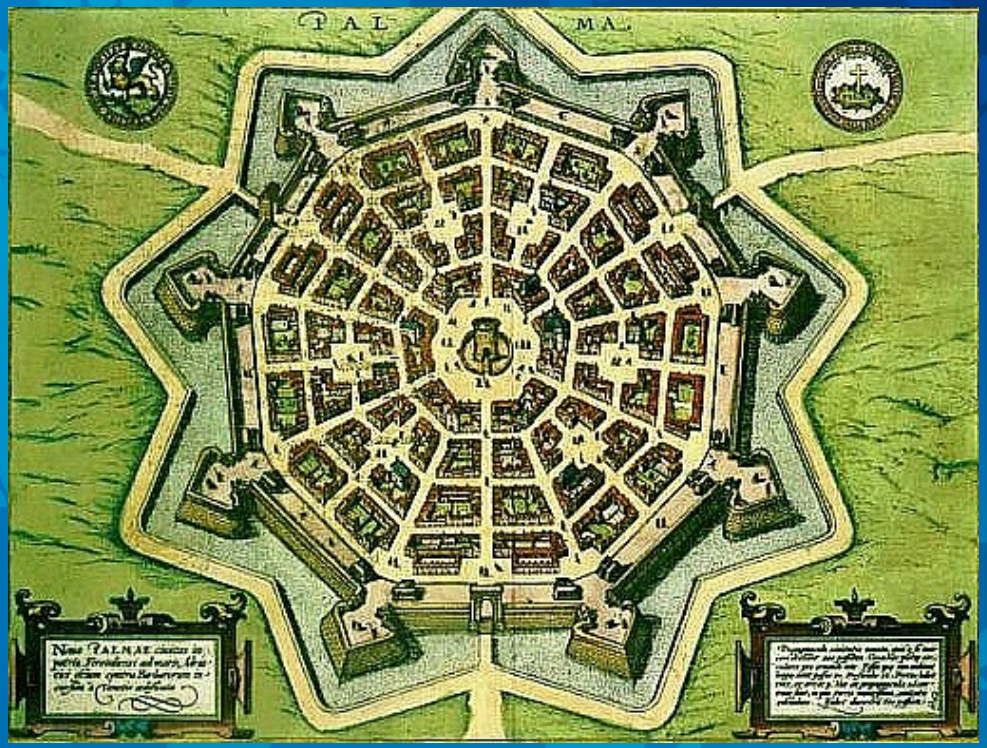
Elizabeth Neubauer, 90 y.o., sherif assistant

# Utopian city of Thomas More (1516)



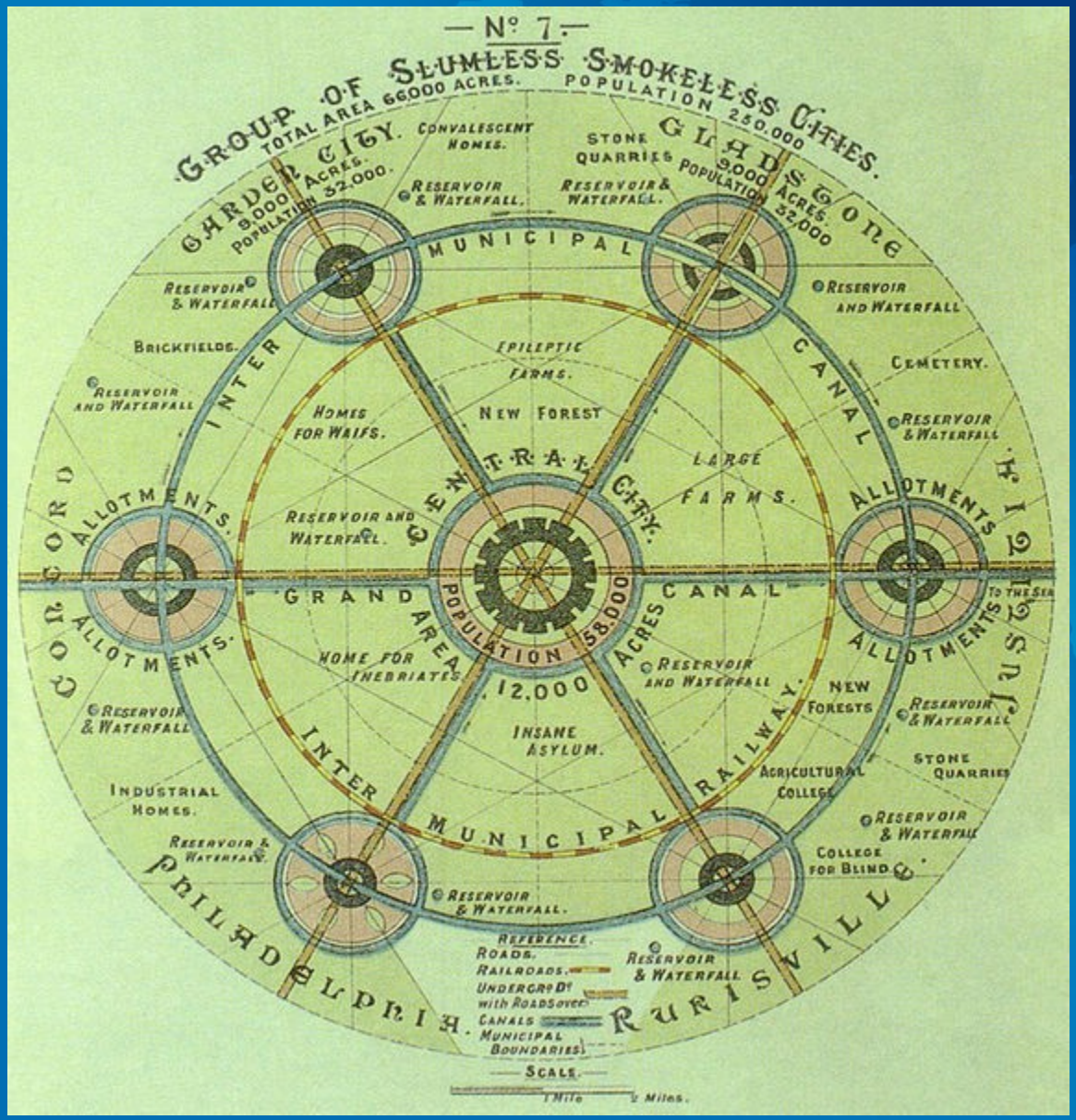
English Humanist (finance, justice) / Henri 8th
Utopia, inspired from Platon's Republic
“in no man's land” or “happiness place
Where tolerance and discipline are imposed

# The “sun city” of Tomaso Campanella (1623)




Italian monk - City with 7 fortified enclosures
“equality” of the people, eugenics, collectivist society

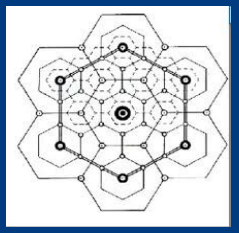
# Shape of “garden cities”

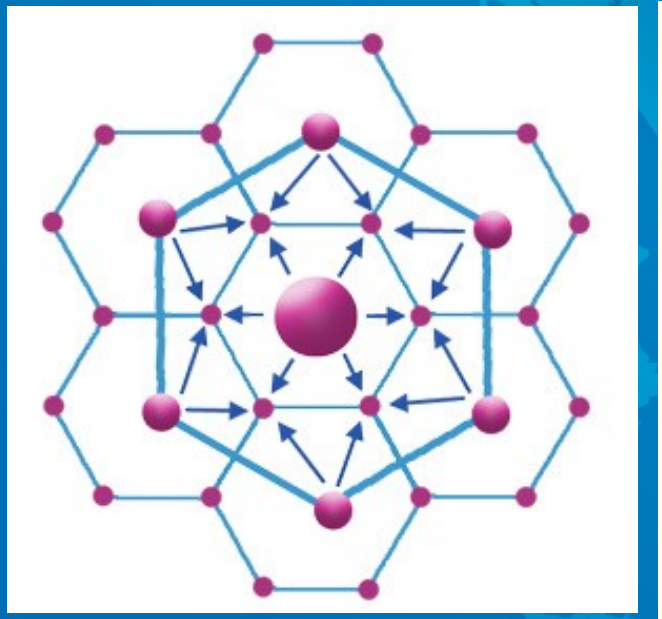


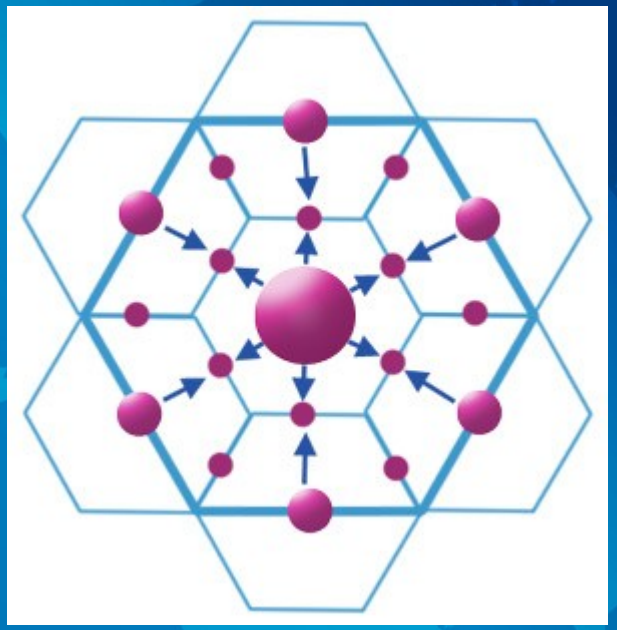

Ebenezer Howard, 1898

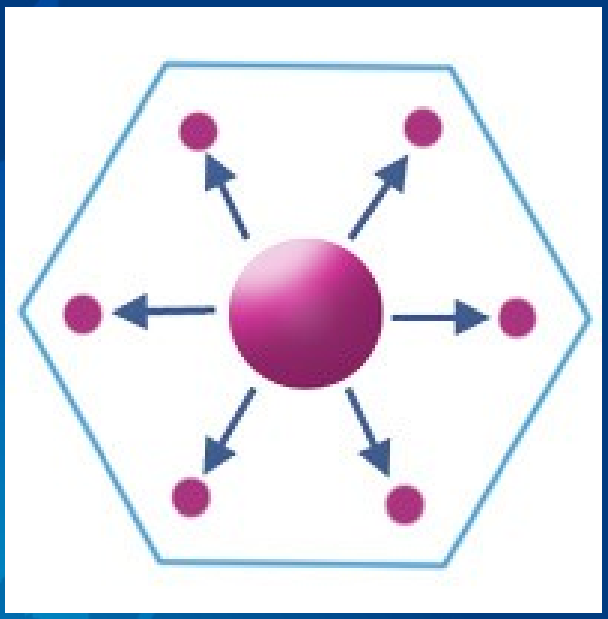
British urbanist
Mixing economy/nature
Center: city council, theatre, hospital ; periph: industry
6 sections separated by large avenues
Ex: Letchworth (London), Arcueil, Suresnes, Genevilliers (Paris)

# Theory of central locations
(Christaller, 1933, Lösh, 1940)





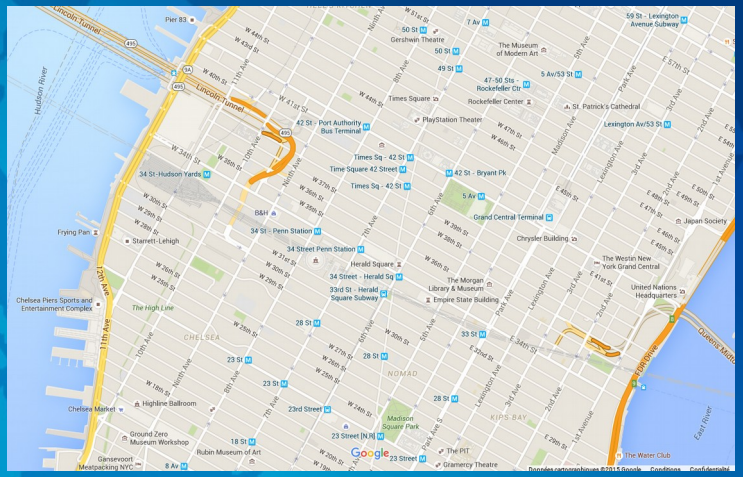




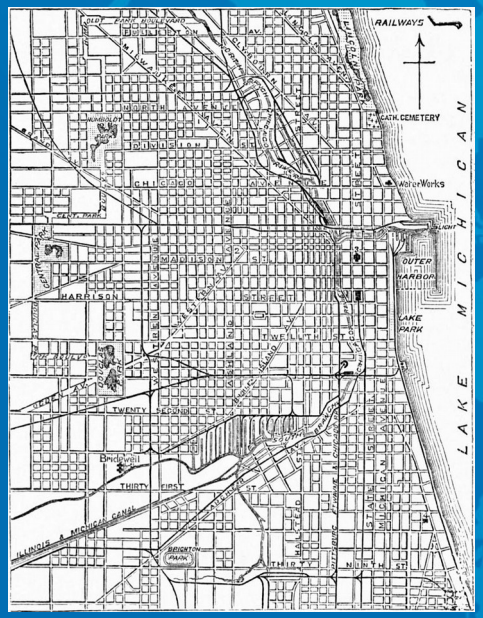
Principles … from market …. to transport…..... to administration

1. Market: richness concentration due to demand-supply economic relationship
2. Transport: cost minimization between hexagons
3. Administration: each center exerts a power on 6 contiguous secondary centers

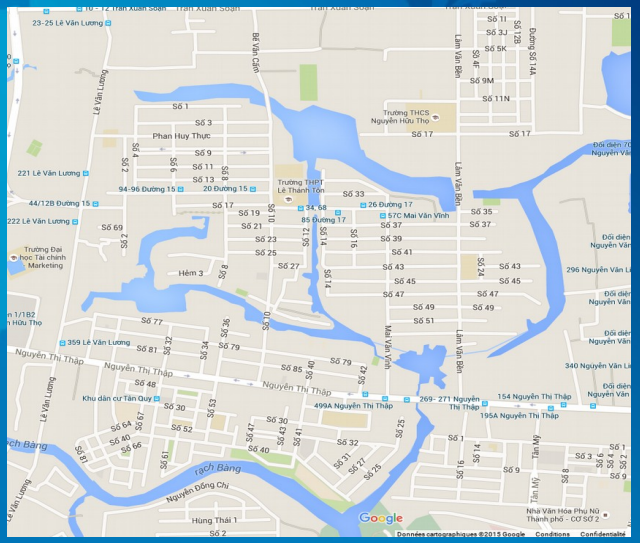
# Other rectilinear network shapes




Manhattan (USA)

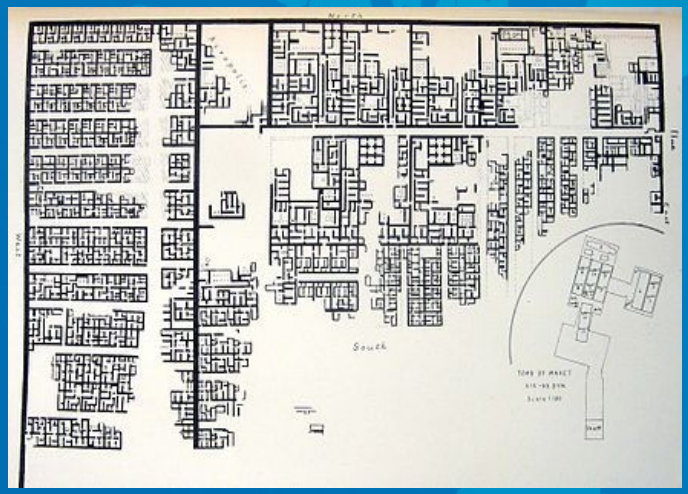



Chicago (USA)




Hô Chi Minh city (Vietnam)

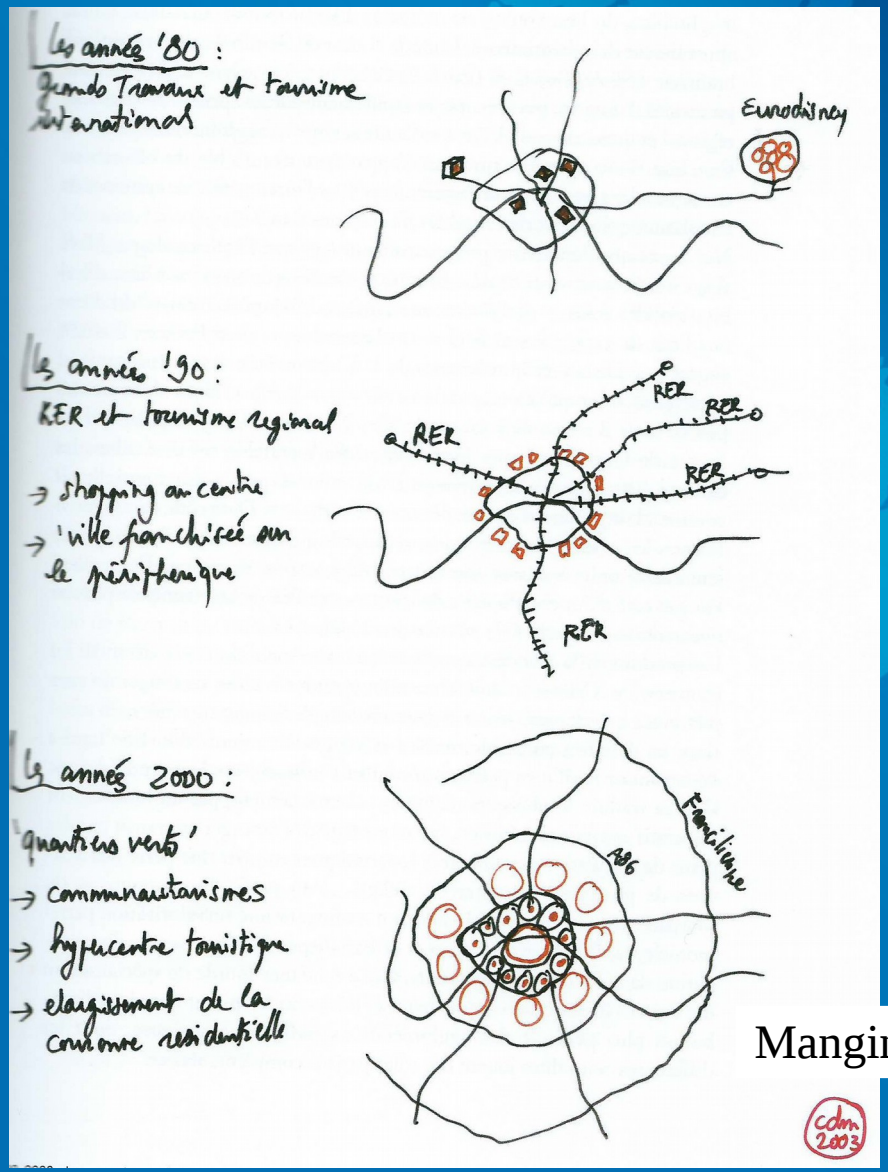
# Antique network structures

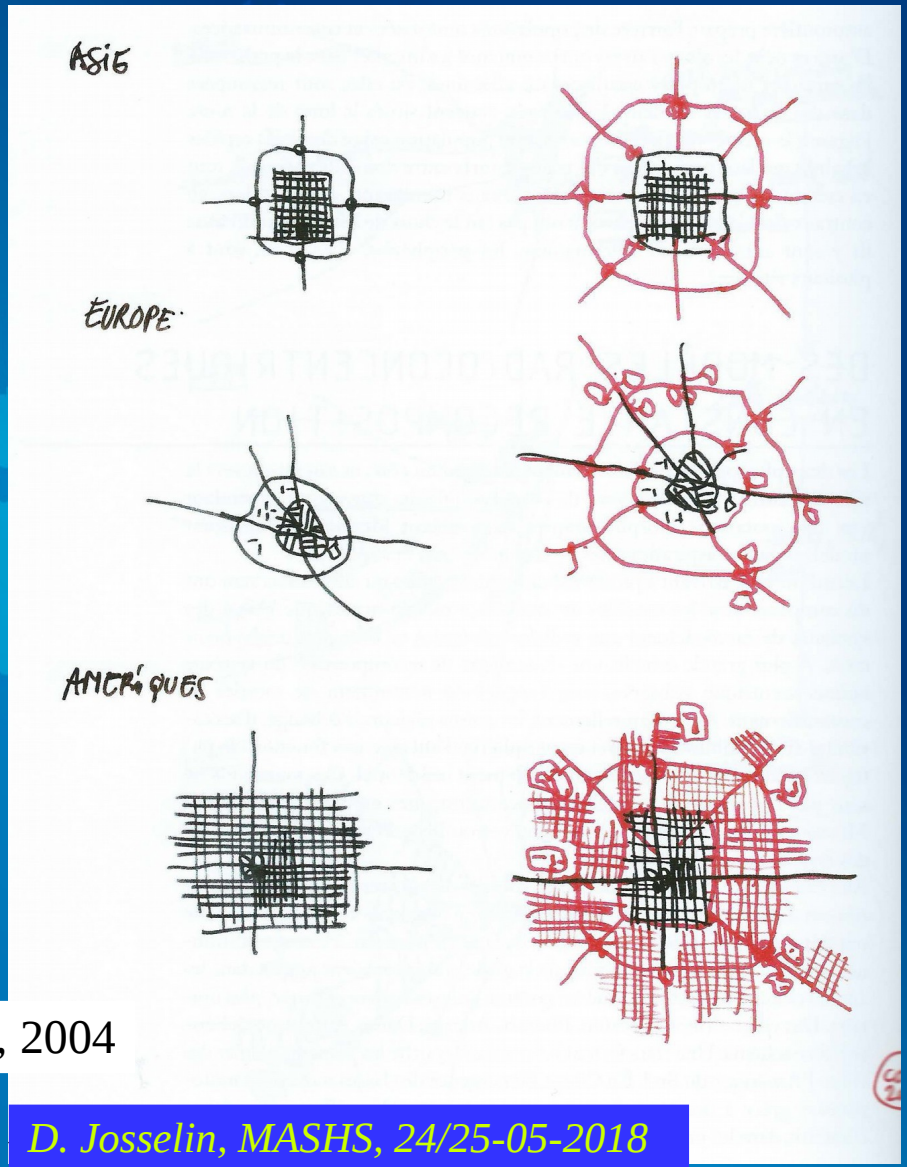


Hippodamian map
of Kahun (Egypt)
*1900 before JC*

City of Mari (Syria)
*2500 before JC*

# Urban evolution in different radiocentric sprawling

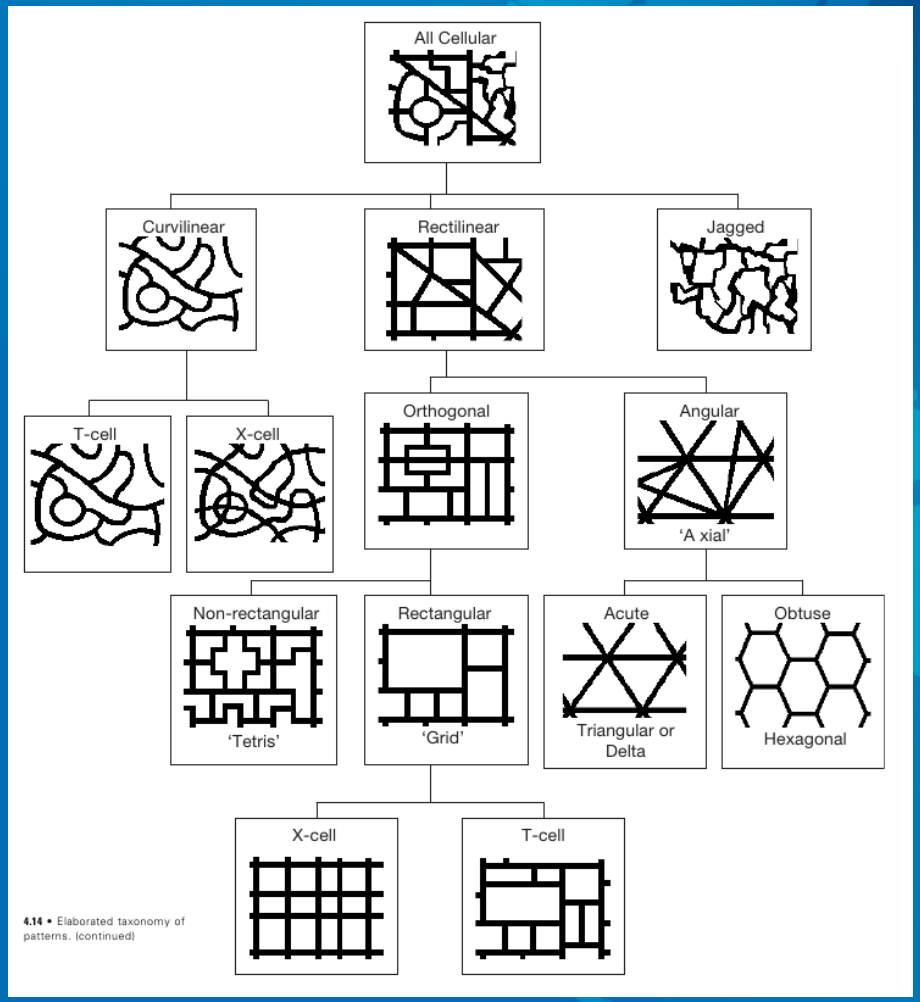


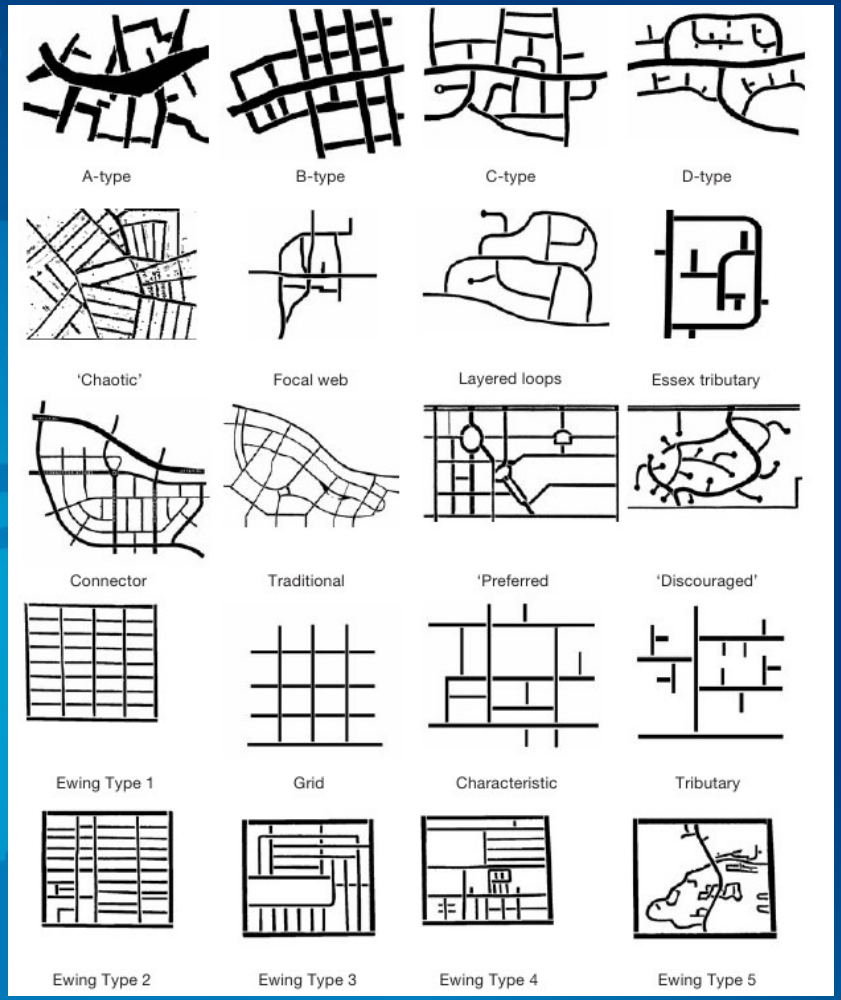




Mangin, 2004

# Multiple network real shapes

# Multiple network theoretical shapes

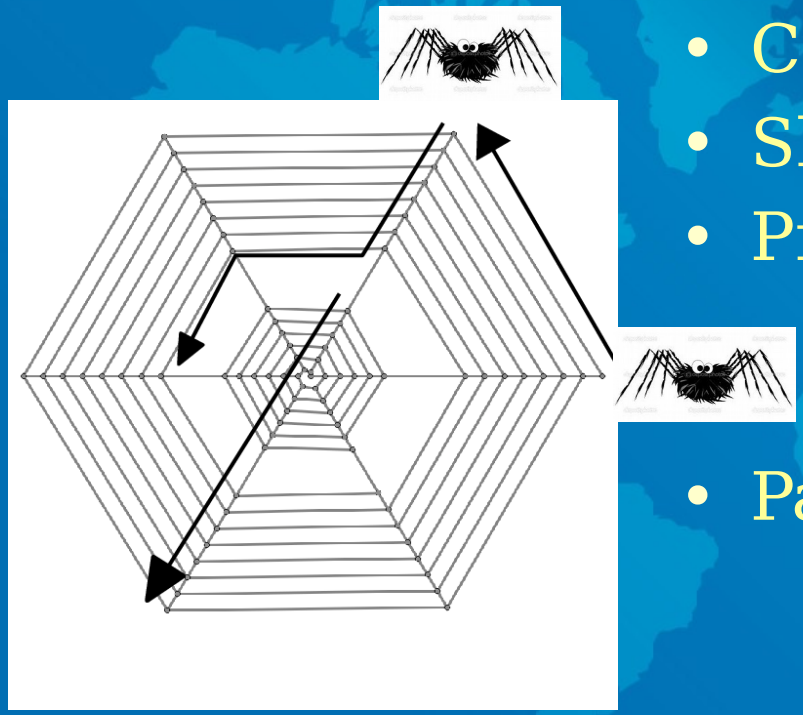



Marshall, 2005

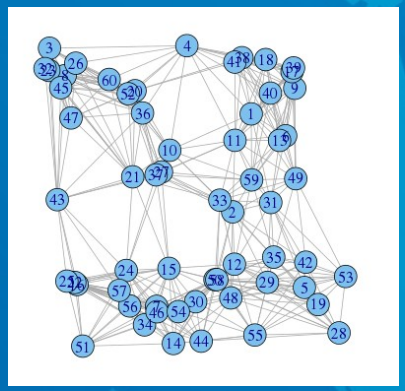
# NETWORK EFFICIENCY

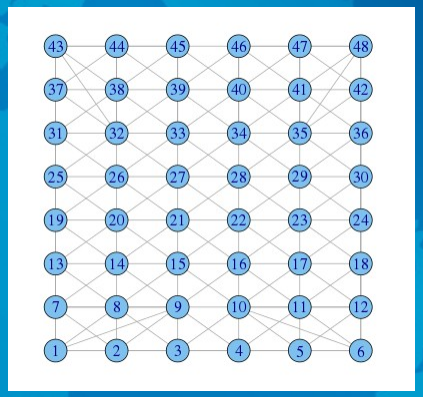
# **Simulation of agents on networks**
(Netlogo + QuantumGIS with Python)

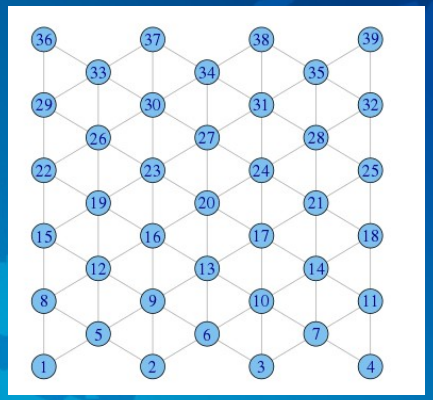


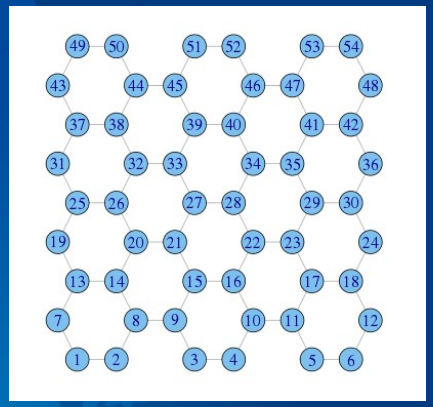
- Agent generation (1000)
- Choice of an OD (node=>node)
- Shortest path calculation
- Processing
  - Counting crossed edges
  - Straightness calculation
- Parameters
  - Constant speed
  - Possibility to move everywhere
  - N interactions between agents

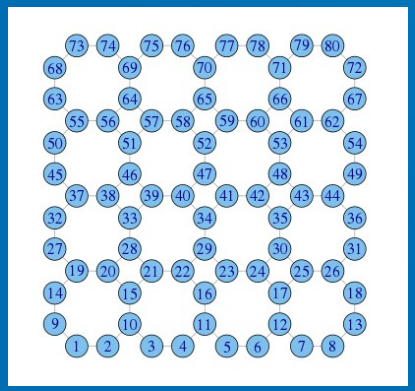
# Building regular networks using R

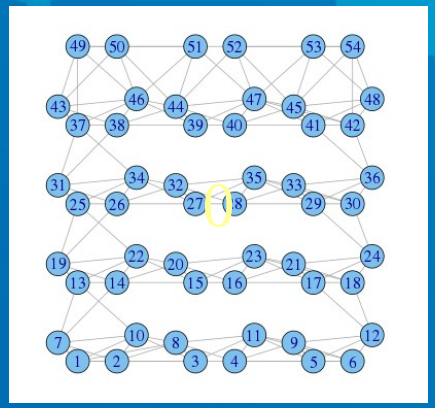


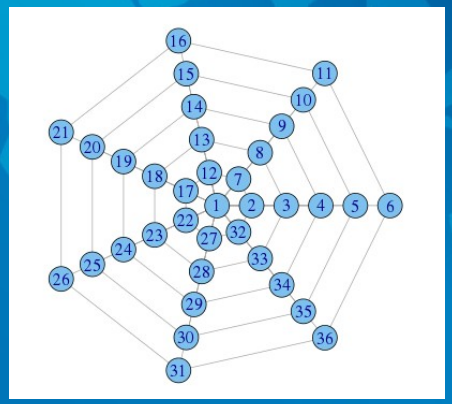


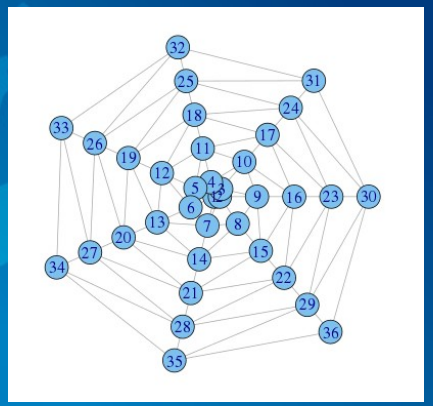








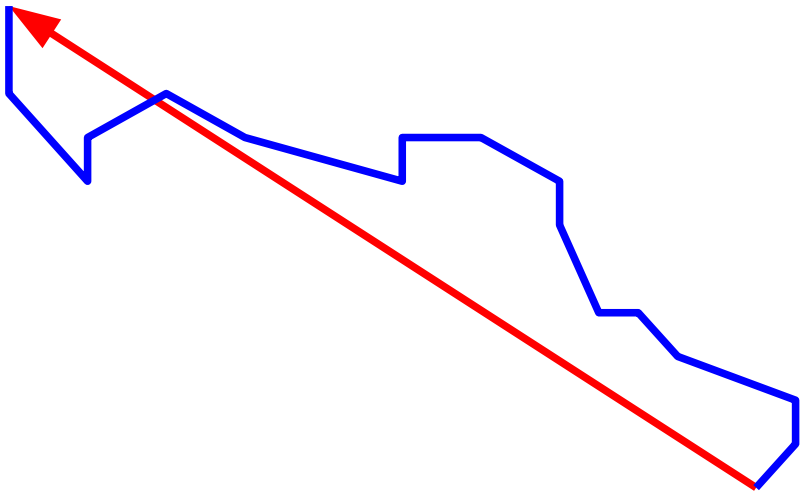




# STRAIGHTNESS

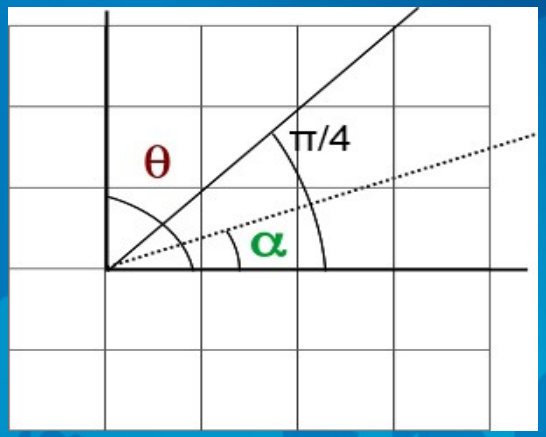
# Straightness S

**Straightness = distance as the crow flies / distance on the network**

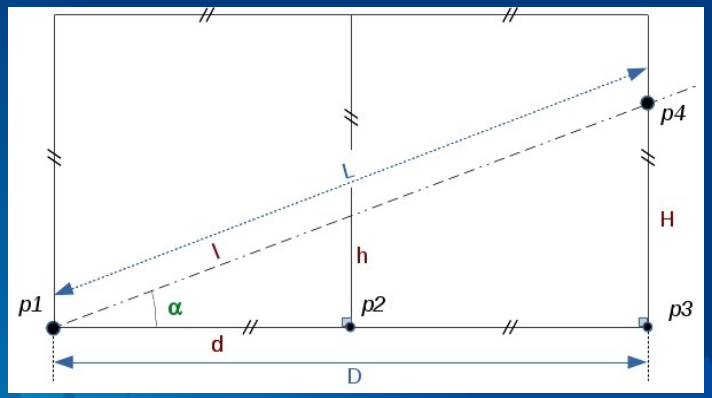


A straightness of 1 est optimal

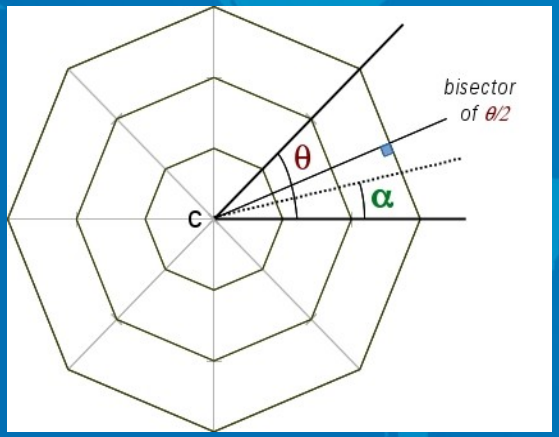
# Homothetic shapes for centrifugal motions



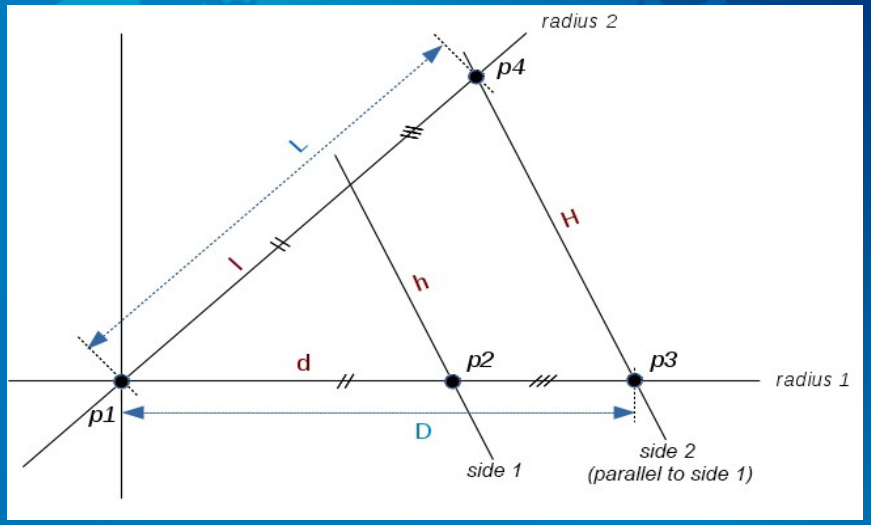

rectlinear



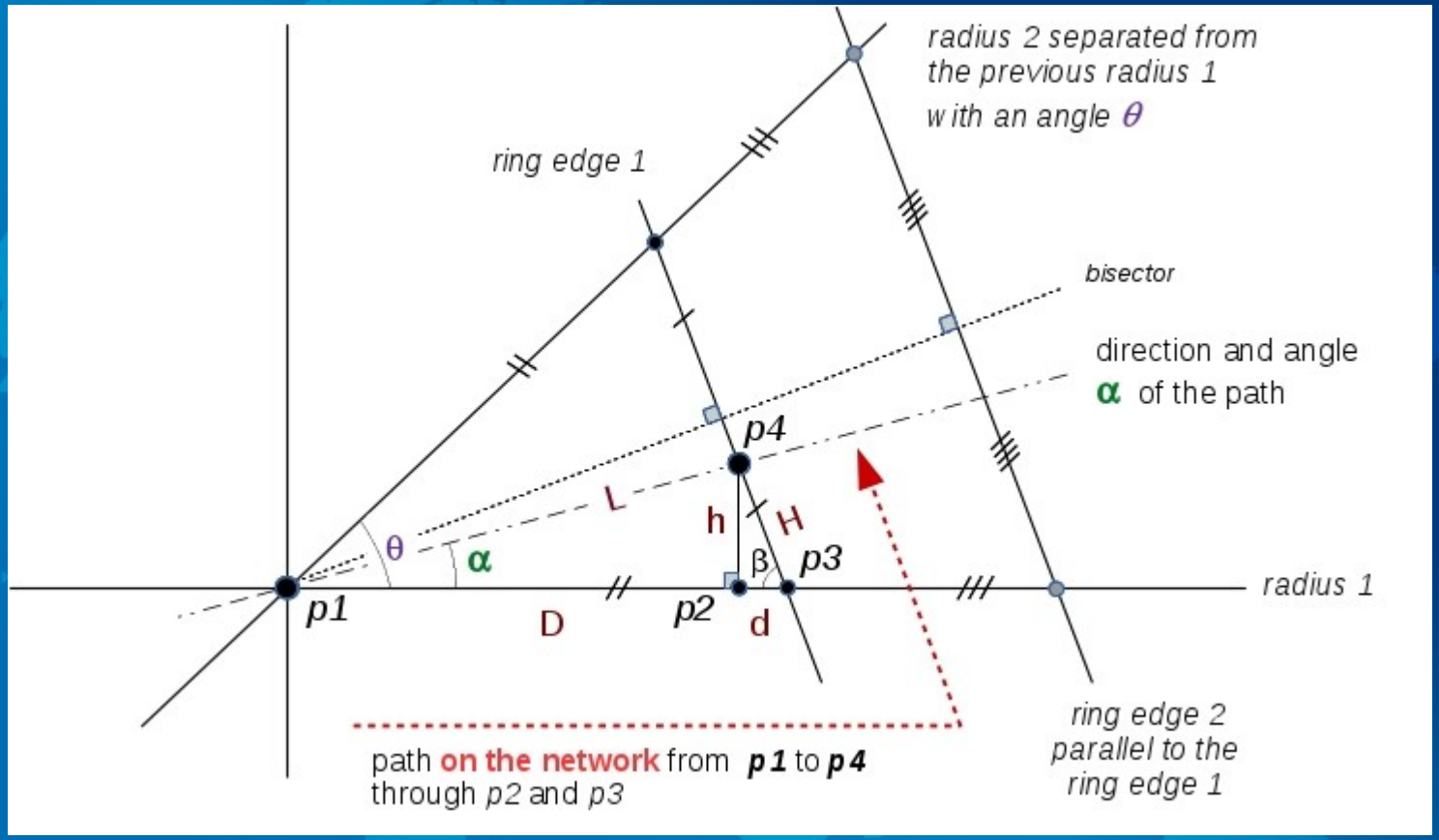

$$S(\alpha) = \frac{l}{d+h} = \frac{1}{\cos\alpha + \sin\alpha}$$




radioconcentric



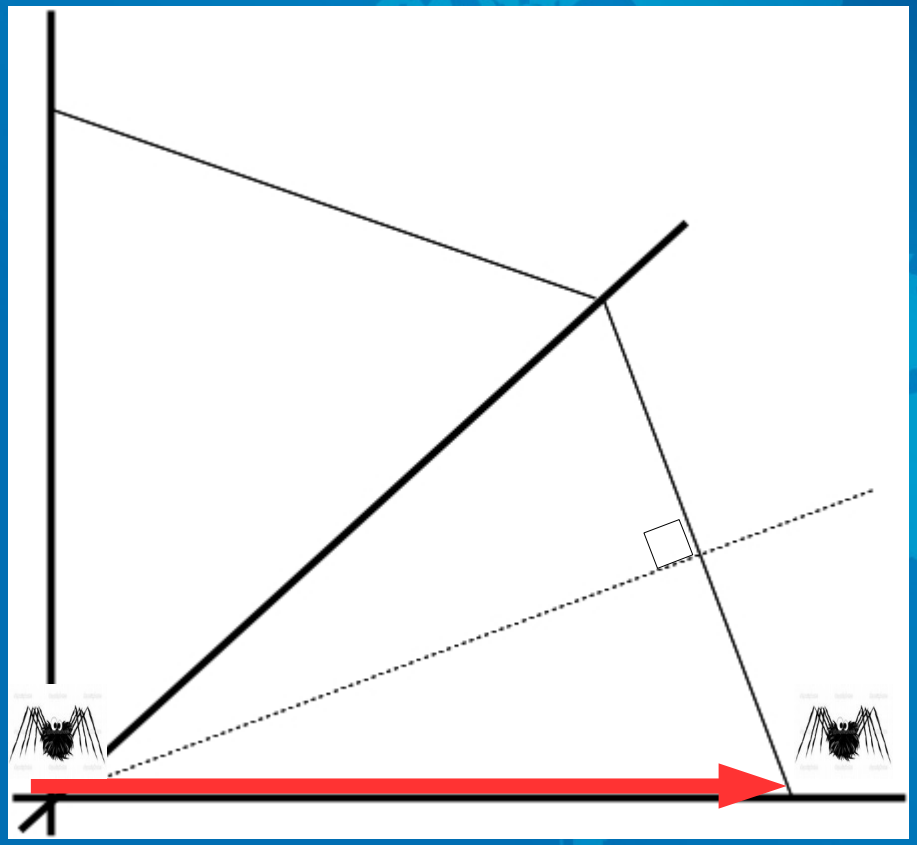
# Centrifugal motion on a radioconcentric network

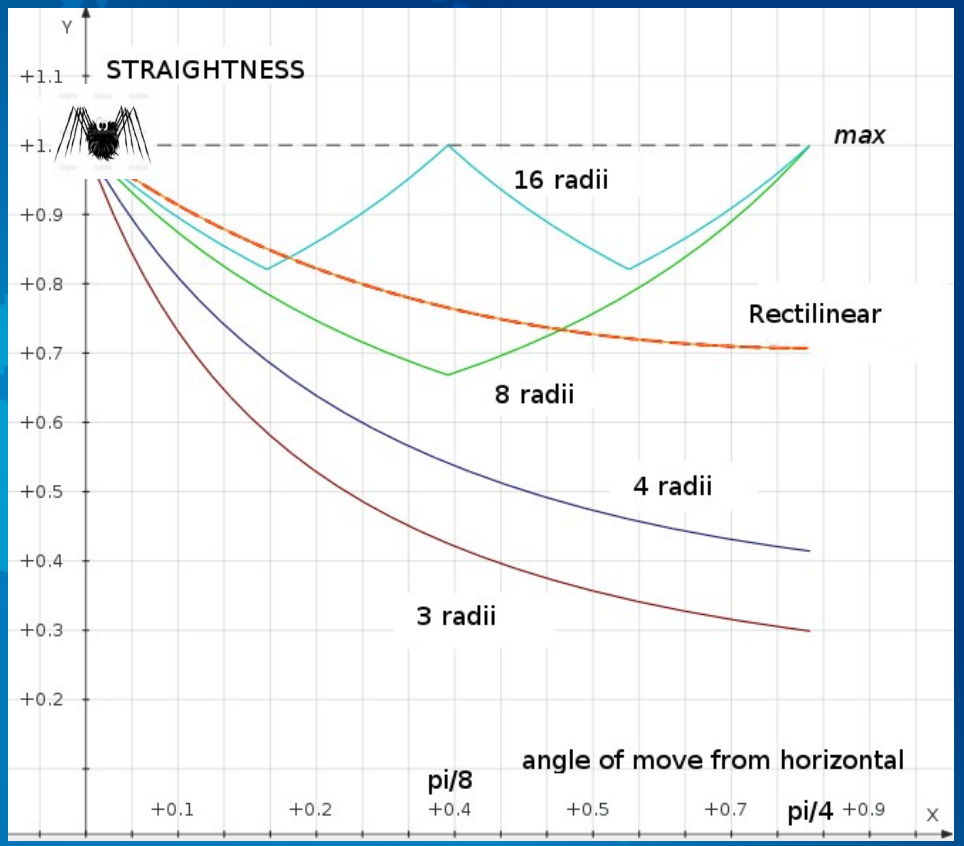



$$S_\theta(\alpha) = \frac{L}{D+d+H} = \frac{1}{\cos\alpha + \frac{\sin\alpha}{\tan\frac{\pi-\theta}{2}} + \frac{\sin\alpha}{\sin\frac{\pi-\theta}{2}}}$$

# Relation between straightness and motion angle

Straightness S



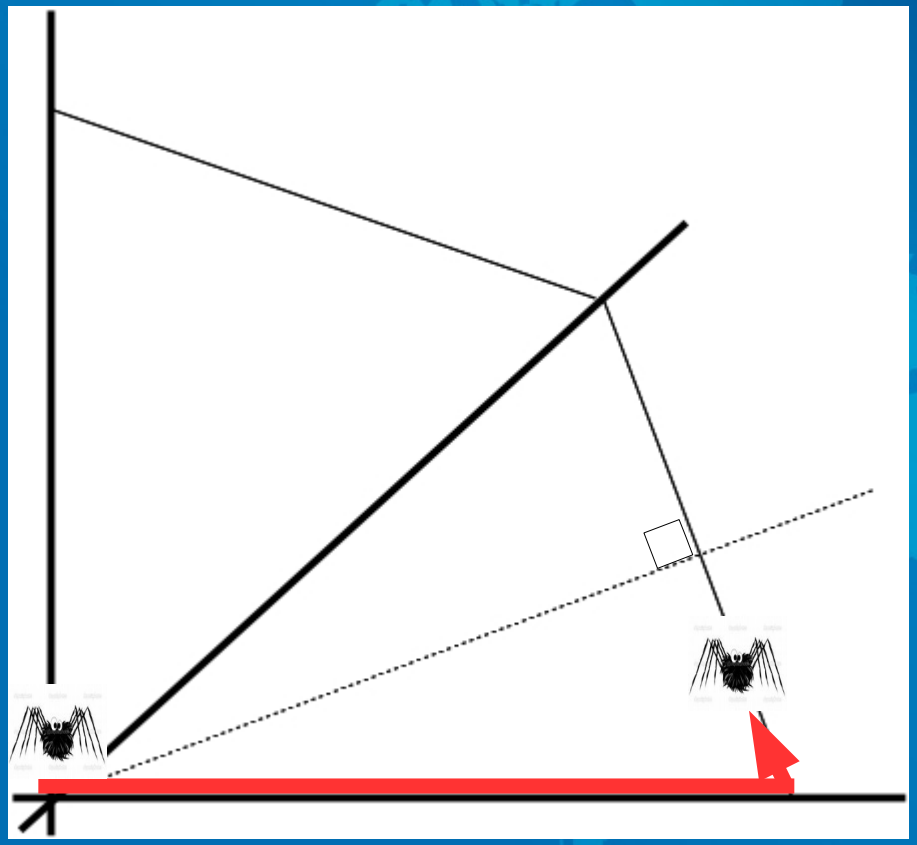


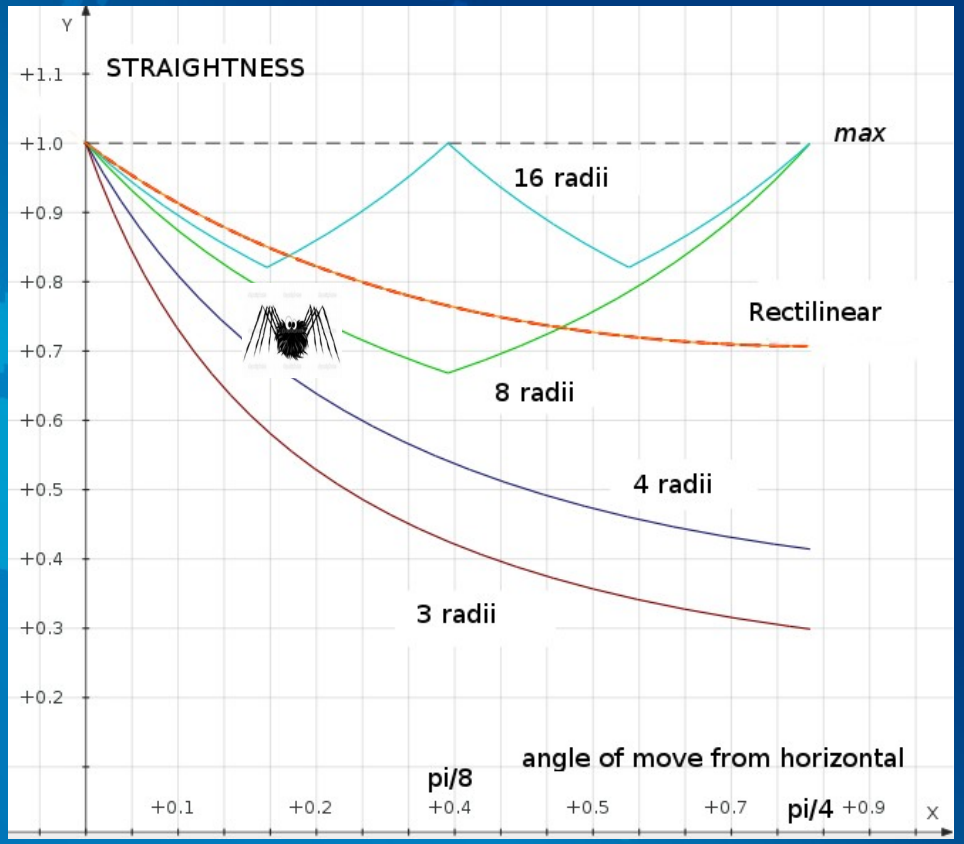

Part of a radioconcentric network

Angle α

# Relation between straightness and motion angle

Straightness S



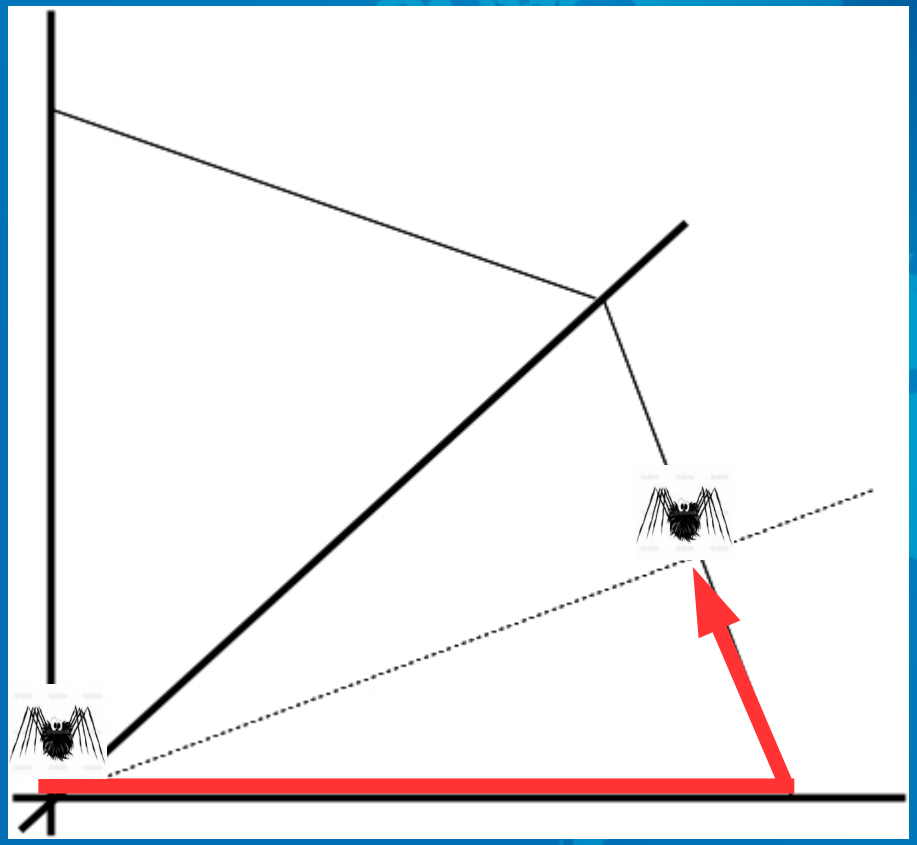


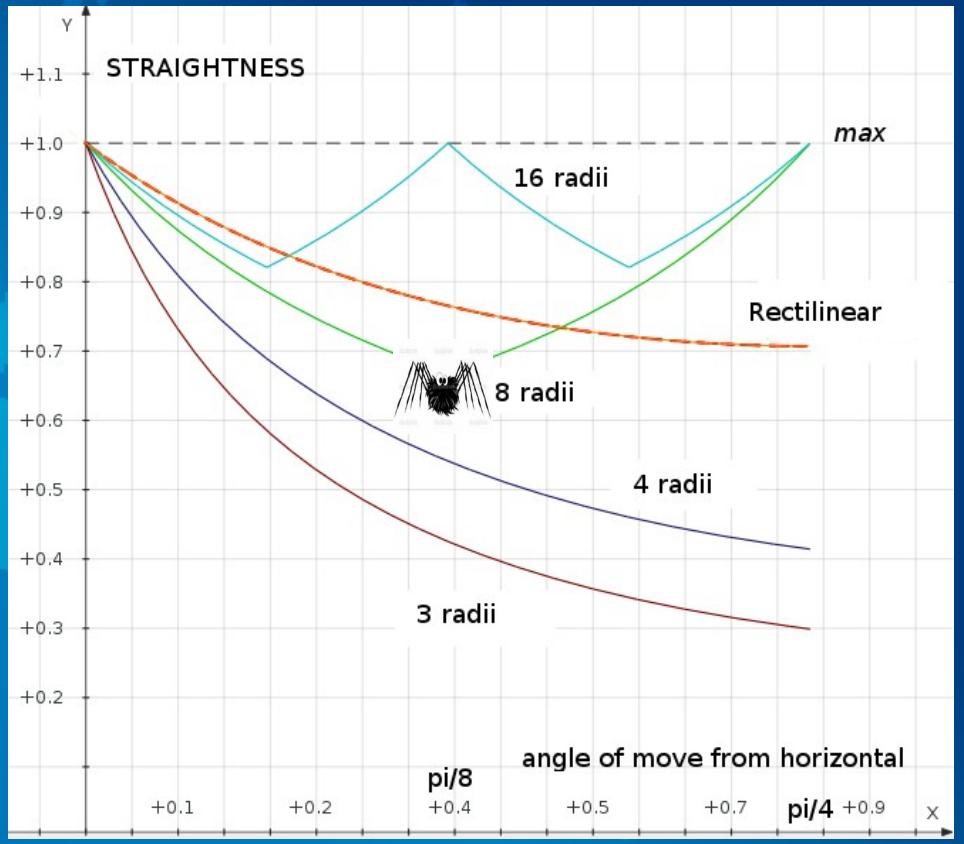

Part of a radioconcentric network

Angle α

# Relation between straightness and motion angle

Straightness S



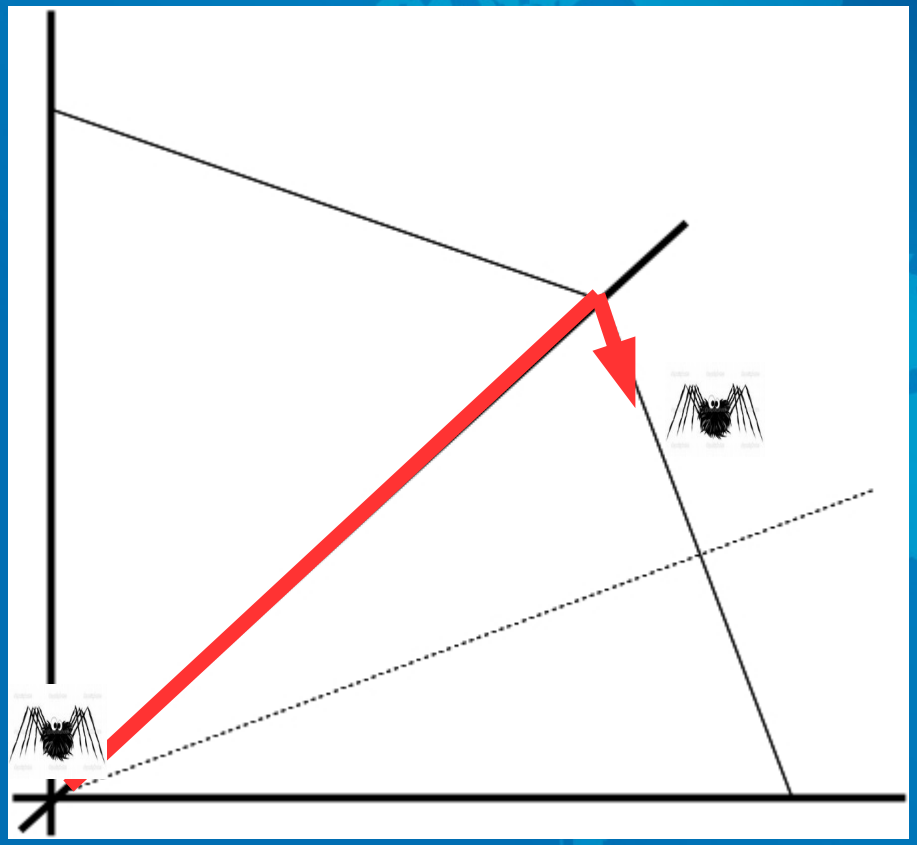


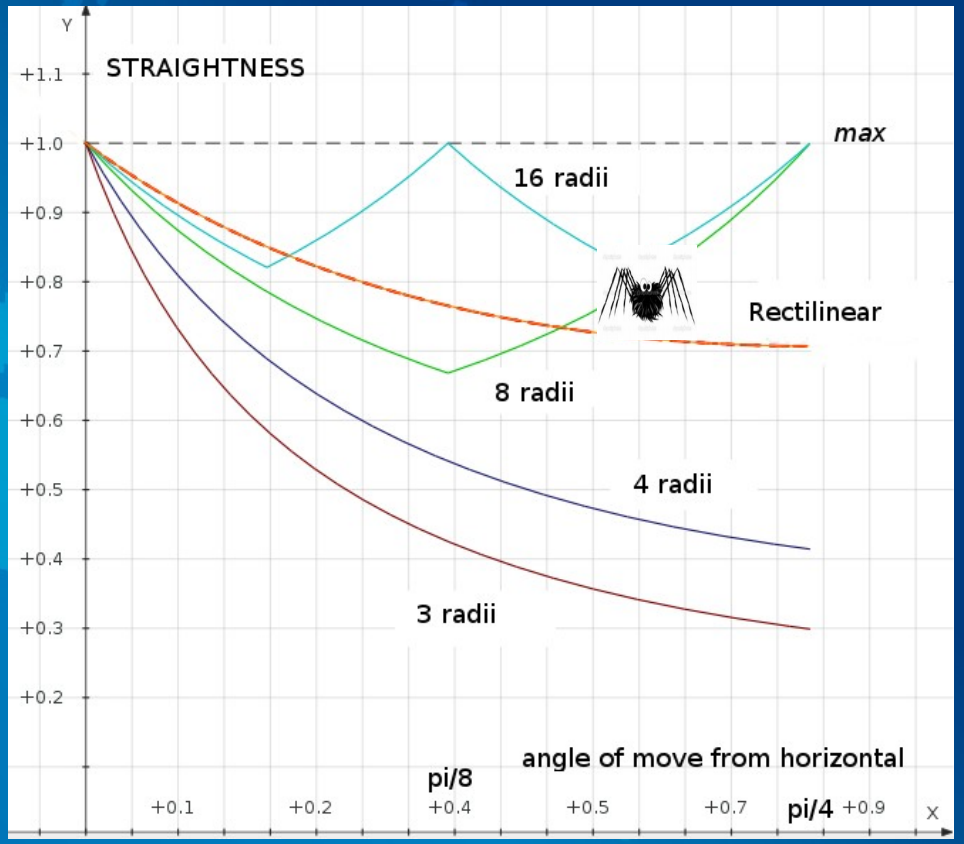

Part of a radioconcentric network

Angle α

# Relation between straightness and motion angle

Straightness S



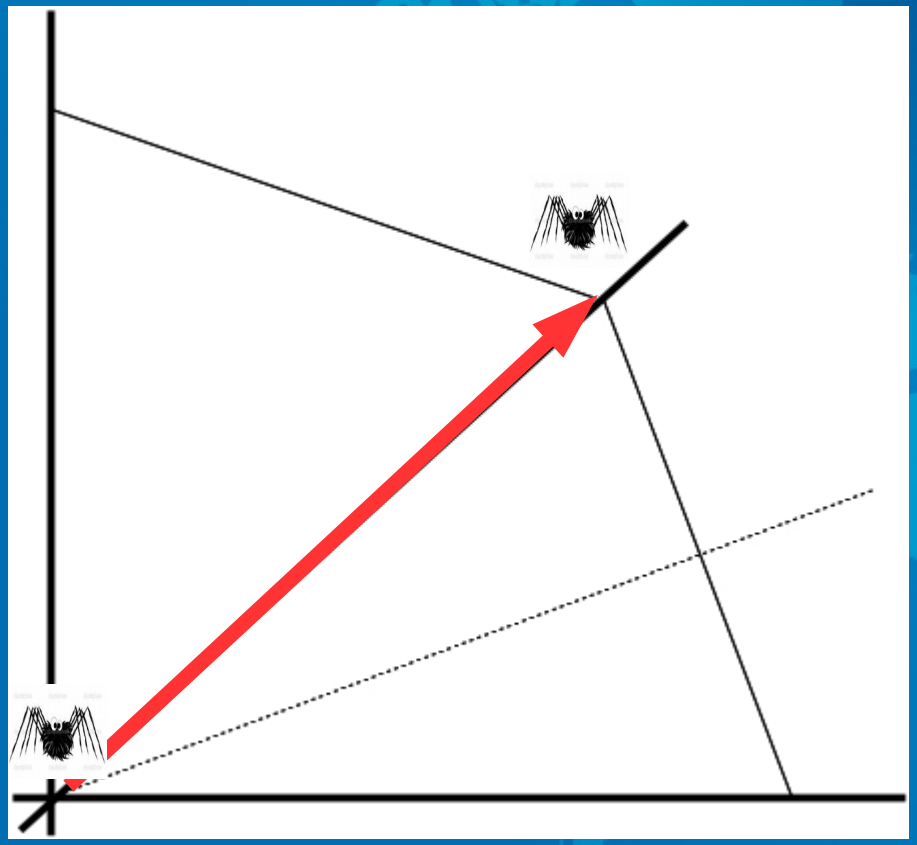


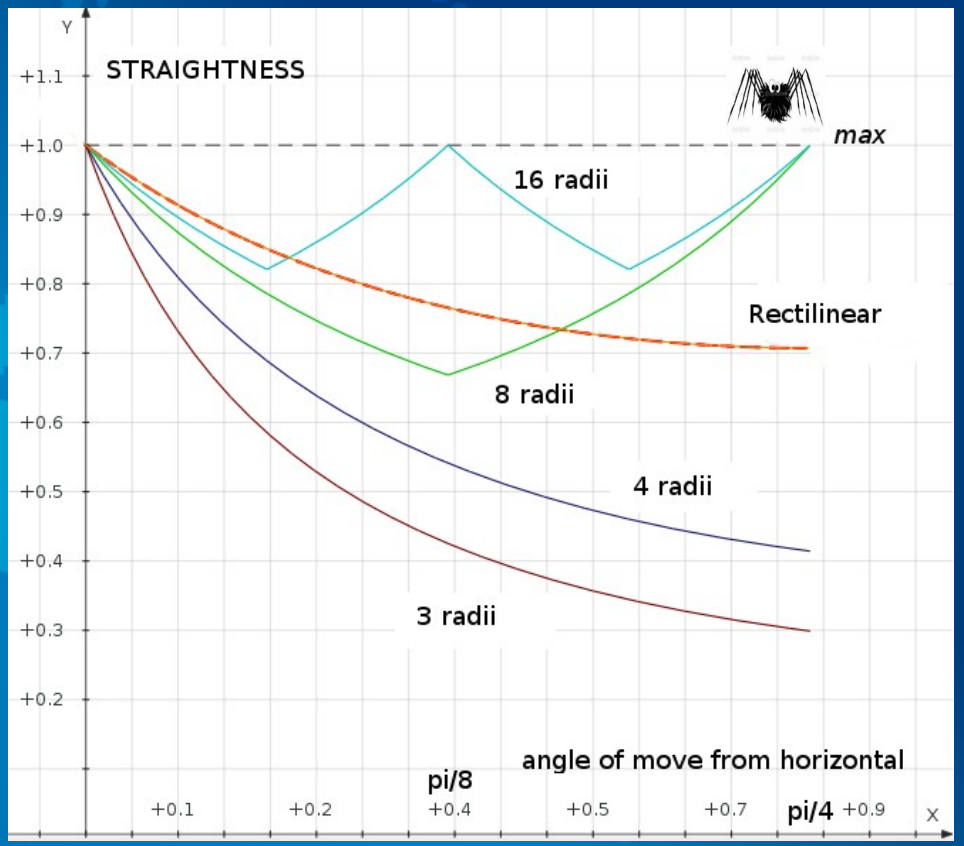

Part of a radioconcentric network

Angle α

# Relation between straightness and motion angle

Straightness S

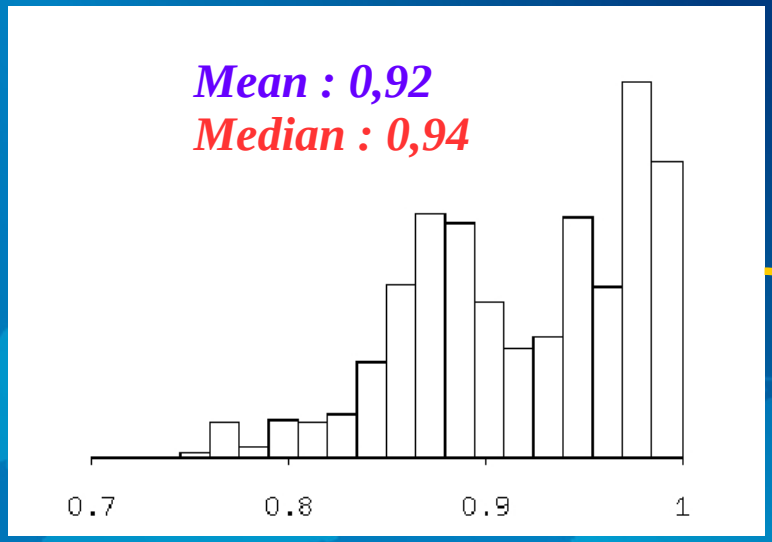





Part of a radioconcentric network

Angle α

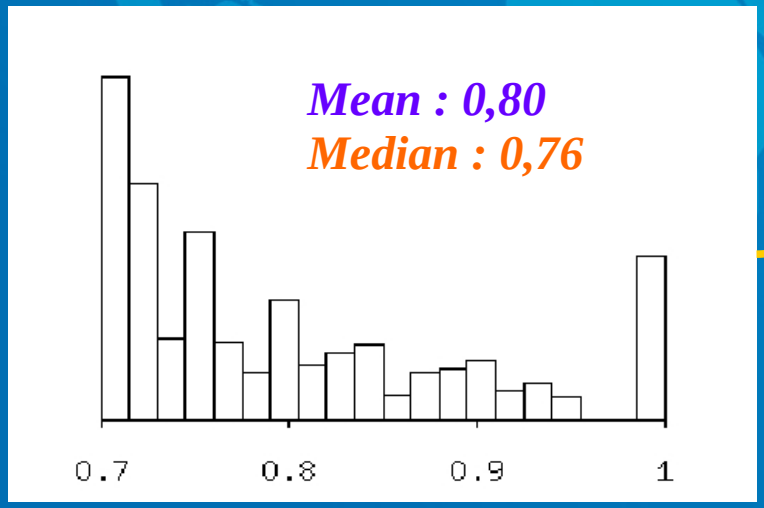
# Straightness calculated with agents




Orbweb

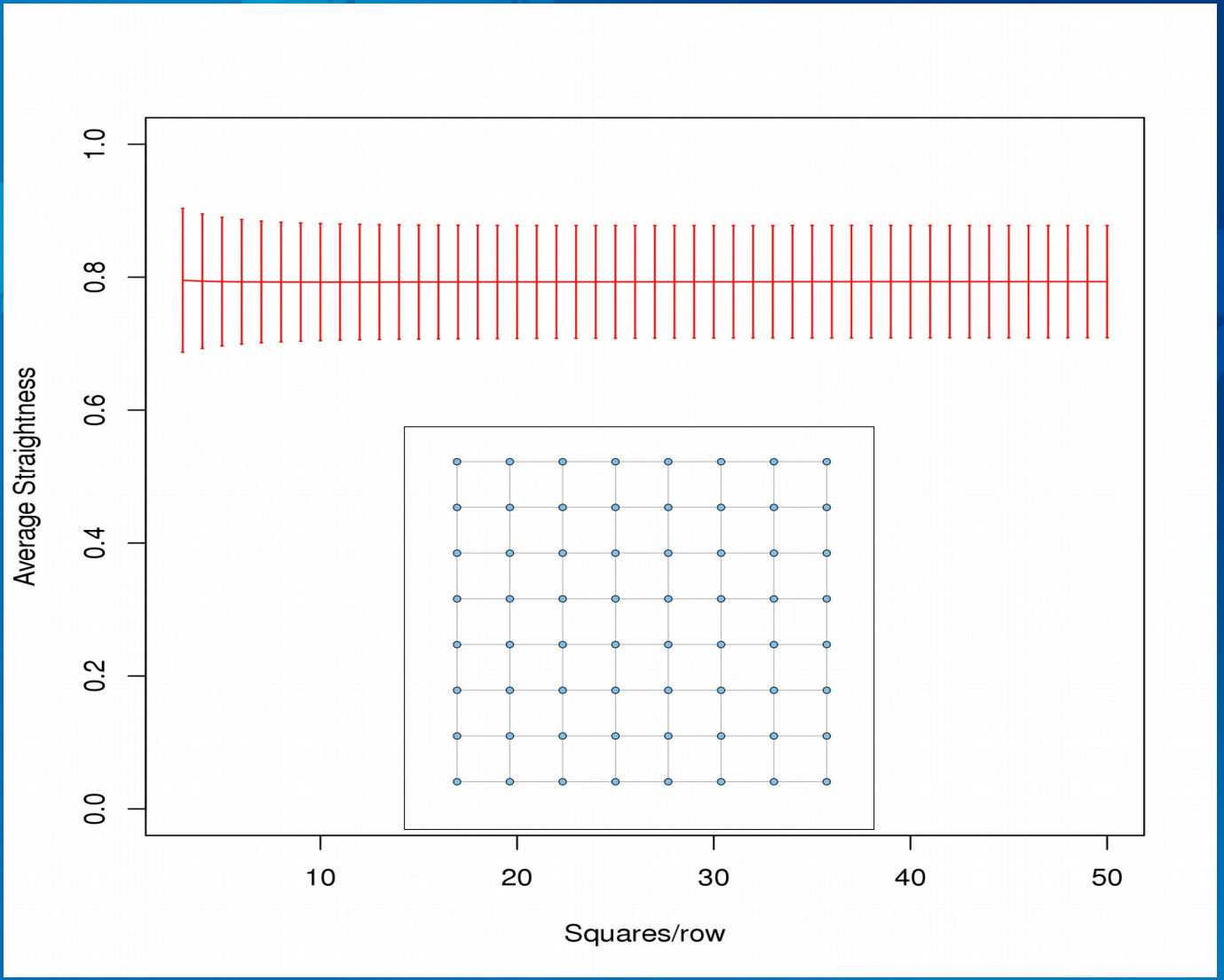
Straightness S

***Inversion of the Straightness distribution shapes***

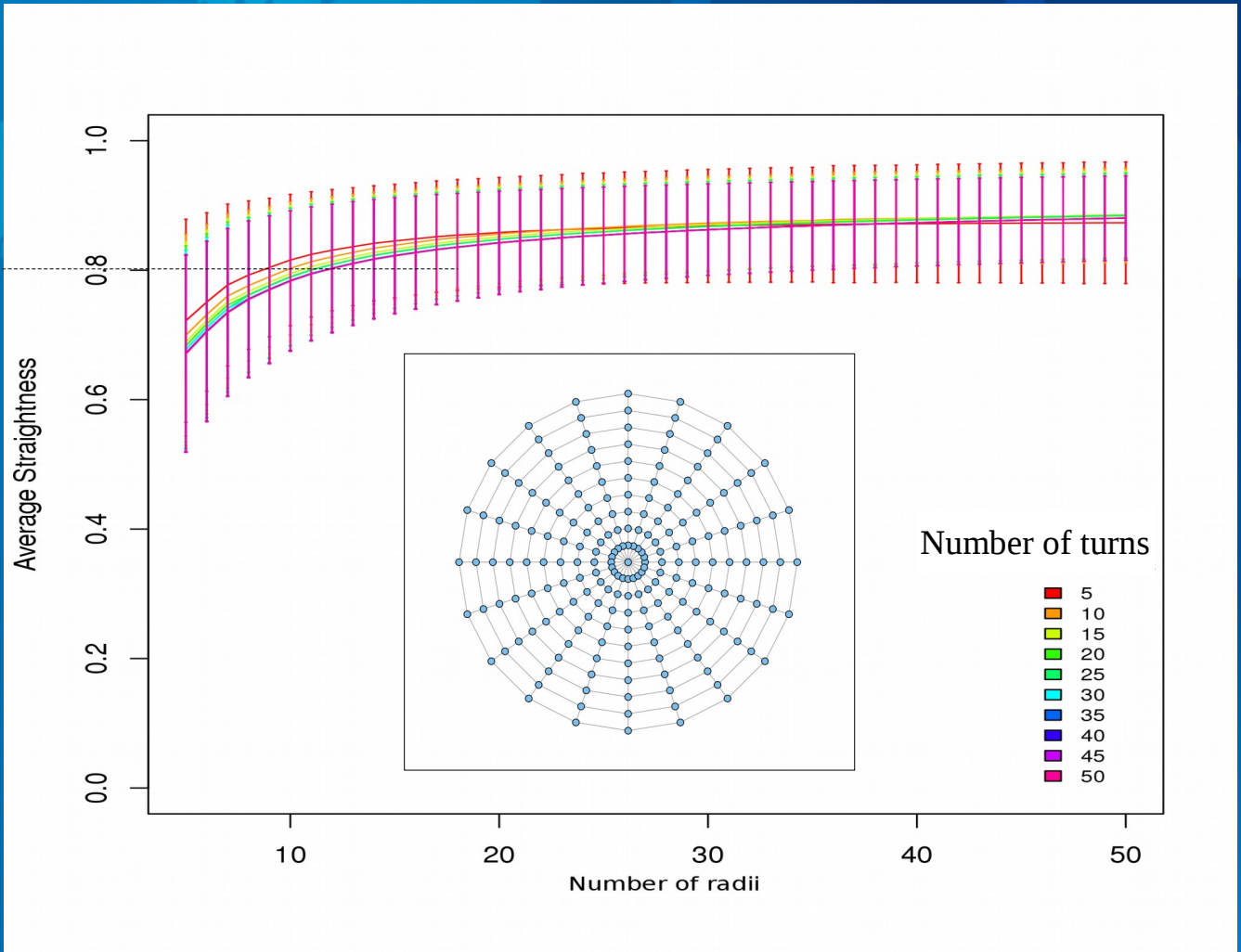



Rectilinear network

# Average straightness S (and standard deviation) for a rectilinear network, as a function of its size (expressed in number of squares by side)

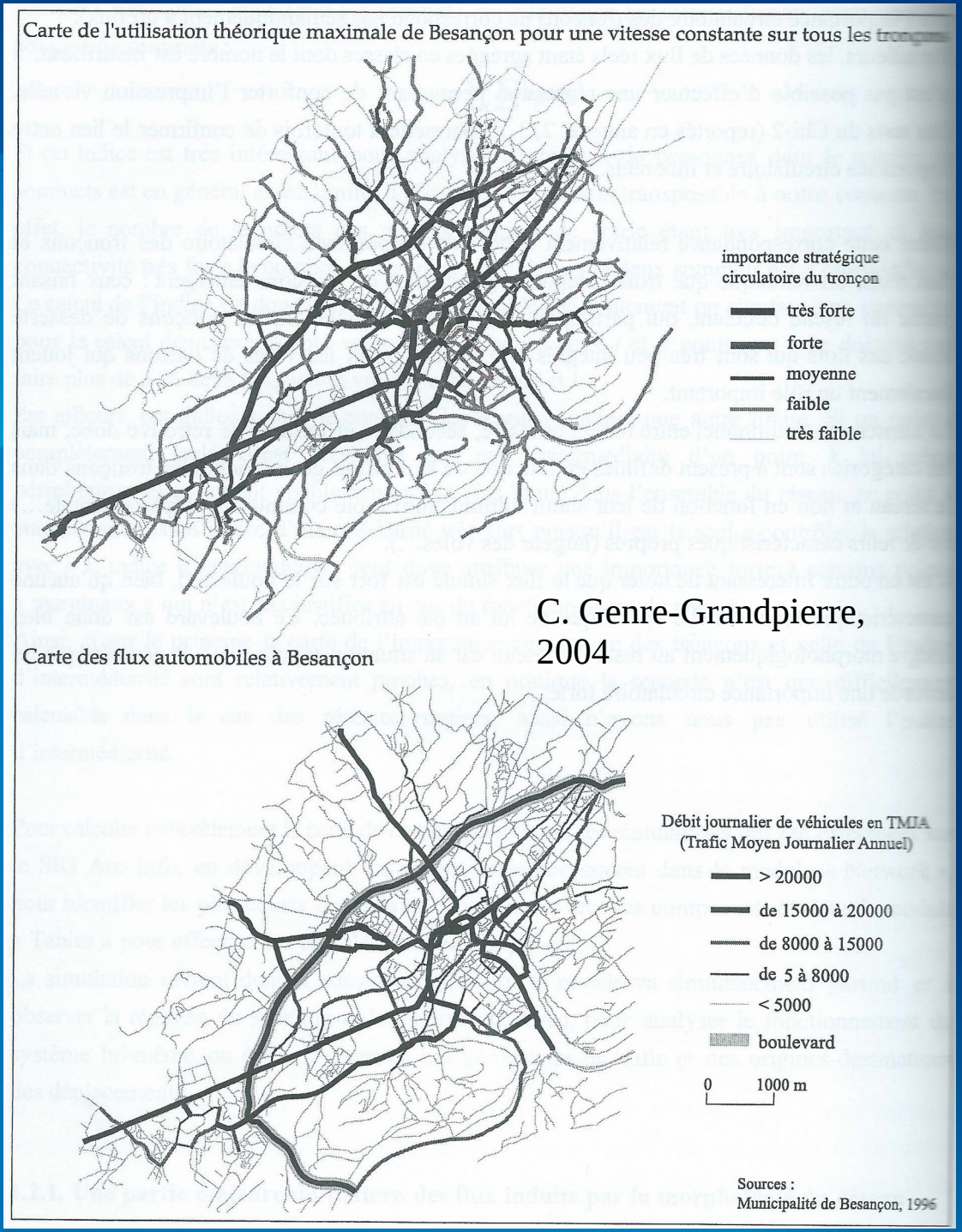


# Average straightness S (and standard deviation) for a radiocentric network, as a function of its number of radii, and for different number of turns (see colors).

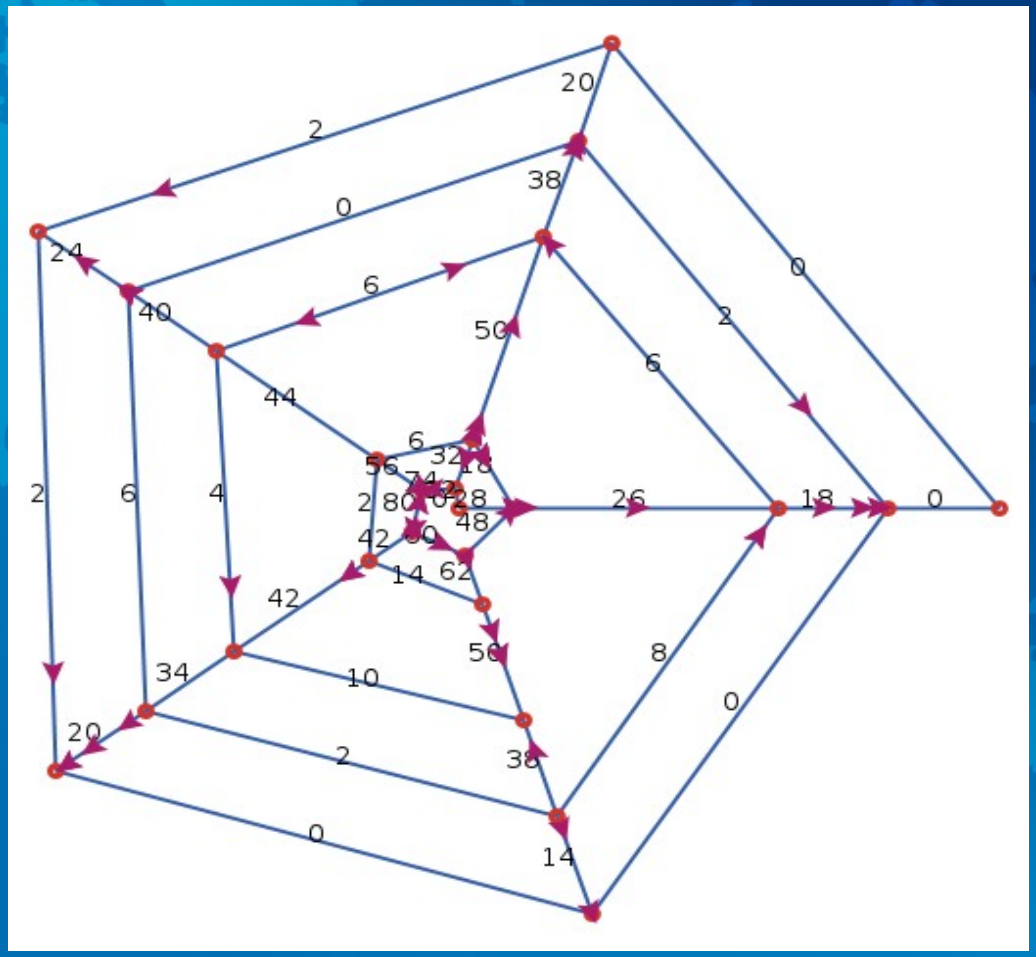


# BETWEENESS CENTRALITY

# Theoretical flows *versus* Observed flows

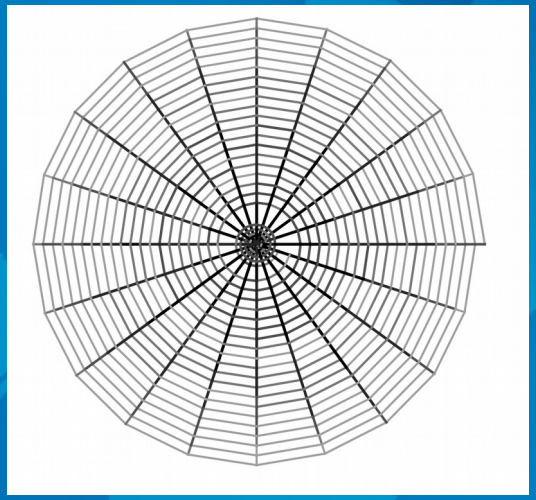


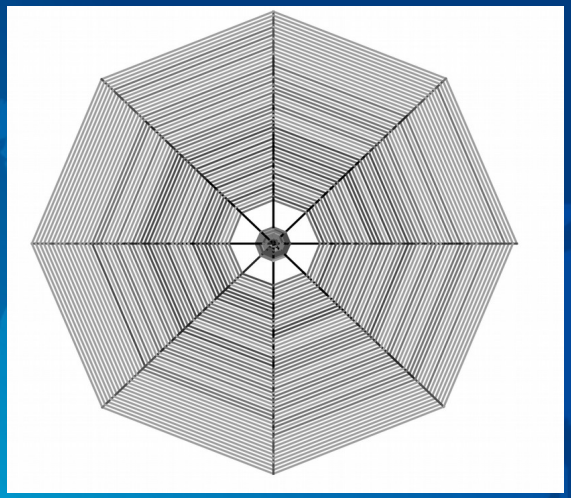
# Summing the agents passing on the network sections

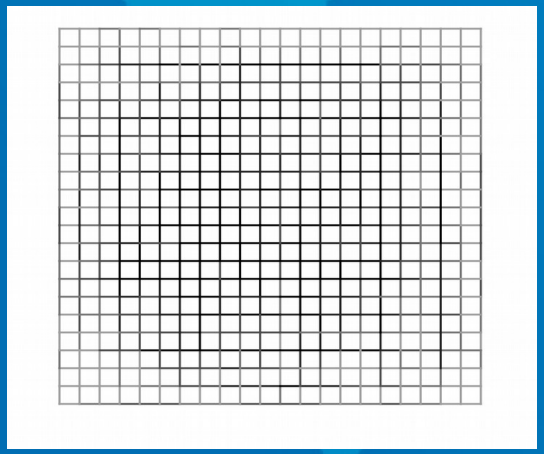


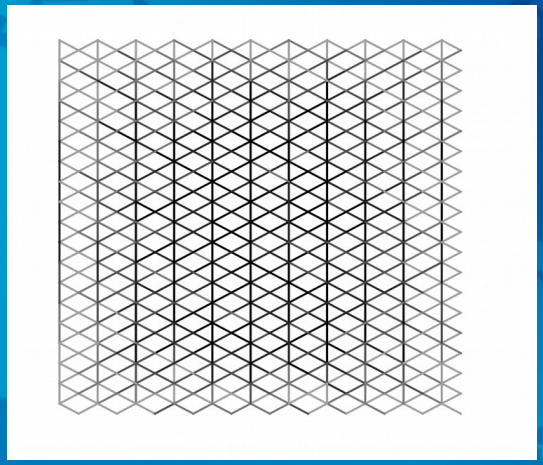

(Freeman, 1977)

# Betweeness centrality



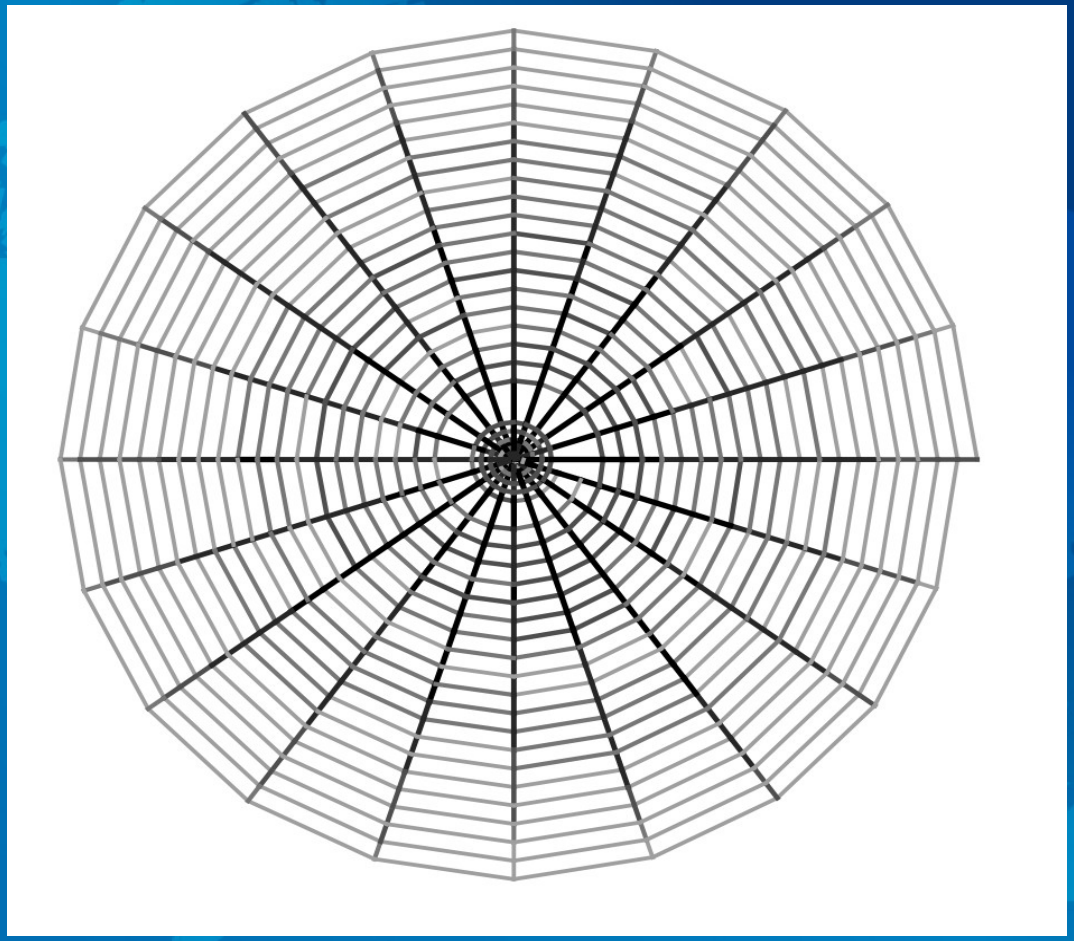






*Darker the line, higher the betweeness cenrality (number of trips)*

# Optimality of the glu location



*Its does not “cost” a lot to the spider to lay the glu on the external turns!*

# CONCLUSION

- Graph theory is a useful approach to assess network efficiency
- Over 10-15 radii, straightness of radioconcentric networks and orbwebs is better than rectilinear networks…
- …for centrifugal routes (spider) but also in general (for any route in average)
- The number or turns (circles/sides) has a lower importance than presumed

# ISSUES

- Can radioconcentic network fight efficiently against urban sprawl (*biomimicry*)?
- How much radioconcentric networks are traffic jam generators (*Multi-Agent simulations*)?
- What is the best network for straightness (*algorithm*)?
- Are orbwebs resilient (*Monte-Carlo simulations*)?
- Are orbwebs more efficient for other properties in graph theory from spider and human points of view (*graph theory*)?
- How to automatically extract graphs from photos (*imagery, mathematical morphology*)?
- Is the shortest path rational (other efficient routes) (*space syntax, Pareto multi-critera analysis*)?

# JIMIS

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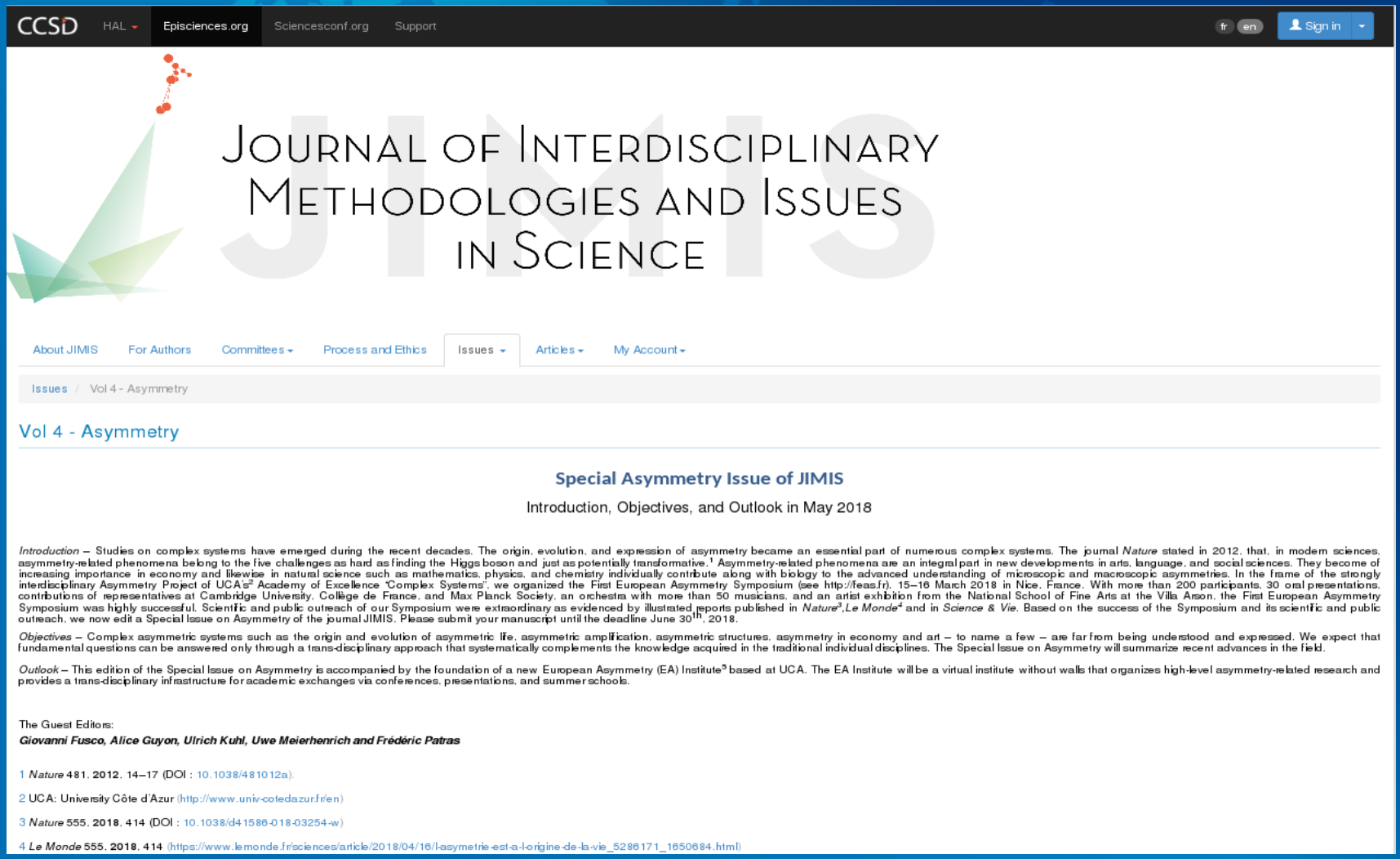

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Issues / Vol 4 - Asymmetry

### Vol 4 - Asymmetry

**Special Asymmetry Issue of JIMIS**

Introduction, Objectives, and Outlook in May 2018

*Introduction* – Studies on complex systems have emerged during the recent decades. The origin, evolution, and expression of asymmetry became an essential part of numerous complex systems. The journal *Nature* stated in 2012, that, in modern sciences, asymmetry-related phenomena belong to the five challenges as hard as finding the Higgs boson and just as potentially transformative.[1] Asymmetry-related phenomena are an integral part in new developments in arts, language, and social sciences. They become of increasing importance in economy and likewise in natural science such as mathematics, physics, and chemistry individually contribute along with biology to the advanced understanding of microscopic and macroscopic asymmetries. In the frame of the strongly interdisciplinary Asymmetry Project of UCA's[2] Academy of Excellence "Complex Systems", we organized the First European Asymmetry Symposium (see http://feas.fr), 15–16 March 2018 in Nice, France. With more than 200 participants, 30 oral presentations, contributions of representatives at Cambridge University, Collège de France, and Max Planck Society, an orchestra with more than 50 musicians, and an artist exhibition from the National School of Fine Arts at the Villa Arson, the First European Asymmetry Symposium was highly successful. Scientific and public outreach of our Symposium were extraordinary as evidenced by illustrated reports published in *Nature*[3], *Le Monde*[4] and in *Science & Vie*. Based on the success of the Symposium and its scientific and public outreach, we now edit a Special Issue on Asymmetry of the journal JIMIS. Please submit your manuscript until the deadline June 30th, 2018.

*Objectives* – Complex asymmetric systems such as the origin and evolution of asymmetric life, asymmetric amplification, asymmetric structures, asymmetry in economy and art – to name a few – are far from being understood and expressed. We expect that fundamental questions can be answered only through a trans-disciplinary approach that systematically complements the knowledge acquired in the traditional individual disciplines. The Special Issue on Asymmetry will summarize recent advances in the field.

*Outlook* – This edition of the Special Issue on Asymmetry is accompanied by the foundation of a new European Asymmetry (EA) Institute[5] based at UCA. The EA Institute will be a virtual institute without walls that organizes high-level asymmetry-related research and provides a trans-disciplinary infrastructure for academic exchanges via conferences, presentations, and summer schools.

The Guest Editors:

***Giovanni Fusco, Alice Guyon, Ulrich Kuhl, Uwe Meierhenrich and Frédéric Patras***

1 *Nature* 481, 2012, 14–17 (DOI : 10.1038/481012a).

2 UCA: University Côte d'Azur (http://www.univ-cotedazur.fr/en)

3 *Nature* 555, 2018, 414 (DOI : 10.1038/d41586-018-03254-w)

4 *Le Monde* 555, 2018, 414 (https://www.lemonde.fr/sciences/article/2018/04/16/l-asymetrie-est-a-l-origine-de-la-vie_5286171_1650684.html)

Merci de votre attention !

# Mesure de l'efficacité des réseaux radio-concentriques, urbains ou bio-inspirés, par deux métriques de la théorie des graphes : la rectitude et la centralité intermédiaire

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*Modèles et Apprentissages en Sciences Humaines et Sociales (MASHS), Paris, 24-25 mai 2018*