e-Human *Grid* Ecology

A New Direction in

Erasmus Computing Grid

Cyberspace and Virtual Societies

Tobias A. Knoch

Prof. U.D. Dr. rer. nat.

TA.Knoch@taknoch.org

Biophysical Genomics & Erasmus Computing Grid

Dept. Cell Biology & Genetics, Erasmus Medical Center, Rotterdam, The Netherlands.

BioQuant Center & German Cancer Research Center (DKFZ), Heidelberg, Germany.

The Challenge of e-Life and a-Life

The advances in information technology are not only the basis of modern life but also lead to cyberspace and virtual societies with entirely new aspects of then called e-Life, which is in principle a subspecies of artificial life in general.

---

e-Life and a-Life are characterized by fundamentally different properties compared to the classical biological life and the emergence of society and culture thereof!

The Principle of b-Life:

⇒ b-Life is locked by the background of biological evolution and cannot exceed its inherent time scales, laws and systems!

=> shifts without violating the basic law of nature to =>

:The Principle of e-Life and a-Life

e-Life and a-Life can leave the background of their evolution and can exceed their inherent <= time scales, laws and systems !!!!!

The e-Life and a-Life challenge lies in the new of human ecology rectangle phenomena:

- **Micro-Phenomena: the new internal properties with their new time scales, laws and systems.**
- **Macro-Phenomena: the entirely new e-Social and a-Social phenomena evolving from the micro phenomena.**

The Erasmus Computing Grid

The largest desktop grid for the biomedical research and care sectors with now ~10 Tera FLOPS and a potential ~30 Tera FLOPS and ~15,000 desktops, at two city wide institutions: the Hogeschool Rotterdam and the Erasmus Medical Center.

Research:

- genomic and proteomic analysis
- epidemiology
- image analysis, e.g. Applied Molecular Imaging (AMI)

Education:

- training of the coming grid generation of IT specialists
- developing new concepts for grid computing

Diagnostics:

- clinical image and data analysis
- operation planning and operation support

Industry:

- brokerage of computing resources

Dedicated and Secured!

MediGRID and Services@MediGRID

MediGRID and Services@MediGRID operate the national biomedial research and care cluster-grid within the national German D-Grid initiative and integrate various disciplines, institutions, and states throughout Germany.

Erasmus Computing Grid

Erasmus MC

HOGESCHOOL ROTTERDAM

~ 20 BioMedical User Groups

Distributed - Office

~ 20 D-Grid Communities

~ 100 D-Grid Donor Organizations (~10 MediGRID)

~10,000 Cluster Nodes

~ 2,000 Medical Secured

Module Coordination:
- coordination of the distributed office

Module Resource Integration:
- sharing of the integrated resources

Module Middleware:
- grid technical virtualization

Module Ontology Tools:
- ontology development for grid user projects

Module BioMedical Informatics:
- user projects in biomedical research

Module Clinical Imaging:
- user projects in clinical imaging

Module Clinical Research:
- user projects in general clinical research

Module e-Science:
- general research on e-grid science

Services@MediGRID:
- services towards MediGRID

Dedicated and Secured!

Large-Scale Resource Sharing in IT:

The *Inverse* Tragedy of the Commons

The grid phenomenon and its implications are similar complicated to the ecology/climate/ environmental challenge!

The Tragedy of the Commons:

=> A resource belonging to all and being on limited demand is overexploited / destroyed by the users due to responsibility diffusion!

<= transforms into =>

:The *Inverse* Tragedy of the Commons

A Resource belonging to all and being in affluent availability on limited demand is <= *underexploited* by potential users due to responsibility diffusion !!!!!

Similarity: Renewable Energy Resource!

The grid challenge lies in the e-Social embedding of grid phenomenons:

- **Micro-Social: the sharing attitude and socialization of the individual.**
- **Macro-Social: the organization culture of the embedding institution.**

Autopoietic Social Sub-Systems:

The Grid Challenge of Integration

The social systems theory by Niklas Luhmann (1927-1998) based on the autopoietic concept of Humberto Maturana and Francisco Varela (1946-2001) is so far the most advanced social systems theory existing to describe the complexity of grid implementation.

The Social Sub-Systems Involved:

- **Religion**
- **Education**
- **Science**
- **Art**
- **Economy**
- **Jurisdiction**
- **Policy**

=> currently grid involves only considerably => SCIENCE

:The Autopeitic Tragedy of Social Sub-Systems

The subsystems have their own code of communication and are separated from each other in a way blocking in principle a consistent integration although they form a society with all their contradictions !!!!!

The e-Social challenge lies in the integration of sub-systems towards a working grid society:

- **Micro-Sub-Systems: the sub-system stickiness of individuals.**
- **Macro-Sub-Systems: the integration of institutionalized sub-systems via soft interfaces.**

Grid Psychology

From Individual to Cultural Risk Management

Erasmus Computing Grid

Erasmus MC

HOGESCHOOL ROTTERDAM

Grid implementation and social spread is carried first by individuals as with any meme introduced into society: in the focus of the transformation of society to e-Society stands - as always - the balance between potential risk and opportunity.

linking grid psychology with autopoietic social sub-systems

The Risk Psycholgy Matrix:

- **Individual Security Perception & Risk Acceptance**
- **Knowledge-Based Security & Risk Acceptance**
- **Incidental Security Reaction Behaviour**
- **Legal and Political Security Scenarios**
- **Religious & Cultural Security Archetypi**

:The Autopoietic Link

Genetics & Deep Psychology (C.G. Jung)

Education & Science

Economics & Realities

Jurisdiction & Politics

Religion, Art & Culture

The grid challenge lies in a unified concept addressing the psychology of grid:

- **Micro-Risk-Management: the micro-risk in the perception the individual and its emotional well-being.**
- **Macro-Risk-Management: the macro-risks in the procedural and institutionalization in organizations.**

e-Human *"Grid"* Ecology

Overcoming of the "Dare-To-Share" Attitude

The success of grid is based on a sustainable grid ecology within the e-Society, i.e. the e-Human Ecology of Grid reaches a equilibrated space within the integration of grid psychology with autopoietic e-Social sub-systems. Human Ecology first evolved in Chicago in the 1920's in the area of city development by Robert Park (1864-1944) and Ernest Burgess (1886-1966).

The Definition of e-Human "Grid" Ecology:

"Under e-Human "Grid" Ecology we understand the complete science of the relationships of grid to the surrounding environment to which we can count all conditions of existence in the widest sense."[1]

[1] Haeckel, E., Generelle Morphology der Organismen, Berlin, Band 2, Allgemeine Entwicklungsgeschichte, p. 286, 1866.

[2] Haeckel, E., Natürliche Schöpfungsgeschichte, 9. Auflage, Berlin, p. 793, 1898

(e-Human "Grid" Ecology "is) …the relationship between grid and all other e-Social systems." [2]

=> Solution to the Inverse Tragedy of the Commons!

The solutions of the grid challenge on the operational layer are addressed by:

- **Micro-Operationality: the participative integration of fundamental IT applications of major individual users complying with the psychology of grid in an e-Human Ecology manner.**
- **Macro-Operationality: the set-up of an open and sustainable management structure complying to all the autopoietic e-Social sub-systems in an e-Human Ecology manner.**

The Curriculum of e-Human Ecology

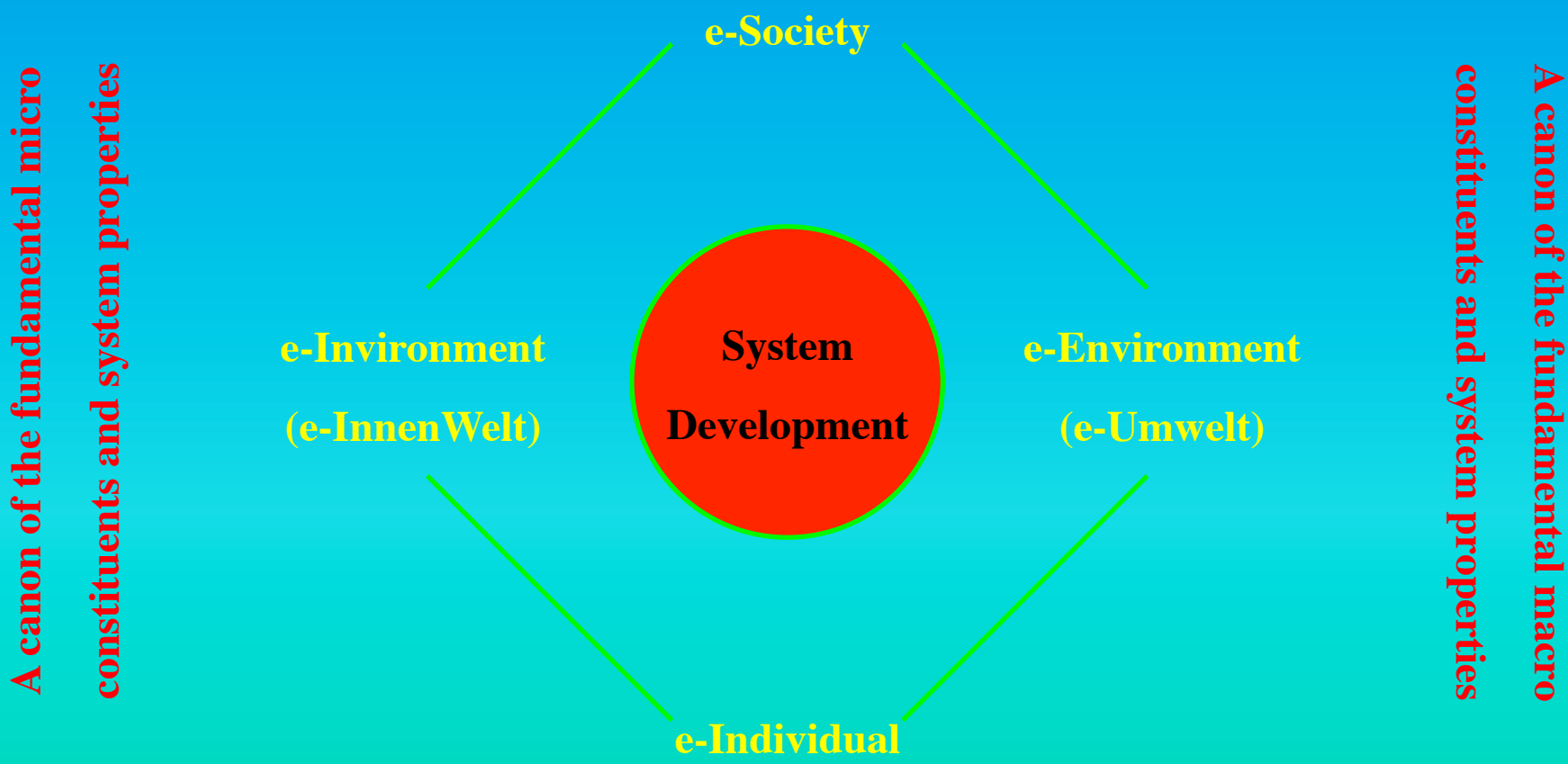
Curricula of the canon and grammar of e-Human Ecology need to contain the further developed classic contents of the human ecology rectangle as well as the knowledge and understanding of the special aspects of e-Life and a-Life.

Erasmus Computing Grid

Erasmus MC

HOGESCHOOL ROTTERDAM

The classic human ecology triangle is transformed into the *human ecology rectangle*, to complete the circle for creation and dependencies for a curriculum canon and grammar!



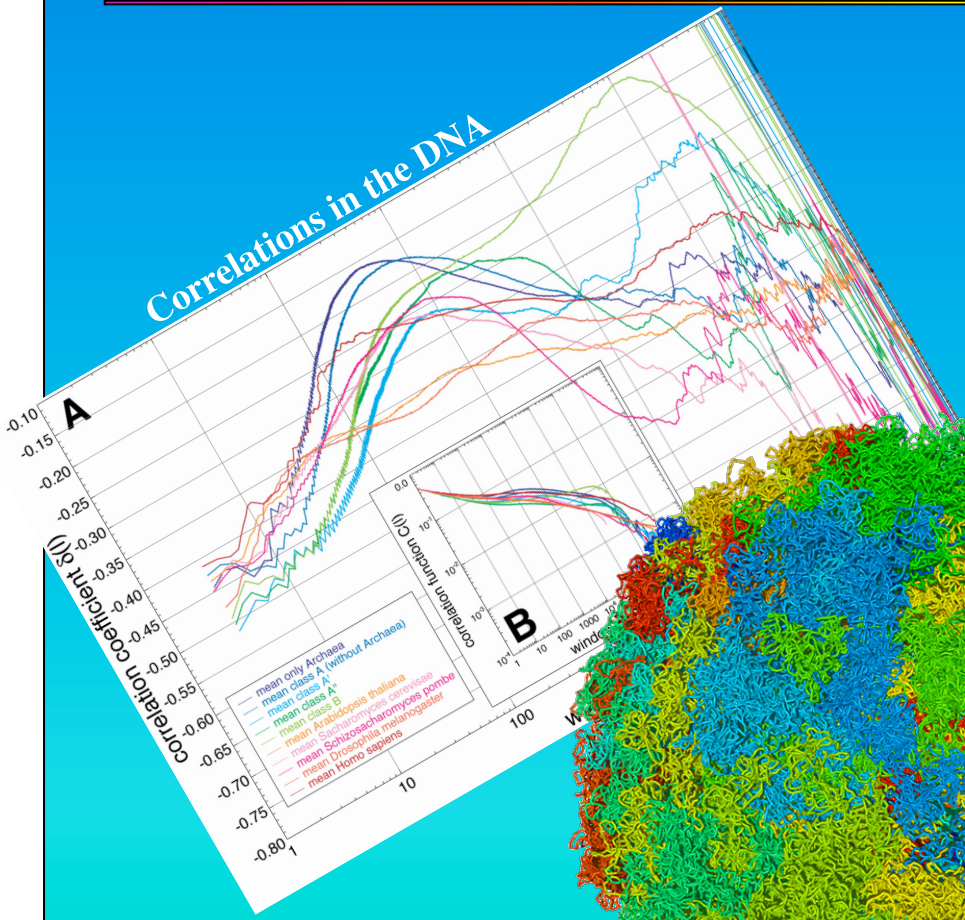
The Happy End - Profits Sharing the Commons

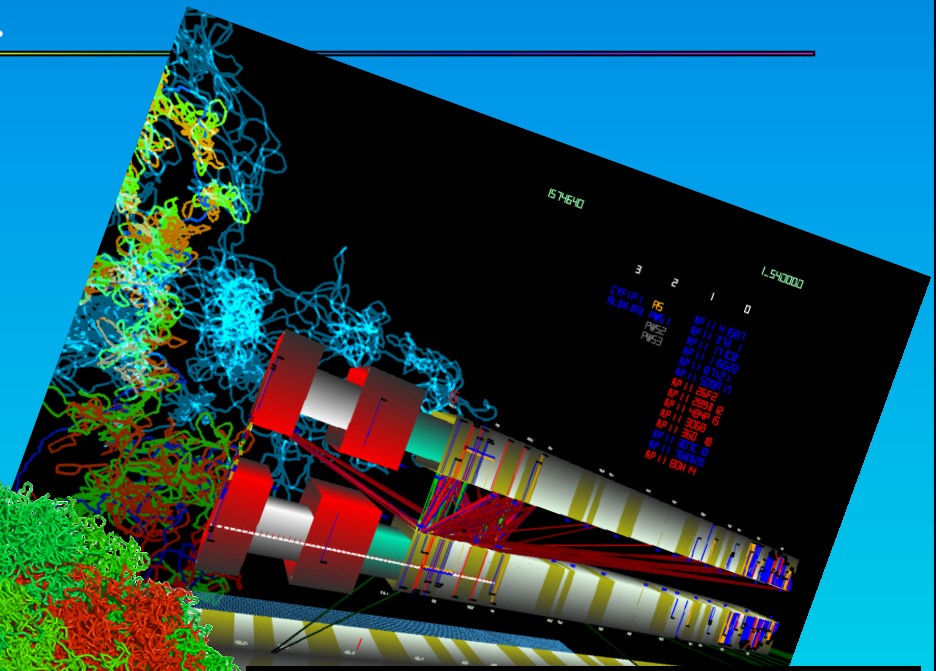
Both the Erasmus Computing Grid and the MediGRID/Services@MediGRID examples show that the IT challenges mankind faces in the biomedical research and care sectors can be successfully approached by exploitation of the commons by e-Human "grid" Ecology means.

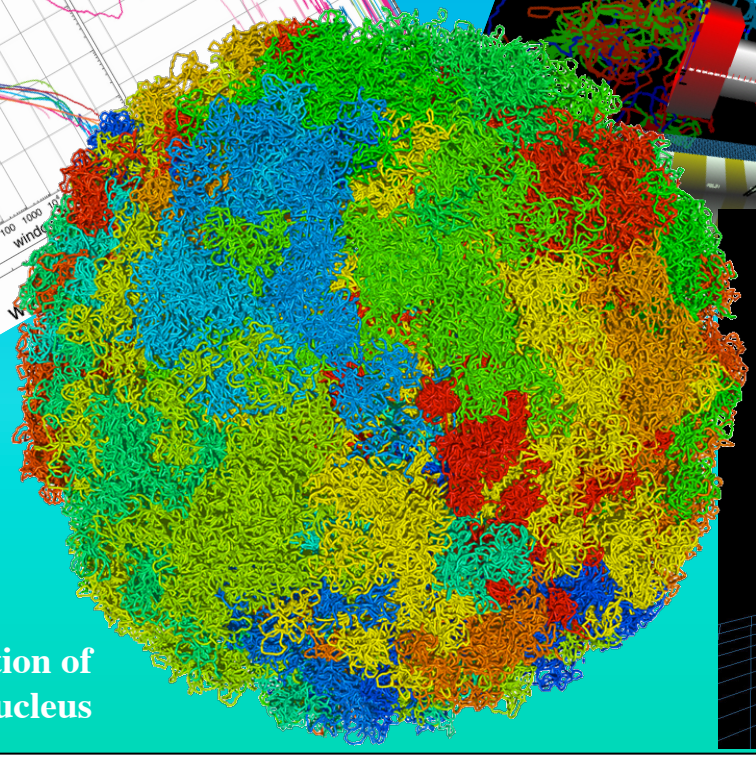
Erasmus Computing Grid

Erasmus MC

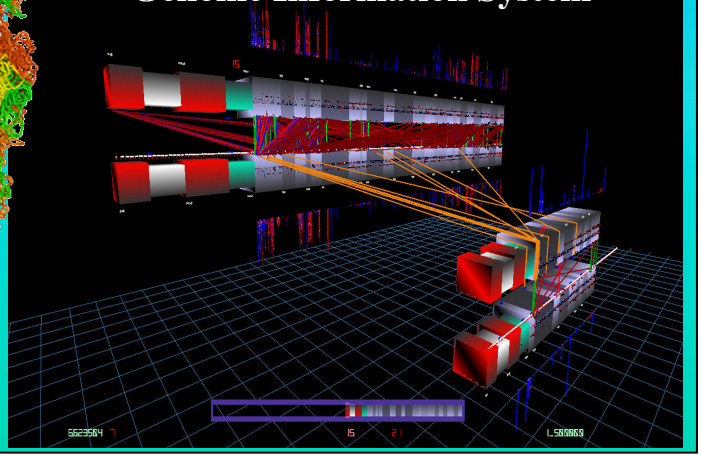
HOGESCHOOL ROTTERDAM







GLOBE 3D System-Biological Genome Information System



Simulation of the Organization of an entire Human Cell Nucleus

Acknowledgements

Biggest thanks go to: resource donors and grid users!!!

Human Ecology

Kurt Egger

Volkmar Baumgärtner

Julia Hampl

Human Ecology Group Heidelberg

German Society for Human Ecology

MediGRID:

Technical: Thomas Steinke & Annette Weisbecker

Organization: Sebastian Semmler

Management: Ulrich Sax & Otto Rienhoff

Institutions:

The Participating Institutions

The German MediGRID & Services@MediGRID

The D-Grid Initiative(s)

The German Ministry for Science and Technology

ECG:

Co-Director: Luc V. de Zeeuw

Technical: Rob de Graaf & Anis Abuseiris

Advisory Board: Frank G. Grosveld & Arthur van der Kamp

Institutions:

Erasmus Medical Center

Hogeschool Rotterdam

The Dutch Ministry for Science and Technology

Approaching the Internalization Challenge of Grid Technologies

Into

e-Society

by

e-Human "Grid" Ecology.

Knoch, T. A., Baumgärtner, V., Grosveld, F. G. & Egger, K.

Economics of Grids, Clouds, Systems, and Services – GECON 2010 7th International Workshop, Hotel Continental Terme Ischia, Ischia - Naples, Italy, 30th - 11st August, 2010.

Abstract

The amount of information is growing exponentially with ever-new technologies emerging and is believed to be always at the limit. In contrast, huge resources are obviously available, which are underused in the IT sector, similar as e.g. in the renewable energy sector. This is especially for grid with its fast turnover rates very astonishing considering the barriers for further development put forward by the inability to satisfy the need for such resources. The phenomenon is a typical example of the *Inverse Tragedy of the Commons*, i.e. resources are underexploited in contrast to the unsustainable and destructing overexploitation in the *Classic Tragedy of the Commons*. An analysis of IT and the grid sector which attempts to share resources for better usage efficiency, reveals two challenges, which lead to the heart of the paradox: i) From a macro perspective all grid infrastructures involve not only mere technical solutions but also dominantly all of the autopoietic social sub-systems ranging from religion to policy. ii) On the micro level the individual players and their psychology and risk behaviour are of major importance for acting within the macro autopoietic framework. Consequently, the challenges of grid implementation are similar to those of other pressing global issues as e.g. climate protection. This is well described by extending the *Human Ecology* triangle to a rectangle: invironment-individual-society-environment. By applying this extension of this classical field of interdisciplinary basic and applied research to the grid sector, i.e. by further extension to an *e-Human Grid Ecology* rational, the *Grid Inverse Tragedy of the Commons* can be understood and approached regarding the internalization challenge into e-Society and e-Life, from which then guidelines for the day-to-day management can be derived. This is of general importance for many complex fields and thus with similar paradoxes and challenges.

Corresponding author email contact: TA.Knoch@taknoch.org

Keywords:

Human ecology, e-human grid ecology, society, social systems, e-social challenge, inverse tragedy of the commons, grid phenomenon, parallel super computing, grid computing, volunteer computing, micro-sociality, macro-sociality, autopoietic tragedy of social sub-systems, micro subsystems, macro subsystems, micro operationality, macro operationality, grid psychology micro riskmanagement, macro riskmanagement, information browser, visual data base access, holistic viewing system, integrative data management, extreme visualization, three-dimensional virtual environment, virtual paper tool.

Literature References

Knoch, T. A. Dreidimensionale Organisation von Chromosomen-Domänen in Simulation und Experiment. (Three-dimensional organization of chromosome domains in simulation and experiment.) *Diploma Thesis*, Faculty for Physics and Astronomy, Ruperto-Carola University, Heidelberg, Germany, 1998, and TAK Press, Tobias A. Knoch, Mannheim, Germany, ISBN 3-00-010685-5 and ISBN 978-3-00-010685-9 (soft cover, 2rd ed.), ISBN 3-00-035857-9 and ISBN 978-3-00-0358857-0 (hard cover, 2rd ed.), ISBN 3-00-035858-7, and ISBN 978-3-00-035858-6 (DVD, 2rd ed.), 1998.

Knoch, T. A., Münkel, C. & Langowski, J. Three-dimensional organization of chromosome territories and the human cell nucleus - about the structure of a self replicating nano fabrication site. *Foresight Institute - Article Archive*, Foresight Institute, Palo Alto, *CA, USA,* http://www. foresight.org, 1- 6, 1998.

Knoch, T. A., Münkel, C. & Langowski, J. Three-Dimensional Organization of Chromosome Territories and the Human Interphase Nucleus. *High Performance Scientific Supercomputing*, editor Wilfried Juling, Scientific Supercomputing Center (SSC) Karlsruhe, University of Karlsruhe (TH), 27- 29, 1999.

Knoch, T. A., Münkel, C. & Langowski, J. Three-dimensional organization of chromosome territories in the human interphase nucleus. *High Performance Computing in Science and Engineering 1999*, editors Krause, E. & Jäger, W., High-Performance Computing Center (HLRS) Stuttgart, University of Stuttgart, Springer Berlin-Heidelberg-New York, ISBN 3-540-66504-8, 229-238, 2000.

Bestvater, F., **Knoch, T. A.**, Langowski, J. & Spiess, E. GFP-Walking: Artificial construct conversions caused by simultaneous cotransfection. *BioTechniques* 32(4), 844-854, 2002.

Knoch, T. A. (editor), Backes, M., Baumgärtner, V., Eysel, G., Fehrenbach, H., Göker, M., Hampl, J., Hampl, U., Hartmann, D., Hitzelberger, H., Nambena, J., Rehberg, U., Schmidt, S., Weber, A., & Weidemann, T. Humanökologische Perspectiven Wechsel - Festschrift zu Ehren des 70. Geburtstags von Prof. Dr. Kurt Egger. Human Ecology Working Group, Ruperto-Carola University of Heidelberg, Heidelberg, Germany, 2002.

Knoch, T. A. Approaching the three-dimensional organization of the human genome: structural-, scaling- and dynamic properties in the simulation of interphase chromosomes and cell nuclei, long- range correlations in complete genomes, *in vivo* quantification of the chromatin distribution, construct conversions in simultaneous co-transfections. *Dissertation*, Ruperto-Carola University, Heidelberg, Germany, and TAK†Press, Tobias A. Knoch, Mannheim, Germany, ISBN 3-00-009959-X and ISBN 978-3-00-009959-5 (soft cover, 3rd ed.), ISBN 3-00-009960-3 and ISBN 978-3-00-009960-1 (hard cover, 3rd ed.), ISBN 3-00-035856-9 and ISBN 978-3-00-010685-9 (DVD, 3rd ed.) 2002.

Knoch, T. A. Towards a holistic understanding of the human genome by determination and integration of its sequential and three-dimensional organization. *High Performance Computing in Science and Engineering 2003*, editors Krause, E., Jäger, W. & Resch, M., High-Performance Computing Center (HLRS) Stuttgart, University of Stuttgart, Springer Berlin-Heidelberg-New York, ISBN 3- 540-40850-9, 421-440, 2003.

Wachsmuth, M., Weidemann, T., Müller, G., Urs W. Hoffmann-Rohrer, **Knoch, T. A.**, Waldeck, W. & Langowski, J. Analyzing intracellular binding and diffusion with continuous fluorescence photobleaching. *Biophys. J.* 84(5), 3353-3363, 2003.

Weidemann, T., Wachsmuth, M., **Knoch, T. A.**, Müller, G., Waldeck, W. & Langowski, J. Counting nucleosomes in living cells with a combination of fluorescence correlation spectroscopy and confocal imaging. *J. Mol. Biol.* 334(2), 229-240, 2003.

Fejes Tóth, K., **Knoch**, **T. A.**, Wachsmuth, M., Frank-Stöhr, M., Stöhr, M., Bacher, C. P., Müller, G. & Rippe, K. Trichostatin A induced histone acetylation causes decondensation of interphase chromatin. *J. Cell Science* 177, 4277-4287, 2004.

Ermler, S., Krunic, D., **Knoch, T. A.**, Moshir, S., Mai, S., Greulich-Bode, K. M. & Boukamp, P. Cell cycle-dependent 3D distribution of telomeres and telomere repeat-binding factor 2 (TRF2) in HaCaT and HaCaT-myc cells. *Europ. J. Cell Biol.* 83(11-12), 681-690, 2004.

Kost, C., Gama de Oliveira, E., **Knoch, T. A.** & Wirth, R. Spatio-temporal permanence and plasticity of foraging trails in young and mature leaf-cutting ant colonies (*Atta spp.*). *J. Trop. Ecol.* 21(6), 677- 688, 2005.

Winnefeld, M., Grewenig, A., Schnölzer, M., Spring, H., **Knoch, T. A.**, Gan, E. C., Rommelaere, J. & Cziepluch, C. Human SGT interacts with BAG-6/Bat-3/Scythe and cells with reduced levels of either protein display persistence of few misaligned chromosomes and mitotic arrest. *Exp. Cell Res.* 312, 2500-2514, 2006.

Sax, U., Weisbecker, A., Falkner, J., Viezens, F., Yassene, M., Hartung, M., Bart, J., Krefting, D., **Knoch, T. A.** & Semler, S. Grid-basierte Services für die elektronische Patientenakte der Zukunft. *E- HEALTH-COM - Magazin für Gesundheitstelematik und Telemedizin*, 4(2), 61-63, 2007.

de Zeeuw, L. V., **Knoch, T. A.,** van den Berg, J. & Grosveld, F. G. Erasmus Computing Grid - Het bouwen van een 20 TeraFLOP virtuelle supercomputer. *NIOC proceedings 2007 - het perspective of lange termijn*. editor Frederik, H. NIOC, Amsterdam, The Netherlands, 52-59, 2007.

Rauch, J., **Knoch, T. A.** , Solovei, I., Teller, K. Stein, S., Buiting, K., Horsthemke, B., Langowski, J., Cremer, T., Hausmann, M. & Cremer, C. Lightoptical precision measurements of the Prader- Willi/Angelman Syndrome imprinting locus in human cell nuclei indicate maximum condensation changes in the few hundred nanometer range. *Differentiation* 76(1), 66-82, 2008.

Sax, U., Weisbecker, A., Falkner, J., Viezens, F., Mohammed, Y., Hartung, M., Bart, J., Krefting, D., **Knoch, T. A.** & Semler, S. C. Auf dem Weg zur individualisierten Medizin - Grid-basierte Services für die EPA der Zukunft. *Telemedizinführer Deutschland 2008*, editor Jäckel, A. Deutsches Medizinforum, Minerva KG, Darmstadt, ISBN 3-937948-06-6, ISBN-13 9783937948065, 47-51, 2008.

Drägestein, K. A., van Capellen, W. A., van Haren, J. Tsibidis, G. D., Akhmanova, A., **Knoch, T. A.**, Grosveld, F. G. & Galjart, N. Dynamic behavior of GFP-CLIP-170 reveals fast protein turnover on microtubule plus ends. *J. Cell Biol. 180(4)*, 729-737, 2008.

Jhunjhunwala, S., van Zelm, M. C., Peak, M. M., Cutchin, S., Riblet, R., van Dongen, J. J. M., Grosveld, F. G., **Knoch, T. A.**$^{+}$ & Murre, C.$^{+}$ The 3D-structure of the Immunoglobulin Heavy Chain Locus: implications for long-range genomic interactions. *Cell 133(2)*, 265-279, 2008.

Krefting, D., Bart, J., Beronov, K., Dzhimova, O., Falkner, J., Hartung, M., Hoheisel, A., **Knoch, T. A.**, Lingner, T., Mohammed, Y., Peter, K., Rahm, E., Sax, U., Sommerfeld, D., Steinke, T., Tolxdorff, T., Vossberg, M., Viezens, F. & Weisbecker, A. MediGRID - Towards a user friendly secured grid infrastructure. *Future Generation Computer Systems 25(3)*, 326-336, 2008.

Knoch, T. A., Lesnussa, M., Kepper, F. N., Eussen, H. B., & Grosveld, F. G. The GLOBE 3D Genome Platform - Towards a novel system-biological paper tool to integrate the huge complexity of genome organization and function. *Stud. Health. Technol. Inform. 147*, 105-116, 2009.

Knoch, T. A., Baumgärtner, V., de Zeeuw, L. V., Grosveld, F. G., & Egger, K. e-Human Grid Ecology: Understanding and approaching the Inverse Tragedy of the Commons in the e-Grid Society. *Stud. Health. Technol. Inform. 147*, 269-276, 2009.

Dickmann, F., Kaspar, M., Löhnardt, B., **Knoch, T. A.,** & Sax, U. Perspectives of MediGRID. *Stud. Health. Technol. Inform. 147*, 173-182, 2009.

Knoch, T. A., Göcker, M., Lohner, R., Abuseiris, A. & Grosveld, F. G. Fine-structured multi-scaling long-range correlations in completely sequenced genomes - features, origin and classification. *Eur. Biophys. J. 38(6)*, 757-779, 2009.

Dickmann, F., Kaspar, M., Löhnhardt, B., Kepper, N., Viezens, F., Hertel, F., Lesnussa, M., Mohammed, Y., Thiel, A., Steinke, T., Bernarding, J., Krefting, D., **Knoch, T. A.** & Sax, U. Visualization in health-grid environments: a novel service and business approach. *LNCS 5745*, 150-159, 2009.

Dickmann, F., Kaspar, M., Löhnhardt, B., Kepper, N., Viezens, F., Hertel, F., Lesnussa, M., Mohammed, Y., Thiel, A., Steinke, T., Bernarding, J., Krefting, D., **Knoch, T. A.** & Sax, U. Visualization in health-grid environments: a novel service and business approach. *Grid economics and business models - GECON 2009 Proceedings, 6th international workshop, Delft, The Netherlands.* editors Altmann, J., Buyya, R. & Rana, O. F., GECON 2009, LNCS 5745, Springer-Verlag Berlin Heidelberg, ISBN 978-3-642-03863-1, 150-159, 2009.

Estrada, K.[*], Abuseiris, A.[*], Grosveld, F. G., Uitterlinden, A. G., **Knoch, T. A.**[+] & Rivadeneira, F.[+] GRIMP: A web- and grid-based tool for high-speed analysis of large-scale genome-wide association using imputed data. *Bioinformatics 25(20), 2750-2752*, 2009.

Kepper, N., Schmitt, E., Lesnussa, M., Weiland, Y., Eussen, H. B., Grosveld, F. G., Hausmann, M. & **Knoch T. A.,** Visualization, Analysis, and Design of COMBO-FISH Probes in the Grid-Based GLOBE 3D Genome Platform. *Stud. Health Technol. Inform. 159*, 171-180, 2010.

Kepper, N., Ettig, R., Dickmann, F., Stehr, R., Grosveld, F. G., Wedemann, G. & **Knoch, T. A.** Parallel high-performance grid computing: capabilities and opportunities of a novel demanding service and business class allowing highest resource efficiency. *Stud. Health Technol. Inform. 159*, 264-271, 2010.

Skrowny, D., Dickmann, F., Löhnhardt, B., **Knoch, T. A.** & Sax, U. Development of an information platform for new grid users in the biomedical field. *Stud. Health Technol. Inform. 159*, 277-282, 2010.

Knoch, T. A., Baumgärtner, V., Grosveld, F. G. & Egger, K. Approaching the internalization challenge of grid technologies into e-Society by e-Human "Grid" Ecology. *Economics of Grids, Clouds, Systems, and Services – GECON 2010 Proceedings*, 7th International Workshop, Ischia, Italy, editors Altman, J., & Rana, O. F., Lecture Notes in Computer Science (LNCS) 6296, Springer Berlin Heidelberg New York, ISSN 0302-9743, ISBN-10 3-642-15680-0, ISBN-13 978-3-642-15680-9, 116-128, 2010.

Dickmann, F., Brodhun, M., Falkner, J., **Knoch, T. A.** & Sax, U. Technology transfer of dynamic IT outsourcing requires security measures in SLAs. *Economics of Grids, Clouds, Systems, and Services – GECON 2010 Proceedings*, 7th International Workshop, Ischia, Italy, editors Altman, J., & Rana, O. F., Lecture Notes in Computer Science (LNCS) 6296, Springer Berlin Heidelberg New York, ISSN 0302-9743, ISBN-10 3-642-15680-0, ISBN-13 978-3-642-15680-9, 1-115, 2010.

Knoch, T. A. Sustained Renewability: approached by systems theory and human ecology. *Renewable Energy 2*, editors M. Nayeripour & M. Keshti, Intech, ISBN 978-953-307-573-0, 21-48, 2011.

Kolovos, P., **Knoch, T. A.**, F. G. Grosveld, P. R. Cook, & Papantonis, A. Enhancers and silencers: an integrated and simple model for their function. *Epigenetics and Chromatin 5(1)*, 1-8, 2012.

Dickmann, F., Falkner, J., Gunia, W., Hampe, J., Hausmann, M., Herrmann, A., Kepper, N., **Knoch, T. A.**, Lauterbach, S., Lippert, J., Peter, K., Schmitt, E., Schwardmann, U., Solodenko, J., Sommerfeld, D., Steinke, T., Weisbecker, A. & Sax, U. Solutions for Biomedical Grid Computing - Case Studies from the D-Grid Project Services@MediGRID. *JOCS 3(5)*, 280-297, 2012.

Estrada, K.[*], Abuseiris, A.[*], Grosveld, F. G., Uitterlinden, A. G., **Knoch, T. A.**[+] & Rivadeneira, F.[+] GRIMP: A web- and grid-based tool for high-speed analysis of large-scale genome-wide association using imputed data. *Dissection of the complex genetic architecture of human stature and osteoporosis.* cummulative dissertation, editor Estrada K., Erasmus Medical Center, Erasmus University Rotterdam, Rotterdam, The Netherlands, ISBN 978-94-6169-246-7, 25-30, 1st June 2012.

van de Corput, M. P. C., de Boer, E., **Knoch, T. A.**, van Cappellen, W. A., Quintanilla, A., Ferrand, L., & Grosveld, F. G. Super-resolution imaging reveals 3D folding dynamics of the b-globin locus upon gene activation. *J. Cell Sci. 125*, 4630-4639, 2012.