

Publication Overview

2004 – 2020

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`https://github.com/jkerdels/pub_overview`

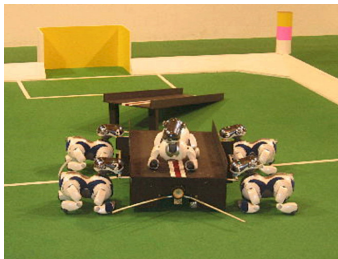
July 25, 2020

RoboCup 2004 ^(1/2)

As an undergraduate I participated in a yearlong **robotics project** in which we programmed ERS-210 and ERS-7 robotic dogs made by Sony to compete in the Standard Platform League (SPL) of the international **RoboCup 2004 competition**.

Our technical report [1] provides an in-depth look into the core challenges of teaching robots to play soccer, the solutions developed by our team, and the involved support infrastructure.

As part of the GermanTeam – a collaboration between the universities of Berlin, Bremen, Darmstadt, and Dortmund – we won the world championship in the SPL as well as the SPL Open Challenge.



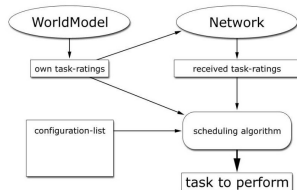
Scene from the SPL Open Challenge [1].

[1] Ingo Dahm et al. *Virtual Robot: Automatic Analysis of Situations and Management of Resources in a Team of Soccer Robots*. Tech. rep. PG 442 Final Report. University of Dortmund, 2004 [PDF](#) [bibtex](#)

We developed a **decentral scheduling algorithm** that allows multiple robots to coordinate their behavior to achieve a common goal in a challenging, dynamic environment where communication might be intermittent and the number of robots might change without prior notice [2, 3].

Characteristics of our approach:

- synchronization free
- low-bandwidth broadcast communication
- graceful degradation in case of
 - communication outages
 - loss of team members
- continuous replanning



Schematic of the proposed scheduler [2].

The scheduling algorithm was successfully used during the RoboCup 2004 competition winning the Standard Platform League Open Challenge [1]. [video](#)

[2] J. Ziegler et al. *Virtual Robot - Adaptive Ressource Management in Robot Teams*. Technical Report 0204. presented at International RoboCup Worldchampion, Lissboa, July 2004. University of Dortmund, 2004 [PDF](#) [bibtex](#)

[3] I. Dahm et al. "Decentral control of a robot-swarm". In: *Autonomous Decentralized Systems, 2005. ISADS 2005. Proceedings*. Apr. 2005, pp. 347–351. DOI: 10.1109/ISADS.2005.1452083 [PDF](#) [bibtex](#)

My diploma thesis [4] presents a novel approach to **discover objects in unlabeled image data** using a combination of traditional methods including image segmentation, feature extraction, clustering, and dynamic programming.

The key idea consists of using **image segmentation to group features** in an image, and use these feature groups to represent the individual segments in a way that is invariant to rotation, scale, and translation.

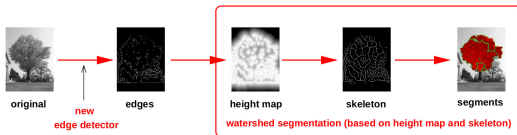
Such feature segments can then be related to each other by an appropriate distance measure to **identify segments that occur repeatedly** in different contexts.

Finally, neighborhood relations among segments can be learned in a similar fashion to **discover stable feature segment constellations** that indicate the presence of reoccurring structures, i.e., putative objects in the images.

[4] [Jochen Kerdels](#). "Dynamisches Lernen von Nachbarschaften zwischen Merkmalsgruppen zum Zwecke der Objekterkennung". [Diplomarbeit](#). [Diplom. University of Dortmund](#), Aug. 31, 2006 [PDF](#) [bibtex](#)

In [5] we present details of the **image segmentation** algorithm that was first introduced in my diploma thesis.

The algorithm has a focus on **robustness with respect to noise and discontinuous structures** like tree foliage.



Overview of the segmentation algorithm [5].

The algorithm was featured on the title page of “Informatik Spektrum” [6], the main organ of the German Informatics Society (GI).

[5] Gabriele Peters and Jochen Kerdels. “Image Segmentation Based on Height Maps”. In: *Computer Analysis of Images and Patterns*. Ed. by Walter G. Kropatsch, Martin Kampel, and Allan Hanbury. Vol. 4673. Lecture Notes in Computer Science. Springer Berlin Heidelberg, 2007, pp. 612–619. ISBN: 978-3-540-74271-5. DOI: 10.1007/978-3-540-74272-2_76. URL: http://dx.doi.org/10.1007/978-3-540-74272-2_76 [PDF](#) [bibtex](#)

[6] Jochen Kerdels and G. Peters. *Höhenbildbasierte Segmentierung*. Springer-Verlag. Jan. 2007 [PDF](#) [bibtex](#)

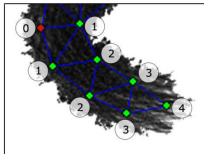
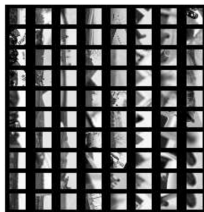


Illustration of distances on a learned topology [7].



Classification of feature vectors into 8 pairwise neighboring nodes. Columns represent nodes. Each column contains examples of 10 feature vectors mapped onto the respective node [7].

In [7] we present details of the **feature similarity measure** that was first introduced in my diploma thesis. The measure utilizes a **learned topology** of the feature space and does not rely on distance in Euclidean space.

Key ideas:

- Utilize a growing neural gas (GNG) to learn a piecewise representation of the feature space as well as its topology.
- Determine the shortest path between all pairs of nodes in the topology.
- The (dis)similarity between two features f_1 and f_2 is then given as the shortest path between those nodes g_1 and g_2 onto which the features are mapped by the GNG.

[7] Jochen Kerdels and G. Peters. "A Topology-Independent Similarity Measure for High-Dimensional Feature Spaces". In: *Artificial Neural Networks. 17th International Conference (ICANN 2007), September 9-13, Porto, Portugal. September 9-13, Porto*. Ed. by Joaquim Marques de Sá et al. Vol. 4669. LNCS Part 2. Porto, Portugal: Springer, Sept. 2007, pp. 331–340 [PDF](#) [bibtex](#)

Project C-Manipulator (1/4)

C-Manipulator [8] is a research project that was conducted from 2006 to 2009 at the German Research Center for Artificial Intelligence (**DFKI**) in Bremen.

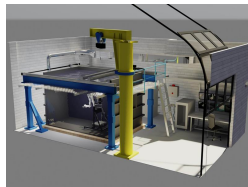
Its main objective was the development of a **manipulator system for deep sea applications** that provides autonomous and assistive functions to the system's operators.

The project used a **hydraulic ORION 7P** by Schilling Robotics as its main robotic arm. As main sensors, the system was equipped with two overhead cameras used for stereo vision and a single camera mounted to the wrist for visual servoing.

The project was finished successfully with an open water test in coastal waters. [video](#)



The ORION 7P manipulator
(c) Schilling Robotics)



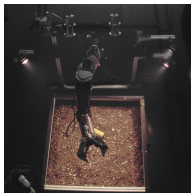
3D rendering of the underwater testbed
(Jan Albiez, DFKI)

[8] Dirk Spenneberg et al. "C-Manipulator: An Autonomous Dual Manipulator Project for Underwater Inspection and Maintenance". In: *Proceedings of OMAE 2007. ASME 2007 International Conference on Offshore Mechanics and Arctic Engineering*. San Diego, USA, 2007

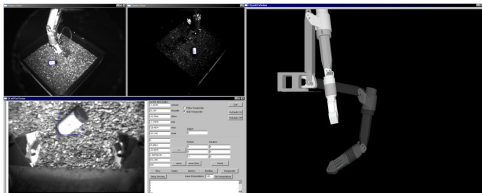
Project C-Manipulator (2/4)

In [9] we report on **early results** of the C-Manipulator project that introduce a number of improvements over the traditional, manual control of underwater robotic arms:

- We developed a **fast inverse kinematic closed form solution** that allows movements in cartesian space and guarantees numerical stability.
- We implemented a two-phase, **semi-autonomous gripping** of objects. [video](#)



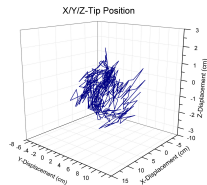
The Orion 7P in our underwater testbed [9].



View of the control software. The left side contains all three camera images. The right side shows a 3D representation of both the current (solid) and future (transparent) positions of the manipulator [9].

[9] Marc Hildebrandt et al. "Robust Vision-Based Semi-Autonomous Underwater Manipulation". In: *The 10th International Conference on Intelligent Autonomous Systems*. Ed. by Wolfram Burgard et al. IOS Press, 2008, pp. 308–315 [PDF](#) [bibtex](#)

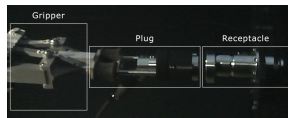
Project C-Manipulator (3/4)



3d plot of tip displacement during movement compensation [10].

Deep sea robotic arms are usually mounted to remotely operated vehicles (ROV). We developed a **novel algorithm to compensate for disturbances** that does not rely on the station-keeping algorithm of the ROV but compensates vehicle movements directly **via a movement overlay** in the robotic arm [10]. [video](#)

We **augmented the built-in controller** of the ORION 7P with a multi-layered controller enabling **high precision end-effector control** well beyond the manipulator's original capabilities [11]. We showcased the achievable precision by the automated plugging of an underwater connector. [video](#)



Automated plugging of a Gisma Series 80 underwater connector [11].

[10] Marc Hildebrandt et al. "Realtime motion compensation for ROV-based teleoperated underwater manipulators". In: *OCEANS 2009 - EUROPE*. 978-1-4244-2523-5. May 2009 [PDF](#) [bibtex](#)

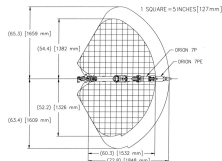
[11] Marc Hildebrandt et al. "A Multi-Layered Controller Approach for High Precision End-Effector Control of Hydraulic Underwater Manipulator Systems". In: *OCEANS 09 MTS / IEEE Biloxi - Marine Technology for Our Future: Global and Local Challenges. OCEANS MTS/IEEE Conference (OCEANS-09), Marine Technology for our Future: Global and Local Challenges, October 26-29, Biloxi, USA.* o.A., Oct. 2009. ISBN: 978-1-4244-4960-6 [PDF](#) [bibtex](#)

Project C-Manipulator (4/4)

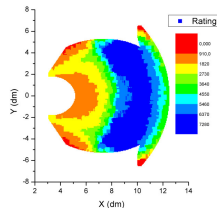
One of the primary tasks of modern ROV deployment is **intervention work**. Intervention in these cases consists of tasks like opening fixtures, or plugging connections.

Robotic operators have to rely solely on visual feedback and their experience to determine if in a given situation a desired position is reachable, and how much dexterity will be available to perform the intended task.

We introduced a **methodology to represent workspace properties** like remaining dexterity with respect to tele-operation tasks [12]. The information gained can be used as a signal to an operator or as the basis for motion commands to the ROV carrying the robot arm.



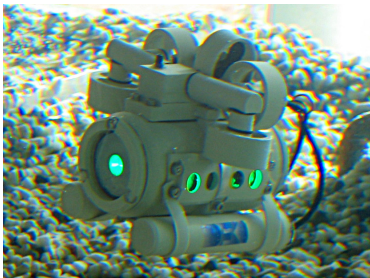
Nominal workspace of the ORION 7P [12].



Dexterous workspace of the ORION 7P for a front-down position of the gripper [12].

[12] Jan Albiez et al. "Automatic Workspace Analysis and Vehicle Adaptation for Hydraulic Underwater Manipulators". In: *OCEANS 2009, MTS/IEEE Biloxi - Marine Technology for Our Future: Global and Local Challenges*. o.A., Oct. 2009 [PDF](#) [bibtex](#)

The **Micro Autonomous Underwater Vehicle** (μ AUV) was developed and built as a demonstrator for the Hannover trade show in just two months [13, 14]. [video](#)



The μ AUV 1 [13].

Vehicle characteristics:

- main body diameter of just 55mm and a body length of 125mm
- autonomous on-board controller
- obstacle detection via active light reflection
- depth measurement via pressure sensor

Successors: μ AUV² and AUVx.

[13] Sascha Fechner et al. "Design of a μ AUV". In: *Autonomous Minirobots for Research and Edutainment (AMiRE-2007). Proceedings of the 4th International AMiRE Symposium (AMiRE-2007), October 2-5, Buenos Aires, Argentinien*. Ed. by U. Rückert, J. Sitte, and U. Witkowski. Best Paper Award. Buenos Aires, Argentinien: Heinz Nixdorf Institut Universität Paderborn, Oct. 2007, pp. 99–106 [PDF](#) [bibtex](#) **best paper award**

[14] Jan Albiez et al. "Sensor Processing and Behaviour Control of a Small AUV". In: *Autonome Mobile Systeme AMS 2007- 20. Fachgespräch Kaiserslautern*. Robotics Research Lab of the University of Kaiserslautern. Kaiserslautern, Germany: Springer, Oct. 2007, pp. 327–333 [PDF](#) [bibtex](#)

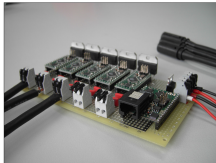
Sensorless Control

The sub-Atlantic underwater manipulator is an electric robotic arm that provides **no sensor feedback**. To control this arm we developed a **Back-EMF controller** that drives the motors via pulse width modulation and uses the voltage generated by the motors during the off-phase to determine their current speed [15].

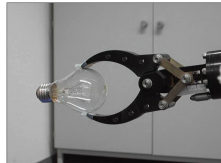
Based on this speed signal it was possible to implement both **position and force control** on this otherwise sensorless manipulator.



Voltage characteristic at the motor terminals while a 33% duty cycle PWM is applied [15].



Electronic prototype to demonstrate the Back-EMF approach [15].



Illustrating the sensitivity achievable with back EMF force control [15].

[15] Jochen Kerdels, Jan Albiez, and Frank Kirchner. "Sensorless Computer Control of an Underwater DC Manipulator". In: *Proceedings of OCEANS '08 (MTS) / IEEE KOBETECHNO-OCEAN '08. Voyage Toward the Future. (MTS) / IEEE KOBETECHNO-OCEAN Conference and Exhibition (OTO-2008), April 8-11, Kobe, Japan. IEEE, 2008* [PDF](#) [bibtex](#)

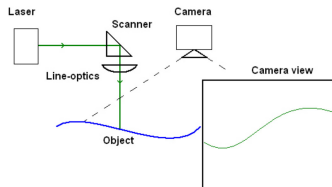
Underwater 3D-Laserscanner

To explore the concept of **underwater, laser line 3D scanning** we built a prototype system. In particular, we were interested in improving the precision of the scanner by designing a calibration procedure that is simple enough to be applicable in practise.

In [16] we suggest to use a planar calibration object that is fitted with a checkerboard pattern for calibration of the camera and a high contrast region for detecting the laser line.

Our results indicate that this is a feasible approach that could be used in non-laboratory environments without too much effort.

The concept was followed up on by a number of later projects and led to a **spin-off company** ([Kraken Robotik](#)) founded by some of my former colleagues.



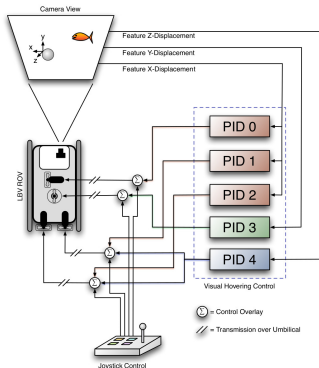
Schematic representation of a laser line 3D scanner [16].

[16] Marc Hildebrandt et al. "A practical underwater 3D-Laserscanner". In: *Proceedings of the MTS/IEEE Conference on Oceans, Poles and Climate*. MTS/ IEEE Oceans. IEEE, 2008 [PDF](#) [bibtex](#)

Visual Hovering

In [17] we present a **vision-based control** algorithm that enables underwater ROV to hover in front of visible structures compensating, e.g., drift.

We introduce a **novel approach to automatically tune the used keypoint detector** to the level of contrast present in each local region of the camera image. This automatic adjustment enables robust, parameter free operation.



Hovering control scheme with 5 PID controllers [17].



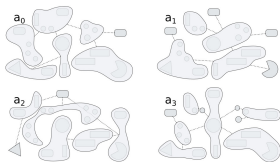
LBV hovering in laboratory test tank *locked* on the tip of a 3D gantry crane (left). Tracking of visual features (right) [17].

The algorithm was successfully tested on a LBV150 ROV [video](#) by Seabotix both under laboratory conditions and in open waters.

Exploratory Modeling (1/2)

After resigning from my research position at the DFKI and joining [Prof. Peters](#) at the University of Hagen I **refocused my work** away from robotic engineering towards more fundamental research aimed at understanding the **processing of information in neurobiological systems** – a topic I pursued already during my spare time at the DFKI.

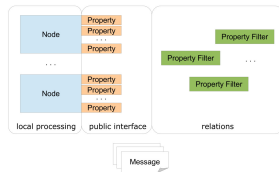
As a basis for this new direction of research we investigated how the **understanding of complex systems** can be improved **by methods of exploratory modeling and simulation**.



The constituents of a complex system may change when analyzed regarding different aspects [18].



Resulting constituents can "conceptually overlap" when they are merged into a single model [18].



Components of the proposed generalized model [18].

Exploratory Modelling (2/2)

In [18] we **identify key aspects** that make modeling complex systems difficult:

- The relations between the constituents of a complex system can vary over time in non-trivial ways and thus cannot be specified in advance.
- Mutual influences between constituents of a complex system are not only represented by higher-level categories as in complicated systems but are also indicated by shared, lower-level categories.
- If a complex system is analyzed with respect to different aspects, the resulting constituents for each aspect can “conceptually overlap” when they are merged into a single model of the system.

Using a computational modeling perspective we reduced the problem space further to a single problem that we call the **addressing problem**.

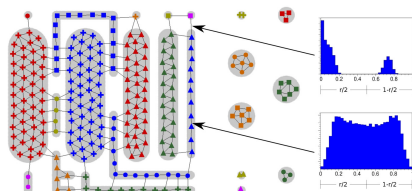
As a solution to the addressing problem we propose a **generalized computational model** that is tailored to the specific needs of modeling and simulating complex systems [18, 19].

[19] Jochen Kerdels and Gabriele Peters. “Exploratory Modeling of Complex Information Processing Systems”. In: *ICINCO (1)*. 2013, pp. 514–521 [PDF](#) [bibtex](#)

Local Input Space Histograms (1/3)

Prototype-based clustering methods like the **growing neural gas** (GNG) can suffer from a lack of detail in their input space representation. To amend their descriptive power we introduced the novel concept of **local input space histograms** (LISH) that capture statistical information on the input space lying between neighboring prototypes [20].

In a regular GNG neighboring prototypes are connected by an edge. We added a small histogram to each edge to **capture information on the positions of input samples** relative to the respective best and second best matching prototypes.



Clustering of an inhomogeneous input space (gray areas) with a GNG network of 250 units resulting in 23 clusters (marked by shapes and colors of the units). Histograms of two edges are shown on the right [20].

We were able to demonstrate that this additional information can be utilized to, e.g., **improve clustering** results for challenging, inhomogeneous input spaces.

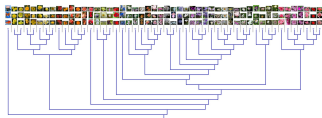
Local Input Space Histograms (2/3)

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The analysis was featured on the title page of “Informatik Spektrum” [22], the main organ of the German Informatics Society (GI).



Foo [21].



Bar [21].

[21] Jochen Kerdels and Gabriele Peters. “Analysis of high-dimensional data using local input space histograms”. In: *Neurocomputing* 169 (2015), pp. 272–280. ISSN: 0925-2312. DOI: <http://dx.doi.org/10.1016/j.neucom.2014.12.094> [PDF](#) [bibtex](#)

[22] Jochen Kerdels and G. Peters. *Clustering Hochdimensionaler Daten*. Springer-Verlag. Apr. 2015 [PDF](#) [bibtex](#)

Local Input Space Histograms (3/3)

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[23] Jochen Kerdels and Gabriele Peters. “A Sparse Representation of High-Dimensional Input Spaces Based on an Augmented Growing Neural Gas”. In: *GCAI 2016. 2nd Global Conference on Artificial Intelligence*. Ed. by Christoph Benzmüller, Geoff Sutcliffe, and Raul Rojas. Vol. 41. EPiC Series in Computing. EasyChair, 2016, pp. 303–313 [PDF](#) [bibtex](#)

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- [24] Jochen Kerdels and Gabriele Peters. "A Computational Model of Grid Cells Based on Dendritic Self-Organized Learning". In: *Proceedings of the International Conference on Neural Computation Theory and Applications*. 2013 **PDF** **bibtex** **nominated for best paper award**
- [25] Jochen Kerdels and Gabriele Peters. "A New View on Grid Cells Beyond the Cognitive Map Hypothesis". In: *8th Conference on Artificial General Intelligence (AGI 2015)*. July 2015 **PDF** **bibtex**
- [26] Jochen Kerdels. "A Computational Model of Grid Cells based on a Recursive Growing Neural Gas". PhD thesis. Hagen, 2016. URL: https://ub-deposit.fernuni-hagen.de/receive/mir_mods_00000438 **PDF** **bibtex**
- [27] Jochen Kerdels and Gabriele Peters. "Modelling the Grid-like Encoding of Visual Space in Primates". In: *Proceedings of the 8th International Joint Conference on Computational Intelligence, IJCCI 2016, Volume 3: NCTA, Porto, Portugal, November 9-11, 2016*. 2016, pp. 42–49. DOI: 10.5220/0006045500420049 **PDF** **bibtex** **best paper award**
- [28] Jochen Kerdels and Gabriele Peters. "Noise Resilience of an RGNG-based Grid Cell Model". In: *Proceedings of the 8th International Joint Conference on Computational Intelligence, IJCCI 2016, Volume 3: NCTA, Porto, Portugal, November 9-11, 2016*. 2016, pp. 33–41. DOI: 10.5220/0006045400330041 **PDF** **bibtex** **nominated for best paper award**
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- [32] Jochen Kerdels and Gabriele Peters. "A Possible Encoding of 3D Visual Space in Primates". In: *Computational Intelligence: International Joint Conference, IJCCI 2016 Porto, Portugal, November 9–11, 2016 Revised Selected Papers*. Ed. by Juan Julian Merelo et al. Cham: Springer International Publishing. 2019. pp. 277–295. ISBN: 978-3-319-99283-9. DOI: 10.1007/978-3-319-99283-9_14 **PDF** **bibtex**

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[34] Jochen Kerdels and Gabriele Peters. "A Grid Cell Inspired Model of Cortical Column Function". In: *10th International Joint Conference on Computational Intelligence (IJCCI 2018)*, Seville, Spain, September 18-20. Jan. 2018, pp. 204–210. DOI: 10.5220/0006931502040210

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[35] Jochen Kerdels and Gabriele Peters. "Challenging the Intuition About Memory and Computation in Theories of Cognition". In: *Proceedings of the 11th International Joint Conference on Computational Intelligence - Volume 1: NCTA, (IJCCI 2019)*. INSTICC. SciTePress, Sept. 2019, pp. 522–527. ISBN: 978-989-758-384-1. DOI: 10.5220/0008493605220527 **PDF** **bibtex**

[36] Jochen Kerdels and Gabriele Peters. "Efficient Approximation of a Recursive Growing Neural Gas". In: *Studies in Computational Intelligence, IJCCI 2018, Revised Selected Papers*. Ed. by Christophe Sabourin et al. Springer International Publishing, 2020 **PDF** **bibtex**

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[37] Kirill Ragozin et al. "Private Reader: Using Eye Tracking to Improve Reading Privacy in Public Spaces". In: *Proceedings of the 21st International Conference on Human-Computer Interaction with Mobile Devices and Services*. Taipei, Taiwan: Association for Computing Machinery, 2019, Article 18. DOI: 10.1145/3338286.3340129  

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