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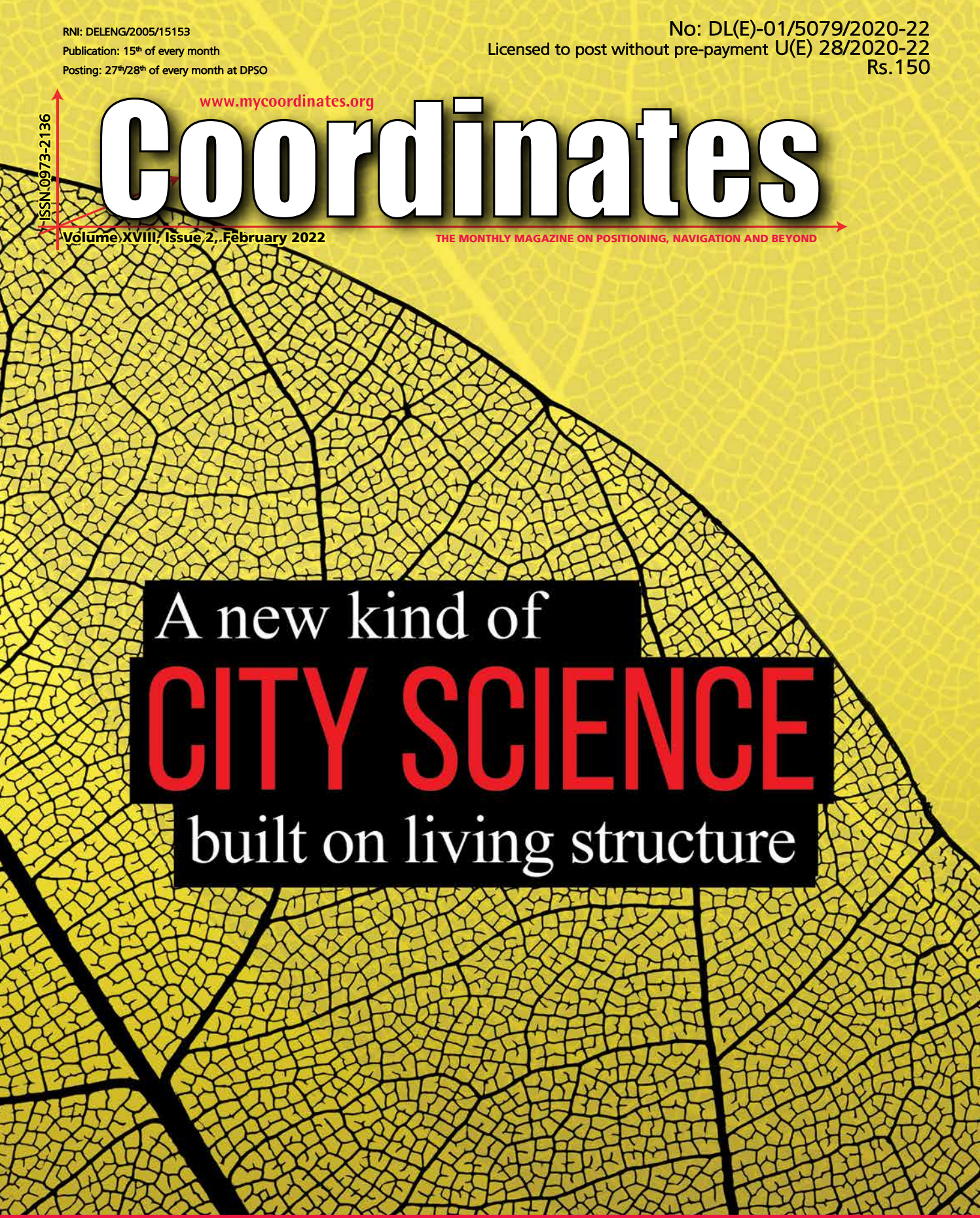

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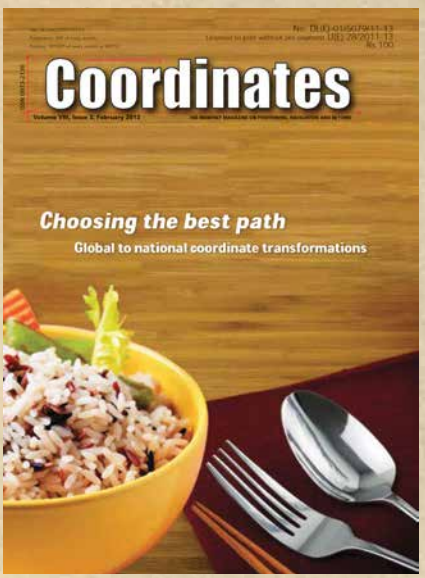

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10 years before...

Choosing the best path: Global to national coordinate transformations

Joel Haasdyk and Volker Janssen

We have demonstrated that differences of up to a few centimetres in each coordinate component can occur depending on the choice of the transformation method applied between GDA94 and ITRF2005. For all transformations, the expected quality of output coordinates degrades with greater time separation from the transformation's reference epoch. These differences can be disregarded for many navigation, mapping and GIS purposes.

Locating dangerous zones prior to drilling the 57 km long Gotthard Tunnel in Switzerland

Edi Meier, edi meier + partner AG Switzerland and Ulrich Sambeth, Stump Foratec AG Switzerland

Georadar is a feasible tool for detecting dangerous waterfilled zones in granitic rocks. It is a very quick methode and can be carried out during the check of the drilling bits. Pilot holes are still necessary for safety reasons. However, the number of pilot holes can be reduced and limited to the critical zones, which also reduces the costs considerably.

Building national capacity through spatial standards policies

Steven Ramage
Executive Director, Marketing and Communications The Open Geospatial Consortium (OGC)

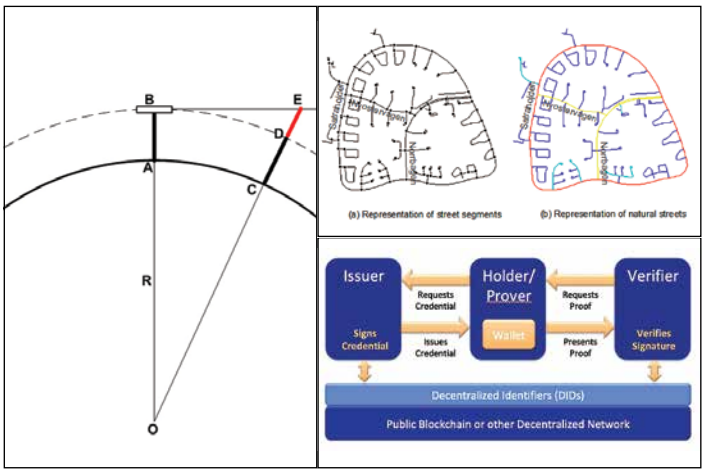
SDIs are a key contributor to economic, social and institutional capacity building, and open standards that enable technical interoperability are a key component of SDIs. Government policies that mandate open geospatial standards from the OGC, ISO/TC 211 and other standards organisations play a critical role in the development of national capabilities in geospatial data, software and services.

"GAGAN is expected to replace the GPS receivers and provide data integrity"

Says A S Ganeshan, Project Director, Navigation Systems, ISRO Satellite Centre in an interview with Coordinates

What are the user segments going to be benefitted by GAGAN?

Even though GAGAN is being developed primarily for civil aviation applications over Indian region, it is expected to provide enhanced service level to the user segments like, Agriculture, Emergency response, Business solutions, Geographical data collection, Natural resources, Land management, Scientific research, Geodynamics, Urban Mapping, Unmanned vehicles, Vehicle tracking, Air navigation, Car navigation, Maritime applications, Search And Rescue Operations, GIS, Timing applications, Canal Transit Management, etc.



In this issue

Coordinates Volume 18, Issue 2, February 2022

Articles

Columns

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Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)

This issue of Coordinates is of 40 pages, including cover.

Wings to fly

The ecosystem for drones in India is set to evolve,

With many recent initiatives such as…

Notification of 'liberalized drone rules',
launch of 'interactive airspace maps',

'Production-Linked Incentive (PLI) for
drones and their components,

Drone Shakti Scheme to promote 'drones-as –a-service' (DrAAS),

Agriculture drones, …

This month, the Directorate General of Foreign
Trade, Government of India has prohibited
the import of drones with exceptions.

However, import for defence & security
purposes shall be allowed.

And also be allowed by the government entities and educational institutions and drone manufacturers for R&D purpose.

Moreover, import of drone components shall be 'Free'.

Will this prohibition encourage 'assembly of drones' in India?

Will this lead India to emerge as a 'drone hub'?

Bal Krishna, Editor
bal@mycoordinates.org

A new C++ programming course in action at Moscow University of Geodesy and Cartography

An experimental course of C++ programming for surveyors and cartographers has been developed and implemented in the educational process at Moscow State University of Geodesy and Cartography. The C++ programming course focuses on the use of cartographic tasks and geodetic exercises to illustrate various programming language constructions. One of these training computer programs is discussed. The program computes absolute and relative errors in measuring the lengths of lines associated with the influence of curvature of the Earth. The developed program can be used in the C++ programming course when the topic of "loop instructions" is being examined.

V R Zablotskii Author is an Associate Professor at the Department of Geoinformatics and Information Security of Moscow University of Geodesy and Cartography. Also, he is an Associate Professor at the Department of Physics of Bauman Moscow State Technical University. The area of scientific interest is related to remote sensing of the Earth, GIS, and the training cartographers and surveyors in C++ programming.

Introduction

Computer science and programming have become very popular disciplines taught in both high school and universities [1]. Currently, it has now become apparent that significant changes in teaching methods are related to the introduction of new information technologies into the educational process. Computer networks have made distance education a preferable form of learning. Projectors are widely used in lecture classrooms as well as personal computers are part of modern laboratories. This shift to digitalization contributes to changing the way computer science is being taught. Earlier the lecturer had to write down only specific parts of a program on the chalkboard, but these days usage of a computer projector makes it possible to demonstrate the complete program code to the audience. Moreover, the application of demonstration software allows showing the work of the program to the audience in real-time.

Programming for Windows using rapid application development (RAD) has been included in the training process. However, programming for Windows consists of different techniques and methods based on extensive use of RAD. The process of creating the program's interface involves the selection of relevant components from the toolbar, their further transferring onto the form, as well as defining properties of these components. All of this requires knowledge about various elements of the programming environment. Students are to learn how to operate a programming environment, in other words; which element must be chosen to implement a particular function; how to work with a variety of menus and submenus; which options for typical control elements exist, and how to set these options, etc. An interactive electronic board that allows demonstrating the work with programming environment while developing programs has become a very convenient tool.

Problems in training programming and software design are revealed due to the fact that teaching C++ programming in different educational institutions is being conducted according to similar plans and on the basis of solving the same tasks for all students, regardless of the specializations of students and related fields of activity. As a result, students are not prepared for the current issues in their industry and will obviously face difficulties when they begin to put their knowledge of programming into practice.

Over the past 10 years, the Moscow

University of Geodesy and Cartography (MIIGAiK) has been conducting a pedagogical experiment [2] in teaching students of cartography and geodesy to program in C++ using a specifically developed training course. An important and distinctive feature of this training course from others is the wide use of material on cartography and geodesy for teaching programming. About seventy programs have been developed to train cartographers and geodesy students. All training examples and programs are aimed at solving certain practical problems of cartography and geodesy accessible to junior students. All program development homework is also based on real-world tasks from the field of cartography and geodesy. The examples of geodetic training programs for first–year students might be the following: determination of the height of a point on the map, computation of a grid bearing of a line. For the purpose of training, students are asked to write the program that converts an angle from a radian measure to degrees, minutes, seconds, or estimates Gaussian convergence of meridians. There are programs for the computation of the slope of a line on the map and the computation of declination of the magnetic needle for an old topographic map. During the period of training students also work with programs theodolite and Adrianov's compass and have to program their tasks.

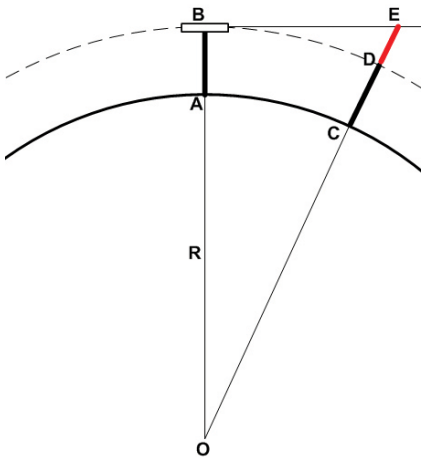

Fig.1. The scheme illustrating the influence of the curvature of the Earth on the measurements of horizontal and vertical lengths

In this paper, the developed program demonstrates loop instructions for multiple repeating of the same calculations using the example of computing the measurement errors of horizontal and vertical line lengths due to the influence of the Earth curvature. This is a typical problem which the students learn in the course of general geodesy and cartography. The computer program below is intended for cartographers and surveyors who study C++ programming during an introductory course.

Methods of research

To execute this task, the Microsoft Windows 10 operating system was used on a personal computer. We also used the open-source "Code::Blocks" programming environment and the GCC C++ compiler. Let's dwell on the geodetic statement of the problem. The influence of the Earth curvature on the absolute measurement errors of horizontal and vertical line lengths is well known for surveyors and determined using the following formulae (1,2):

$$\Delta d \cong \frac{d^3}{3R^2} \qquad (1),$$

$$\Delta h \cong \frac{d^2}{2R} \qquad (2),$$

$$\frac{\Delta d}{d} \cong \frac{d^2}{3R^2} \qquad (3)$$

where Δd - the error in determining horizontal length , Δh - the error in determining the vertical length and d the horizontal distance for which this error is calculated, R- the average radius of the Earth (6371.11 km).

In Fig.1 the influence of the curvature of the Earth on the measurements of horizontal and vertical lengths is illustrated. This is only the quick explaining scheme and the sizes of individual portions are distorted for example the radius of the Earth and high of the instrument. The following notation was used in Figure: O is Earth's center, R is the radius of the Earth, AB is a geodetic instrument for determining length and height of the lines, BE – AC is an error of horizontal line and DE is an error of vertical line due to curvature of the Earth.

The relative error of measuring horizontal line lengths (3) is obtained via the formula (1). The discussed program calculates absolute errors of horizontal and vertical measurements and relative errors for horizontal measurements. The formulae allow estimating the typical dimensions of surface areas on which it is possible not to take into account distortions in the lengths of the lines. The effect of Earth curvature on measurements of distances and elevations is well known and widely used in practice. In the Appendix, we will consider the influence of the curvature of the Moon and Mars on geodetic measurements of the lengths of horizontal and vertical lines.

An example of training program

Figure 2 is the code of the developed program.

Discussions and results

Design and programming for educational purposes should be built on the following important principles: the first is to be thematically oriented for expansion professional skills of students, the second is to be to the maximum extent friendly towards students and the third is to be easily modifiable for student's experiments.

Let's scrutinize these principles. The thematically oriented software should be based on the scientific discipline that is the basis for a particular institution. For instance, at the Moscow University of Geodesy and Cartography, the basic disciplines are geodesy and cartography, which students begin to learn from the first year. This makes it possible to develop the training in programming

```
01: #include <iostream>
02: #include <iomanip>
03: using namespace std;
04:
05: int main(void)
06: {
07:  const double radiusOfEarth = 6371.11;
08:  double absoluteErrorOfDistance, relativeErrorOfDistance, m;
09:  double absoluteErrorOfHeight, scale;
10:  int d;
11:
12:  cout <<"-----------------------------------------------"<< endl;
13:  cout <<"  d, km   AbsoluteError d, m   RelativeError d   "<< endl;
14:  cout <<"-----------------------------------------------"<< endl;
15:
16:  for( d = 1; d < 26 ; d += 1)
17:  {
18:   absoluteErrorOfDistance =
18:                    (d*d*d)*1e+3/(3*radiusOfEarth*radiusOfEarth);
19:   relativeErrorOfDistance = absoluteErrorOfDistance/(1000*d);
20:   scale = 1/relativeErrorOfDistance;
21:
22:   cout << setw(5) << d  << setw(15)  << setprecision(2)
22:        << setiosflags(ios::showpoint)  << absoluteErrorOfDistance;
23:   cout << setw(15) <<"1:" << setiosflags(ios::scientific)
23:   << setprecision(1)<<scale<<resetiosflags(ios::scientific)<< endl;
24:  }
25:
26:   cout <<"-----------------------------------------------"<< endl;
27:   cout <<"  d, m          AbsoluteError H, cm              "<< endl;
28:   cout <<"-----------------------------------------------"<< endl;
29:
30:  for( d = 100; d < 2100 ; d += 100)
31:  {
32:   absoluteErrorOfHeight = (d*d)/(2*radiusOfEarth*10);
33:
34:   cout <<setw(5) <<  d  << setw(25) << setprecision(3)
34:        <<setiosflags(ios::showpoint)<< absoluteErrorOfHeight<<endl;
35:  }
36: return 0;
37:}
```

Fig. 2. Listing of the program to compute the impact of the Earth curvature on the measurement of the lengths of horizontal and vertical lines

according to the «work in parallel» principle. If programming is taught in the second year, then their students might not have any problems with geodesy and discipline-related knowledge.

User-friendly software should be understandable and readable from the very first start. To achieve this goal several well-proven methods are applied. First, the names of program entities must fully reflect the assignment or purpose of using these entities. For example, the meaningful name *magneticAzimuthOfDirection* tells the surveyor that this variable contains significantly more than another short or abbreviated name. Secondly, programs should be as short as possible, with no more than 70 lines of code. Since there is a direct link between the amount of code and its readability, the larger the program, the harder it is for the learner to retain the material.

And finally, it is required that the program could be changed or modified easily. That means that the program can be independently changed, for example, new functionality to the program could be added to it. Independent computer experiments are extremely useful and therefore training programs should motivate students to deepen their knowledge of programming.

Below there is an example of a guide for the discussed program. This text is put into a methodological guide for students learning the C++ programming language for each training program. The text is provided to each student studying the program. Let's take a look at this reference material.

In lines, 07- 10 variables are declared. The integer variable *d* is used for distances, at which the absolute and relative errors in determining horizontal and vertical lengths of lines are calculated. Lines 12 - 14 form the first table with the results of the calculations. The initial value of the loop counter *d* is 1 km. At each step of the first loop *for* the counter increases by 1 km and the end of the calculations when *d* reaches 25 km. In line 18 absolute error of horizontal line length when removed from the initial point is calculated. The relative error of the horizontal length of the line is calculated (line 19), and then in line 20 the variable *scale* that is the inverse value of the error, is found. The relative errors in the format of the numerical scale of the map are obtained. The result is recorded in the *scale* variable and displayed on the screen. The scientific notation of a number is used to represent the value of the scale denominator as a rounded integer. Thus, the exact relative error value such as 1:1006880 is recorded in a table in a usable form of 1:1.0e+06 otherwise 1:1000000. When a table is displayed, a *setw* modifier to set the width of the blank spaces is to be used. For example, *setw (5)* displays 5 spaces in a row. The results are displayed in line 22, first 5 spaces are printed, then goes the value of variable *d*, then again 15 spaces are to be typed and the value of the variable *absoluteErrorOfDistance* with two significant figures are displayed. Next, the value of the *relativeErrorOfDistance* variable is printed. The first loop ends in line 24 and starting from lines 26-28 the title of the second table is printed, showing the effect of the curvature of the Earth on the absolute error in determining the vertical line lengths. In the second loop *for* (lines 31 - 35), the counter *d* takes the initial value of 100 m and changes gradually in increments of 100 m, the loop ends when *d* reaches 2000 m. This loop calculates the absolute error that is displayed on the screen in the form of a table. As a result, the program displays two tables with errors for horizontal and vertical line lengths respectively.

The results of computing made by the program are presented in tables 1 and 2 below. The errors of the measurements

of the lengths of the lines are shown in the tables for greater visibility and the relative error is presented in the format of the numerical scale of the map. Some data has been omitted to reduce table size. In this case, the cells of tables contain the special symbol as three dots (...).

Consider the results of the computations presented in Tables 1 and 2. These results should be familiar to cartographer and surveyor students. But if this is not the case, the results printed by the program will help students to remember important items of geodesy and cartography.
The highest accuracy of geodetic measurements on the Earth, equal to 1:1000000, is achieved by measuring horizontal lengths of lines at distances not exceeding 11 km. In such surface circle areas, the influence of the Earth curvature on the measurement of horizontal distances can be ignored. In geodetic measurements with the error of 1:200000, it is possible to neglect the curvature of the Earth at distances of about 25 km. Table 2 shows measurement errors in determining vertical line lengths due to the influence of the curvature of the Earth. Let see the obtained errors. An absolute error of height equal to 1 mm corresponds to a distance on the ground of about 113 m. At a distance of 1 km, this error reaches 7.8 cm. Thus, when the students are studying C++ programming, they are surrounded by the exercises of cartography and geodesy and learn to apply programming to solve their specific cartographic and thematic geodesy problems.

Table 1. Errors in measuring horizontal line length

d, km	*AbsoluteError d, m*	*RelativeError d*
1	0.0000082	1 : 120000000
2	0.000066	1 : 30000000
3	0.00022	1 : 14000000
4	0.00053	1 : 7600000
5	0.0010	1 : 4900000
...	...	...
10	0.0082	1 : 1200000
...	...	...
15	0.028	1 : 540000
...	...	...
20	0.066	1 : 300000
...	...	...
25	0.13	1 : 190000

Table 2. Errors in measuring vertical line length

d, m	*AbsoluteError H, cm*
100	0.0785
200	0.314
300	0.706
400	1.26
500	1.96
...	...
1000	7.85
...	...
1500	17.7
...	...
2000	31.4

Conclusions

At the Moscow University of Geodesy and Cartography, a new approach to teaching C++ programming for students specializing in cartography and geodesy was developed. Methods of implementing the educational process aimed at improving the effectiveness of teaching programming in training groups of cartographers and surveyors are considered. The new C++ programming course is geared towards the needs of the surveying and cartographic industry. This is the request of today to create programming courses suitable for particular higher education institutions taking into account their scientific specialization. A training program for cartographers and surveyors studying the basics of C++ programming has been developed. The program computes the distortions that occur when measuring horizontal and vertical line lengths associated with the curvature of the Earth. Using the program, the typical dimensions of surface areas were obtained, which can be conditionally considered flat with an accuracy of 1: 1000000 and 1: 200000. The program can be used as training material in the C++ programming course to illustrate the loop instructions. The program code is described in detail and the purpose of the instructions used is explained.

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Zablotskii V.R. (2021) Ten-Years Pedagogical Experiment at Moscow University of Geodesy and Cartography: C++ Programming Course Tailored for Surveying Students. FIG e-Working Week 2021, Commission: 02.2 - Innovation in Professional Education during COVID-19, 21 - 25 June 2021.*https://www.fig.net/resources/proceedings/fig_proceedings/fig2021/papers/ts02.2/TS02.2_zablotskii_10883.pdf*

Appendix

It is interesting to apply the discussed program to assess the influence of the curvature of other celestial bodies on the measurements of horizontal and vertical lines. Let's try to use the program to compute the influence of the curvature of the Moon and Mars. To do this, take the average radius of the Moon equal to 1,738 km and the average radius of Mars equal to 3,396 km. The computation results can be formulated as follows. The radius of the site approximated by plane surface (with the accuracy of measurements of 1:100,0000) on Mars is just under 6 km, and on the Moon reaches only 3 km. In geodetic measurements with the error of 1:200,000, it is possible to neglect the curvature of Mars at distances no more than 13 km, and for the Moon, such a limiting distance is 6 km. Computations show that on the surface of Mars an error in determining the vertical line length equal to 1 mm is achieved at a distance of 83 m. On Mars, this error increases to 14.7 cm at a distance of 1 km. On the Moon, the error in determining the vertical length of a line in 1 mm corresponds to a distance of 63 m and at a distance of 1 km the error increases to 28.8 cm.

Cryptographic digital technology for the prevention of property theft

Using cryptographic digital technology, a mobile application could be developed to eliminate property registry fraud even before it occurs

Jethro Jones
Medici Land Governance
Utah, USA

Abstract

Property registry fraud is a form of identity theft used to steal property by forging documents in the name of the property's rightful owner. Property registry fraud impacts land rights across the globe and, in the United States, is a crime that commonly affects the most vulnerable: the elderly and families of the recently deceased. Many times, property registry fraud is not detected until irreparable harm has been done. The costs of this crime are economic, social and judicial. Using cryptographic digital technology, a mobile application could be developed to eliminate property registry fraud even before it occurs. In deploying such an application, developing countries could leapfrog the capabilities of more technologically advanced governments in securing the property ownership of individuals and prevent property registry fraud from occurring, thereby protecting the land rights of the most vulnerable people.

Introduction

Property registry fraud is a form of identity theft used to steal property by forging and recording documents in the name of the property's rightful owner. As stated in a consumer report from the California Department of Real Estate:

> the county recorder is not responsible for verifying the validity, authenticity or legitimacy of the document that is recorded. In other words, the recorder is not responsible for detecting a fraudulent document, and the recorder does not look beyond the document itself. If the document meets the essential recording requirements, and the proper fees are submitted, the county recorder is obligated to and will record the document. (Bell & Bakotich, 2012)

A news article published by the United States Federal Bureau of Investigation details a number of ways this type of fraud can be perpetrated (The Federal Bureau of Investigation, 2008). A South African news article details the theft of a widow's home (Barbeau, 2015). Between 2015 and 2018 property registry fraud cases totaled over $112 million in impacted property in New York City alone (The Grand Jury of the Supreme Court of the State of New York County of New York, 2019). It commonly also impacts the most vulnerable: the elderly, medically disabled and families of the recently deceased. In case after case, families have lost properties representing the whole of their accumulated wealth and history (The Grand Jury of the Supreme Court of the State of New York County of New York, 2019). Property registry fraud is an expensive and ubiquitous problem that impacts countries across the globe.

Current government agencies including the New York Department of Finance (NYC Department of Finance, 2019) and the United Kingdom Land Registry (HM Land Registry, 2019) recommend a variety of property registry fraud security measures to make property owners less

vulnerable including: make the property look maintained and cared for, sign up for alerts to all changes in recorded documents in relationship to owned property, and to report any fraudulent activity immediately to the sheriff's office.

Unfortunately, the global status quo involves catching perpetrators after the fact, sometimes after irreparable financial harm has been done (Frost, 2019). In deploying preventive technologies, developing countries could leapfrog the current state of affairs in developed countries and provide more secure land ownership for all citizens.

The web enabled digital advancements of the past decade have made property registry fraud more likely to be profitable without detection. Property thieves have the ability to correlate data from many sources to identify vulnerable properties. A thief can correlate death records with property data from a variety of sources to find properties owned by the recently deceased. In this case, a forged property transfer document can be less likely to be detected before the thief is able to profit. The speed and global nature of modern digital finance in the ability to get a loan with the stolen property as collateral, or for the thief to sell the property outright make realizing profit and disappearing with the funds even easier. Our current methods of registering and recording property records were not designed with these realities in mind. While they may have been sufficient for a pre-digital world where the pace of finance was slower and real estate transactions were more localized; in our modern world they represent a significant security vulnerability. The fraud resistant conveyance of property requires secure verification of all parties at the time of notarization and at the time of recording.

Public key cryptography

Public key (commonly known as RSA) cryptography involves the generation of public/private key pairs. The private key is known only to the owner, while the public key is disseminated to anyone that the private keys owner would like to communicate securely. RSA key pairs are widely used, trustable, and form the basis for nearly all secure online services (Rivest, Shamir, & Adleman, 2019). Beyond its role in our daily lives in e-commerce and online banking (Tip Top Security, 2017), RSA key pairs can serve as a basis for preventing the creation and recording of fraudulent documents.

Public/private key pairs can be used to digitally sign information in such a way as to securely tie the owner of the private key to the signed artifact. A holder of the public key can verify that a digital signature represents the information that was provided. The public key holder can also verify that a specific private key holder was the signer, making the digital signature and the associated information impossible to forge by another party.

Public Key Infrastructure (PKI) refers to a centralized collection of public keys from known users of known identities. A type of PKI managed by certificate authorities secures all internet traffic via the SSL protocol (Russel, 2019). PKI can eliminate fraud by allowing digital documents to be created and signed in a way that guarantees that the signer of a document is who they purport to be. Paperless land transfer systems of unprecedented efficiency can be built by recording these digital documents to a blockchain based public registry.

A paperless land title transfer system was designed by Medici Land Governance[1] to facilitate streamlined communication with government agencies in Rwanda.

The system was designed to allow a notary to securely identify a buyer and seller and then digitally sign the transfer agreement with PKI private keys. This creates a secure digital transaction of the transfer through a government agency on to a blockchain. This paperless transfer of land titles, secure registration of ownership and the elimination of the requirement to visit a land office prevents three main failings in the land registry today.

1. The double selling of land.
2. The impersonation of a seller.
3. Independent verification of land titles.

The system demonstrates a substantial increase in security, ease of use and efficiency together with automatic transfer of title.

In the absence of universal Public Key Infrastructure, which is the current situation in nearly all countries, a PKI system for notaries could be used to improve the security of the creation and public recording of property records, significantly lowering the risk of fraud. A mobile application could be developed to enable notaries both to securely identify an individual and to securely capture the key elements of a notarized document in a fraud proof way.

To securely identify an individual at the time of document signing, the notarization application would verify identity by matching the name, ID number, and even government issued identification card photos with a centralized service.

The mobile application would also hold a private key for the notary with the public key recorded with the notary PKI system. A cryptographically signed digital receipt of the document notarization would be created and stored with a centralized service for reference when the physical documents are officially recorded with the registrar. When the physical document is notarized, crucial information about that document would be captured, digitally signed and centrally stored for later reference. This would include the date and time provided by the signing device, the names of parties involved along with identifying information (state ID number) and a short note about the nature of the document, i.e., a named party conveys a given property to another named party. The date, along with a short unique identifier to cross reference with the centrally stored digital receipt, would be written on the physical document being notarized along with the official stamp.

At the time of recording, the registrar would pull up the digitally signed

and centrally stored receipt of this notarized document for cross referencing all information: date, parties involved and intent.

The key benefits to this system are that it becomes impossible to forge the notarization of a document because the key information and the notarization itself are signed in a cryptographically secure and tamper-proof way by a notary who is securely and uniquely identifiable in the PKI system. The digitally signed record is stored in a central service as a receipt for later reference. A secure chain is created from the moment of notarization to the time of recording that makes the forging of notarized property transfer documents extremely difficult. This makes it significantly harder, if not impossible, to record fraudulent documents at an official registrar.

Decentralized Public Key Infrastructure

A suite of new technologies in the cryptographic space provides additional opportunities to extend these ideas and create more robust systems with even greater efficiency, security, convenience and workflows with greater complexity. Decentralized Public Key Infrastructure (DPKI) refers to the suite of technologies that do not rely on a centralized authority for the management and security of keys which is part of current PKI systems used by certificate authorities. In a DPKI system public keys are stored on a public blockchain or distributed ledger and can be created, updated and revoked at will. This lowers cost and adds flexibility and capability (The Sovrin Foundation, 2018). The two most prominent DPKI systems are uPort and Sovrin.

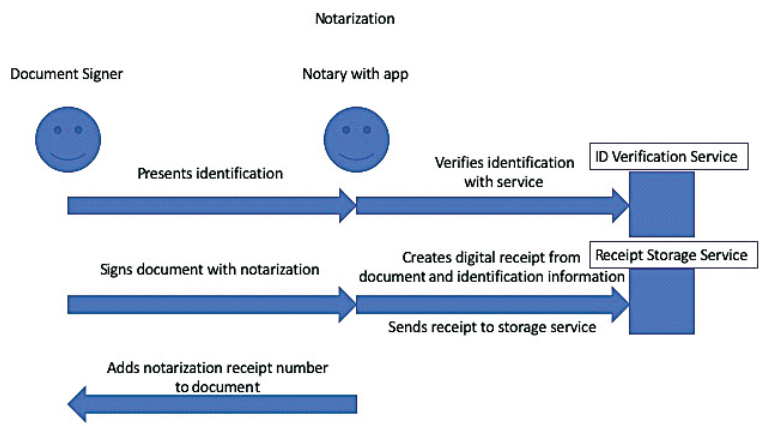

Figure 1. Notarization application flow. Jethro Jones, 2020

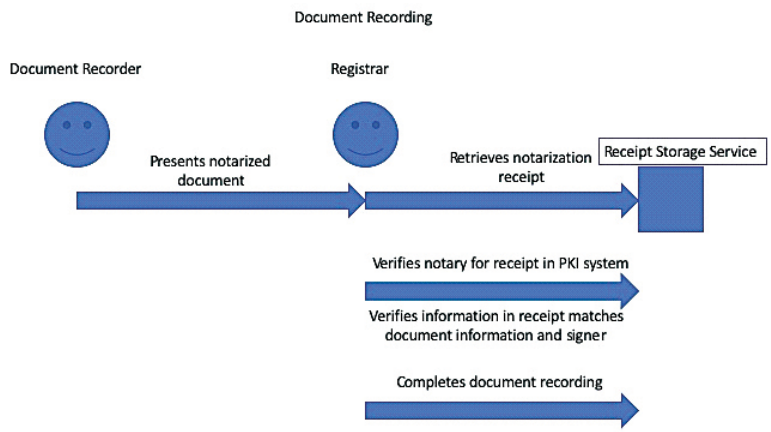

Figure 2. Document recording application flow. Jethro Jones, 2020

Decentralized identity

Decentralized identifier (DID) refers to a public key addressing system, and is a standard coming from the W3C. It includes the public key as well as routing information to communicate directly with the holder of the associated private key. DIDs can be exchanged in a peer to peer fashion for encrypted communication and document exchange. DIDs can also be published to a public blockchain forming the basis of DPKI. With a DID publicly accessible and associated to a specific authorized identity any signed artifacts for that key pair can be publicly verified without reliance on a centralized authority. As stated by the Sovrin foundation:

> DIDs are the first globally unique verifiable identifiers that require no registration authority… DIDs enable true self-sovereign identity-lifetime portable digital identity for any person, organization, or thing that can never be taken away. (The Sovrin Foundation, 2018)

The DID can be included in the signed artifact itself, creating a very straightforward verification method with the associated DID, including the public key published to the blockchain.

Verifiable credentials (VC)

In the Sovrin system, a verifiable claim, also known as a verifiable credential, is defined as:

> a piece of information that is cryptographically trustworthy. In Sovrin, a verifiable claim is shared as a proof and is anchored to the public ledger by a credential definition and public DID written by the credential issuer. Typically, this proof is in the form of a digital signature. A Sovrin Verifiable

The system was designed to allow a notary to securely identify a buyer and seller and then digitally sign the transfer agreement with PKI private keys. This creates a secure digital transaction of the transfer through a government agency on to a blockchain. This paperless transfer of land titles, secure registration of ownership and the elimination of the requirement to visit a land office prevents 3 main failings in the land registry today.

> Claim may be verified by a public key associated with the Issuer's DID. An example of a verifiable claim could be a digitally issued driver's license. (The Sovrin Foundation, 2018)

The use of verifiable claims involves a triangle of trust. Every verifiable claim has a claim issuer (the entity that issues a claim to a holder), the holder (the user keeps the credential in a digital wallet on a personally held mobile device), and potential verifiers who would request some digital proof from the holder which can be satisfied by the verifiable claim.

There are two additional artifacts published to a blockchain which include the schema definition and credential definition. The schema definition is a machine-readable artifact that allows for interoperability. An example could be a passport schema definition which could include full name, birthdate, and country of origin.

The credential definition is a specific instance of a schema definition associated with a single issuer. A single national government could publish a credential definition which references the generic passport schema definition. Any digital passports issued as verifiable credentials would reference the published credential definition which would in turn reference the specific schema definition. In this case the issuing national government would be the credential issuer and the individual receiving the passport would be the credential holder. The credential issuer would have a publicly registered DID published to a blockchain.

When the time comes for an individual to use their digital passport, they would receive a digital verification request from the credential verifier. This could be the passport officer at a port of entry. The verification process includes verifying that the credential was digitally signed by the issuing government and matches the blockchain DID. This is the digital identity of the national government and includes the public key, which as previously demonstrated proves identity and authority. The verifier would also reference the published schema definition and credential definition to validate all information required. At this point in the process, additional verifiable credentials could be issued to the holder which would be analogous to entry/exit stamps in a passport book or visa which would expire at a certain point in time (The Sovrin Foundation, 2018).

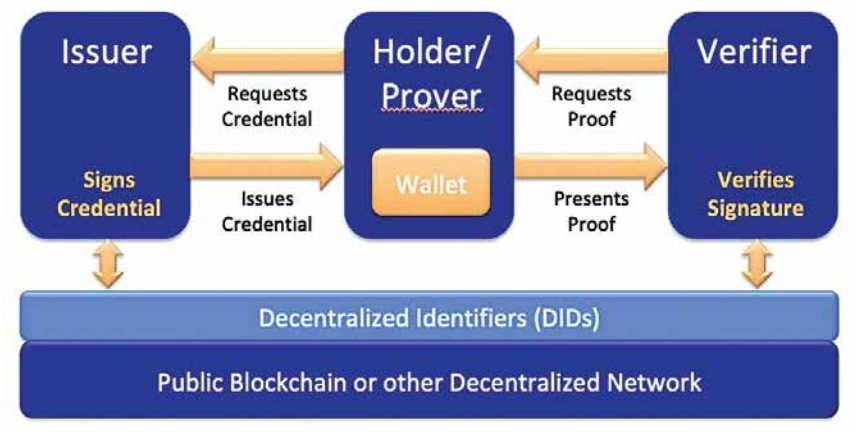

Figure 3. Credential Exchange Layer Roles and Interactions. Reprinted from Sovrin Glossary V2, The Sovrin Foundation, Retrieved January 31, 2020, from https://sovrin.org/wp-content/uploads/Sovrin-Glossary-V2.pdf.

Let's now look at another real-world example: The Department of Motor Vehicles (DMV), a licensee and a police officer. All parties will have DID capable wallets. The DMV would issue a driver license verifiable credential to a licensee which would be held in their digital wallet. This would contain the licensee's necessary information: age, driver's, license number, whether their license is valid, and if they are allowed to drive. This data is also cryptographically signed by the DMV's private key. The corresponding public key is published to a public ledger.

If a police officer pulls the licensee over while the licensee is driving, the officer would use a device to verify the verifiable credential held by the licensee, verify that is what signed by the DMV and that the licensee is able to drive.

Strong Identification or validated identification refers to a DID which is connected to a real-world identity through a credential issued by a trusted authority. This could be a driver license, passport, or a digital credential issued by a notary after reviewing the credential holders physical identifying documents.

These ideas can be extended to building land administration systems and processes. From our previous examples using private keys and traditional PKI, we can build a system using DPKI, DIDS and verifiable credentials. Using a verifiable credential to prove identity allows for removing the identification verification step from notarization and possibly removing the notarization step entirely. With a secure identity credential issued by an appropriate government authority, we get the same fraud resistant guarantees in our previous system. It is guaranteed that the signer is who they claim to be. With this digital infrastructure in place and DPKI that extends to all users in the system, paper documents can be eliminated entirely. A digital purchase agreement can be created in an application that is digitally signed by the buyer and the seller. The identity credentials from all users become part of the secure workflow. Because there is no dependency on a paper-based agreement, the digitally signed purchase agreement can be instantly transferred to the government registrar for recording. Any other required steps, such as guarantees of clear title and mortgage origination, can be handled through verifiable credentials as well. For example, if a buyer needs to prove employment, a verifiable credential could be issued by their employer or to prove available funds, a verifiable credential could be issued by the bank. After recording a verifiable credential could be issued to the new buyer to be held in a mobile wallet to prove ownership with the government registrar as the issuer.

With these tools and infrastructure, bureaucratic workflows of unlimited complexity can be built that are orders of magnitude more secure and efficient than the paper-based processes that are the current status quo. Significant savings will be realized by landowners and governments by eliminating property registry fraud and other forms of document fraud before they can happen. This includes the economic and social cost of the fraud itself and the savings in not having to litigate and prosecute such cases in the justice system. In deploying such applications, developing countries could leapfrog the capabilities of more technologically advanced governments in securing the property ownership of individuals and prevent property registry fraud from occurring, thereby protecting the land rights of the most vulnerable people.

Endnote

[1]Medici Land Governance was established as a public benefit corporation to use advanced technology including blockchain to improve trust in information and institutions while helping individuals secure their land rights and improve their economic situation.

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Emerging IoT paradigm – A technology perspective

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There is still huge potential yet to be imagined. Let me replace Internet of Things (IoT) with Internet of Sensors. The old saying goes, 'you cannot manage what you don't measure'. The best parallel process I can think of is in the design of instrumentation and control systems – when the most accurate sensors are relied upon to for making decisions about what to do next.

In sensor design, the goal is measuring environmental phenomena with correlation. The device must change the same way the environment does every time to be considered accurate. Once the sensor is considered accurate with what it is measuring, it becomes part of the instrumentation suite for an application. The next step is a control system. Adding a feedback loop – taking those measurements to and applying a change to the environment to those measurements – like a thermometer and a thermostat for temperature control or a water pressure gauge and a pump for flow control.

The main gap between instrumentation and control systems is having them as soon as possible, and the exchange of data delivered economically as possible - while balancing the accuracy the sensor can deliver. With Network Infrastructure constantly being upgraded, the potential of IoT can be realized.

The challenge of a GNSS chipset in an IoT application needs the supplement of GNSS assistance and GNSS correction services position for positioning quickly and accurately but often constrained by RF physics.

When higher fidelity data exchanged between IoT is used to support or check each other, the control systems next command is more confident. If we expand on the thermostat example, when adding information on open windows and doors, humidity, outside ambient temperature and wind speed, the logic on how much to turn up the heat or air conditioner might be very different than just the thermometer alone. The multi dimensional data driven decision will have an objective to maintain user comfort or maintain equipment longevity.

In IoT, I think we are in the phase of discovering more sensors are needed to get the full context of what we are managing - A single sensor alone needs to be combined with other sensors to get the full picture of what is happening and innovations in other sensors are happening to meet this. Different applications will need a different variety of sensors with the spatial dimension being common the need in providing strategic clarity. The challenge of a GNSS chipset in an IoT application needs the supplement of GNSS assistance and GNSS correction services position for positioning quickly and accurately but often constrained by RF physics. When adding GNSS assistance and GNSS corrections services into the inherent connectivity of IoT device, the network of IoT devices can be denser to make a higher resolution picture of what you are managing.

The commonality with all sensors is that when the spatial dimension is accurate and timely the response of the decision maker shifts from reactive to proactive, and changing from managing your sensors, to using the information they bring to you.

A new kind of city science built on living structure and on the third view of space*

The new city science aims not only to better understand geographic forms and processes but also – maybe more importantly – to make geographic space or the Earth's surface living or more living

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Abstract

The third view of space states that space is neither lifeless nor neutral, but a living structure capable of being more living or less living, which was formulated by Christopher Alexander under the organismic world view that was first conceived by the British philosopher Alfred Whitehead (1861–1947). The living structure is defined as a physical and mathematical structure or simply characterized by the recurring notion (or inherent hierarchy) of far more small substructures than large ones. The more substructures the more living or more beautiful structurally, and the higher hierarchy of the substructures the more living or more beautiful structurally. This paper seeks to lay out a new kind of city science on the notion of living structure and on the third view of space. The new city science aims not only to better understand geographic forms and processes but also – maybe more importantly – to make geographic space or the Earth's surface living or more living. We introduce two fundamental laws of living structure: Tobler's law on spatial dependence or homogeneity and scaling law on spatial interdependence or heterogeneity. We further argue that these two laws favor statistics over exactitude, because the statistics tends to make a structure more living than the exactitude. We present the concept of living structure through some working examples and make it clear how a living structure differs from a non-living structure. In order to make a structure or space living or more living, we introduce two design principles – differentiation and adaptation – using two paintings and two city plans as working examples. The new city science is a science of living structure, dealing with a wide range of scales, from the smallest scale of ornaments on walls to the scale of the entire Earth's surface.

1. Introduction

The great architect Christopher Alexander had some remarkable insights about architecture, which applies equally to geography. Over the past century, geography (or architecture) has always been a minor science, seeking application of the physical sciences such as physics and anthropology. In the next two centuries, geography (or architecture) might become a major science, a sort of complexity science, when the deep question of space has been properly understood (Grabow 1983). The deep question touches the very nature of space or the organismic view of space, as formulated by Alexander (2002–2005, 1999), that space is neither lifeless nor neutral but a living structure capable of being more living or less living. Living structure is such a structure that consists of far more small things (or substructures) than large ones across all scales ranging from the smallest to the largest (scaling law, Jiang 2015), yet with more or less similar sized things (or substructures) on each of the scales (Tobler's law 1970). It is initially the

* The title was inspired by Stephen Wolfram's *A New Kind of Science*, which is a generative science using cellular automata, but the book or cellular automata in general never discusses goodness or quality of generative patterns or structure. This paper or the new kind of city science in general directly confronts the goodness or quality of structure, arguing that it is a matter of measurable or quantified fact rather than opinion or personal preferences.

deep question or the very notion of living structure or the organismic view of space that triggered us to develop this paper.

The third view of space differs fundamentally from the first two views of space: Newtonian absolute space and Leibnizian relational space, which are framed under Cartesian mechanistic world view (Descartes 1637, 1954). The mechanistic world view is so dominated in science and in our thinking as if it were the only mental model, or even worse it may be considered to the world itself. It is a powerful model about our world, for what we human beings have achieved in science over the past hundred years is largely attributed to the mental model. However, the mechanistic mental model is limited when comes to design or creation, as the goodness of designed or created things is sidelined as an opinion or personal preference rather than a matter of fact (Alexander 2002–2005). Under Newtonian absolute and Leibnizian relational views of space – a geographic space is represented as a collection of geometric primitives such as points, lines, polygons, and pixels (c.f., Figure 2 for illustration), which tend to be *"cold and dry"* (Mandelbrot 1982), so it is not seen as a living structure.

The mechanistic world picture has two devastating results according to Alexander (2002–2005). The first was that the "I" went out of the world picture and the inner experience of being a person is not part of this picture. The second was that the mechanistic world picture no longer has any definite feeling of value in it, or value has become sidelined as a matter of opinion rather than as something intrinsic to the nature of the world. The organismic world picture first conceived by Whitehead (1929) extends the mechanistic world picture to include human beings as part of the organismic world picture. The same world view has been advocated by quantum physicist David Bohm (1980) among many others. Under the organismic world view, we human beings are part of the world rather than separated from the world. In other words, the physical world or the universe is organism like rather than machine like (Whitehead 1929). It is under the organismic world picture that Alexander (2002–2005, 1999) formulated the third view of space. Under the third view of space, value lies on the underlying configuration of space, and the goodness of space is no longer conceived as a matter of opinion, but a matter of fact. The shift from the opinion view to the fact view or from the mechanistic world view to the organismic world view represents something fundamental (Kuhn 1970) in our thinking about geography, for design or how to make living or livable space is at the forefront of geographic inquiry.

We in this paper attempt to setup city science on the notion of living structure and on the third or organismic view of space, leading to a new kind of city science or new city science. Living structure is said to be governed by the two fundamental laws: the scaling law (Jiang 2015) and Tobler's law (1970). Among the two laws, the scaling law is the first, or dominant law, as it is universal, global, and across scales, while Tobler's law is available locally or on each of the scales. Conventionally, city science or the new science of cities (Batty 2013) has been viewed as a minor science or an applied science that seeks to apply major sciences for understanding geographic forms and processes. In this paper, we argue that the new city science is a major science, a science of living structure, not only for understanding geographic forms and processes, but also for making and remaking geographic space or the Earth's surface towards a living or more living structure.

The remainder of this paper is organized as follows. Section 2 introduces the two fundamental laws of living structure that favors statistics over exactitude. Section 3 illustrates how living structure differs from non-living one under two different world views. Section 4 presents two design principles differentiation and adaptation in order to make or transform a space to be living or more living. Section 5 further discusses the new city science and its deep implications. Finally in Section 6, the paper concludes with a summary pointing to a prosperous future of the new city science.

2. Two statistical laws together for characterizing living structure

The notion of living structure applies to all organic and inorganic phenomena in the scales ranging from the smallest Planck's length to the largest scale of the universe (Alexander 2002–2005, 2003), so do the scaling law and Tobler's law. The applicability implies that there are far more small particles than large ones, far more rats than elephants, far more small stars than large ones, far more small galaxies than large ones, and so on. This paper deals with a range of scales of the Earth's surface between 10^-2 and 10^6 meters. The Earth's surface is governed by two fundamental laws: the scaling law and Tobler's law, as mentioned at the outset of this paper. Table 1 shows how these two laws complement rather than contradict to each other from various perspectives (Jiang and Slocum 2020). It is wise to keep the scaling law as the dominant one, as it is global or across scales, whereas Tobler's law is local or on each scale. In conventional city science or the new science of cities, Tobler's law is usually overstated as the first law of

Table 1: Two complementary laws of geography or living structure

Scaling law	Tobler's law
There are far more small things than large ones	There are more or less similar things
across all scales, and	available at each scale, and
the ratio of smalls to larges is disproportional (80/20).	the ratio of smalls to larges is closer to proportional (50/50).
Globally, there is no characteristic scale, so exhibiting	Locally, there is a characteristic scale, so exhibiting a
Pareto distribution, or a heavy-tailed distribution,	Gauss-like distribution,
due to spatial heterogeneity or hierarchy, indicating	due to spatial homogeneity or dependence, indicating
complex and non-equilibrium character.	simple and equilibrium character.

geography, and it implies that the Earth's surface is in a simple and well-balanced equilibrium state. However, we know that the Earth's surface is unbalanced and very heterogeneous and every place is unique (Goodchild 2004). Dominated by the scaling law or the non-equilibrium character, the new city science aims not only to better understand the complexity of the Earth's surface, but also to make the Earth's surface a living or more living structure. For creating living structures, two design principles – differentiation and adaptation – will be presented later on.

Unlike many other laws in science, these two laws are statistical rather than exact. The statistical nature is more powerful than the exactitude one. Below, we cite three sets of evidence in science and art to make it clear why exactitude is less important. First, Zipf's law (1949) is also statistical rather than exact. It states that in terms of city sizes, the largest city is about twice as big as the second largest, approximately three times as big as the third largest, and so on. Here twice, three times, and so on are not exact, but statistical or roughly. Among the two sets for example: [1, 1/2, 1/3, …, 1/10] and [$1 + e_1$, $1/2 + e_2$, $1/3 + e_3$, …, $1/10 + e_{10}$] (where e_1, e_2, e_3, … e_{10} are very small values), the first dataset does not follow Zipf's law, while the second does. Zipf's law is a major source of inspirations of fractal geometry (Mandelbrot 1982). In his autobiography, Mandelbrot (2012) made the following remark while describing the first time he was introduced to a book review on Zipf's law: *"I became hooked: first deeply mystified, next totally incredulous, and then hopelessly smitten … to this day. I saw right away that, as stated, Zipf's formula could not conceivably be exact."* A dataset following Zipf's law meets the scaling law, but not vice versa, which means that the scaling law is even more statistical than Zipf's law. Zipf's law requires a power law while the scaling law does not.

The second evidence is not only statistical, but also geometrical. The leaf vein shown in Figure 1 (Jiang and Huang 2021) apparently has far more small substructures than large ones from the largest square to the smallest white spots. Carefully examining the structure of the leaf vein, it is not difficult to find that there are four different levels of scale according to thickness of their outlines. In contrast, the Sierpinski carpet also has far more smalls than larges; that is, far more small squares than large ones, exactly rather than statistically (Sierpinski 1915). Let us carefully examine the exactitude of the carpet. The largest square in the middle of the carpet is size 1/3, which is surrounded by eight squares of size 1/9, each of which is surrounded by eight squares of size 1/27, each of which is surrounded by eight squares of size 1/81. Thus, there are two exponential data series, each of which is controlled by some exact number. The size of squares is exponentially decreased by the exact number 1/3: (1/3, 1/9, 1/27, 1/81), whereas the number of squares is exponentially increased by the exact number 8: (1, 8, 64, 512). Clearly there are far more small squares than large ones exactly rather than statistically. Because of the exactitude, the Sierpinski carpet is less living structurally than the leaf vein.

> The scaling law and Tobler's law are really two fundamental laws about livingness or beauty. They can be used to examine many patterns or structures (e.g., Wade 2006, Wichmann and Wade 2017) for understanding not only why they are beautiful, but also how beautiful they are.

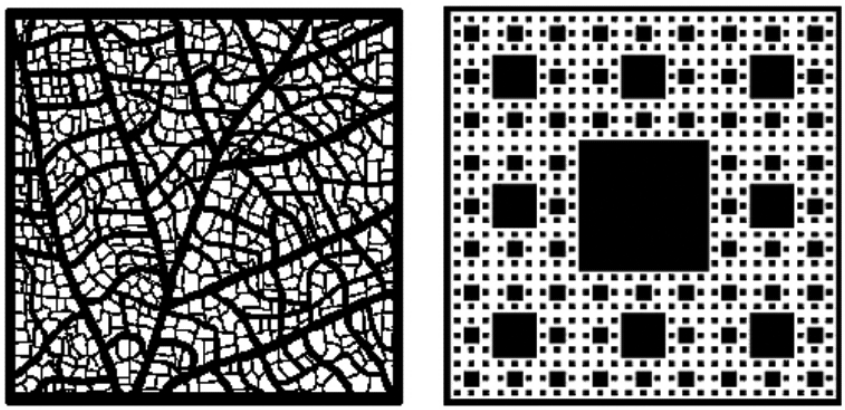

Figure 1: The leaf vein looks more living or more structurally beautiful than the stiff Sierpinski carpet
(Note: As a general rule about livingness or structural beauty, the more substructures the more living or more beautiful structurally, and the higher hierarchy of the substructures the more living or more beautiful structurally. The leaf vein (a) and the Sierpinski carpet (b) both meet the scaling law and Tobler's law, but the leif vein is more living than the Sierpinski carpet. This is because the squares of the Sierpinski carpet on each scale are precisely the same rather than more or less similar, thus violating Tobler's law to some extent.)

French painter Henri Matisse (1947) made a famous statement about the essence of art: *"Exactitude is not truth"*. In terms of exactitude, a photo is far better than a painting. However, the value of a painting lies not in its exactitude, but in something else, which is not only inexact, but also distorted or exaggerated. The distorted

or exaggerated nature is often used in drawing a cartoon. A human face is a living structure governed by the scaling law and Tobler's law, with the recurring notion of far more smalls than larges. The eyes, nose, mouth, and ears are the largest features and are therefore the most salient; each of them – if examined carefully – is a living structure again, with the recurring notion of far more smalls than larges. All human faces are universally beautiful in terms of the underlying living structure, despite some tiny cultural effects on their beauty.

The scaling law and Tobler's law are really two fundamental laws about livingness or beauty. They can be used to examine many patterns or structures (e.g., Wade 2006, Wichmann and Wade 2017) for understanding not only why they are beautiful, but also how beautiful they are. For example, the leaf vein is living or beautiful because of the recurring notion of far more small structures than large ones. This way, through these two laws, the livingness or beauty of a structure or pattern can be objectively or structurally judged. Importantly, the livingness judged through these two laws can be well reflected in the human mind and heart, thus evoking a sense of beauty. This point will be further discussed in the following.

3. Living versus nonliving structure: The "things" the two laws refer to

The two laws introduced above have a common keyword – "things": (1) more or less similar things on each scale, and (2) far more small things than large ones across all scales. What are the "things" the two laws refer to? In general terms, the things that collectively constitute a living structure are the right things, whereas the things that collectively do not constitute a living structure are not the right things. For example, if the leaf vein was saved as a gray-scale image with 1024 by 1024 pixels, each of which has a gray scale between 0 and 255, careful examination of these pixel values would show that they do not have far more light (or dark) pixels than dark (or light) ones. This way, we would end up with an absurd conclusion that the leaf vein is not a living structure. In fact, the pixels are not the right things, or the pixel perspective is not the right perspective for seeing the living structure.

In addition to the perspective discussed above, the scope also matters in seeing a living structure. A tree has surely far more small branches than large ones across scales from the largest to the smallest, while branches on each scale are more or less similar. Thus, the tree is no doubt a living structure, not biologically but in terms of the underlying structure. However, its leaves can be both living and non-living structure depending on the scope we see them. It is a living structure, if we go down to the scope or scale of intra-leaves, each of them has multiple scales (as shown in Figure 1). It is a nonliving structure, if we on the other hand concentrate on inter-leaves, they are all more or less similar sized, being the smallest scale of the tree. In addition, the leaf vein shown in Figure 1 is not a complete leaf, but part of it, with the large enough scope for us to see the living structure. All geographic features are living structures, if they are seen correctly with the right perspective and scope.

Let us further clarify the term "things" or substructures through two working examples: A street network and a coastline (Figure 2, Jiang and Slocum 2020). Conventionally, in geography, the things often refer to geometric primitives such as pixels, points, lines, and polygons.

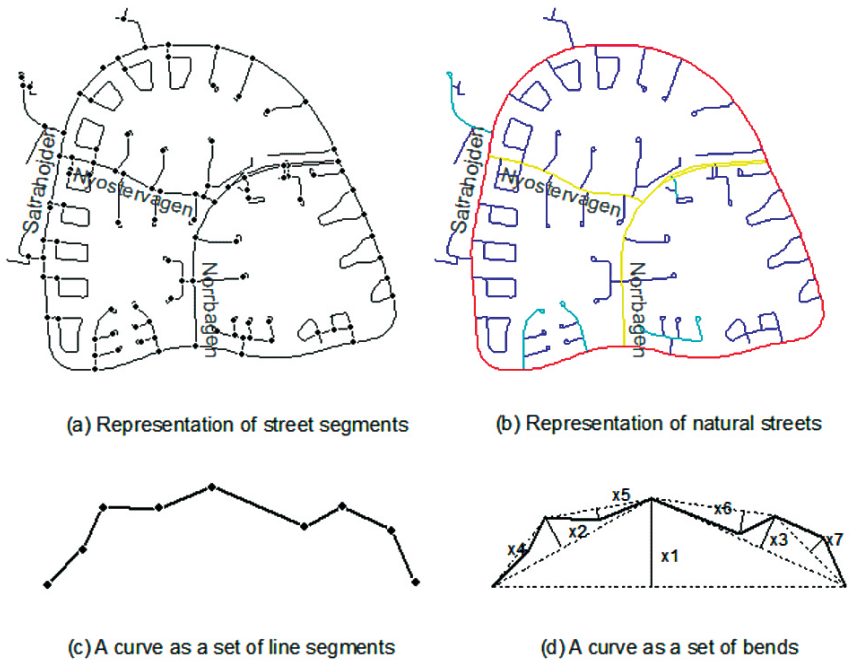

Figure 2: (Color online) Non-living versus living structure views of geographic features (Note: Conventionally, a street network is represented as a set of geometric primitives, which are not the right things or substructures (a), whereas it is more correctly perceived as a collection of named streets, which are the right things or substructures for seeing the street network as a living structure (b). Each street is colored as one of the four levels of scale: blue for the least connected streets, red for the most connected street (only one), and yellow and turquoise for those between the most and the least connected. A coastline is conventionally represented as a set of line segments, which are not the right things or substructures (c), but it is more correctly perceived as a collection of far more small bends than large ones, which are the right things or substructures for seeing the coastline as a living structure (d). It is because the notion of far more small bends than large ones occurs twice: (1) $x_1 + x_2 + x_3 > x_4 + x_5 + x_6 + x_7$, and (2) $x_1 > x_2 + x_3$.)

It is little wonder that Tobler's law is seen pervasively, as there are more or less similar sized things seen from the perspective of geometric primitives. For example, a street network has more or less similar street segments, or all the street junctions have more or less similar numbers of connections (1–4) (Figure 2a). A coastline consists of a set of more or less similar line segments (Figure 2c). Unfortunately, all these geometric primitives are not the right things for seeing the street network or coastline as a living structure. There is little wonder, constrained by the geometric primitives, that living structure was not a formal concept in geography or city science.

A street network is more correctly conceived of as a set of far more short streets than long ones, or a set of far more less connected streets than well connected ones (Figure 2b). The street network has four levels of scale, indicated by the four colors, far more short streets than long ones across the scales, and more or less similar streets on each of the four scales. A coastline is more correctly represented as a set of far more small bends than large ones (Figure 2d). The coastline has three levels of scale, indicated by three sets of bends: $[x_1]$, $[x_2, x_3]$, and $[x_4, x_5, x_6, x_7]$. The notion – or recurring notion – of far more smalls than larges should be the major criteria for whether things are the right things that enable us to see a living structure, or whether we have the right perspective and scope for seeing a living structure.

The "things" that collectively constitute a living structure are also called centers (Alexander 2002–2005), a term that was initially inspired by the notion of organisms conceived by Whitehead (1929). Centers or organisms are the building blocks of a living structure, and their definitions are somewhat obscure. Instead, in this paper we use substructures to refer to the right things for seeing a living structure. This way, a living structure can be stated – in a recursive manner – as the structure of the structure of the structure, and so on. The things or substructures constitute an iterative system. To make the point clear, it is necessary to introduce the head/tail breaks (Jiang 2013), a classification scheme for data with a heavy-tailed distribution.

For the sake of simplicity, we use the 10 numbers [1, 1/2, 1/3, …, 1/10] to show how they are classified through the head/tail breaks (Figure 3, Jiang and Slocum 2020). The dataset is a whole, and its average is about 0.29, which partitions the whole into two subwholes: those greater than the average are called the head [1, 1/2, 1/3], and those less than the average are called the tail [1/4, …, 1/10]. The average of the head subwhole is about 0.61, and it partitions the head subwhole into two subwholes again: those greater than the average are called the head [1], and those less than the average are called the tail [1/2, 1/3]. Instead of expressing the dataset as a set of numbers, we state the 10 numbers as an iterative system consisting of three subwholes recursively defined: [1], [1, 1/2, 1/3], and [1, 1/2, 1/3, …, 1/10]. Instead of perceiving these numbers as a set of 10 numbers, we consider them as a coherent whole, consisting of three subwholes including the whole itself. Or alternatively, these numbers as a coherent structure consists of three substructures including the structure itself. The dataset [1, 1/2, 1/3, …, 1/10], because of its inherent hierarchy of 3, is more living than the other dataset [1, 2, 3, …, 10] that is without any inherent hierarchy, or violates the notion of far more smalls than larges.

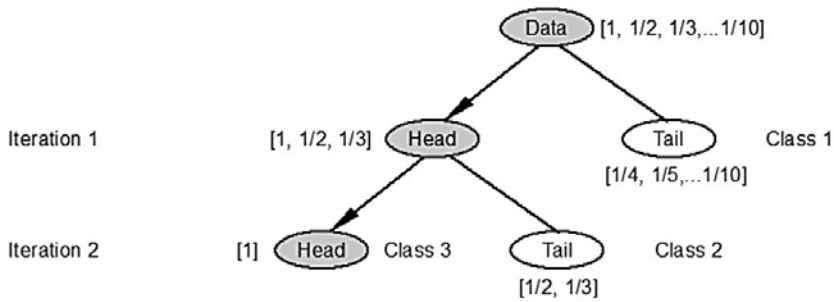

Figure 3: Head/tail breaks with a simple example of the 10 numbers. (Note: The 10 numbers [1, 1/2, 1/3, …, 1/10] are classified into three classes: [1/4, 1/5, …, 1/10], [1/2, 1/3], and [1], which can be said to have three inherent hierarchical levels. The dataset, due to its inherent hierarchy, is therefore more living or more structurally beautiful than another dataset [1, 2, 3, …, 10], which lacks any inherent hierarchy, or violates the scaling law.)

Now let us apply the recursive way of stating a whole or structure into the street network illustrated in Figure 2. Seen from above, the sample street network consists of 50 streets at four hierarchical levels indicated by the four colors: red (r), yellow (y), turquoise (t) and blue (b). Instead of stating the street network as a set or as four classes, we state it as an iterative system consisting of four subwholes or substructures that are recursively defined: [r], $[r, y_1, y_2]$, $[r, y_1, y_2, t_1, t_2, t_3, t_4, t_5]$, and $[r, y_1, y_2, t_1, t_2, t_3, t_4, t_5, b_1, b_2, b_3, \ldots, b_{42}]$. In the same way, it is not difficult to figure out the three recursively defined subwholes for the coastline: $[x_1]$, $[x_1, x_2, x_3]$, and $[x_1, x_2, x_3, \ldots, x_7]$. This living structure representation is recursive and holistic, so it differs fundamentally from existing representations that tend to focus on segmented individuals or mechanistic pieces. An advantage of the living structure representation is that the inherent hierarchy of space is obvious. To this point, we have seen clearly how the right things constitute an iterative system, being a living structure consisting of far more smalls than larges.

4. Two design principles: differentiation and adaptation

In line with the two laws of living structure, there are two design principles – differentiation and adaptation – for transforming a space or structure to be living or more living. The purpose of the differentiation principle is to create far more small substructures than large

ones, while the adaptation principle ensures that the created substructures are well adapted to each other, e.g., nearby substructures are more or less similar. These two design principles ensure that any geographic space would become living or more living from the current status. Importantly, goodness of a geographic space is considered as a fact rather than an opinion, as mentioned above. These two design principles are what underlie the 15 structural properties (Figure 4)

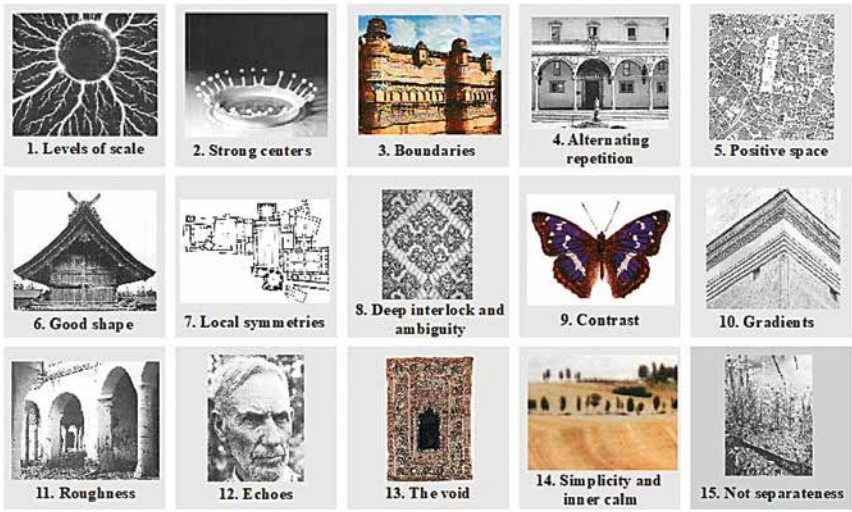

Figure 4: (Color online) Fifteen properties in natural and human-made things (Note: The fifteen properties exist pervasively in physical space, not only nature but also in what we human beings make and build. The two fundamental laws and the two design principles are distilled from these fifteen properties.)

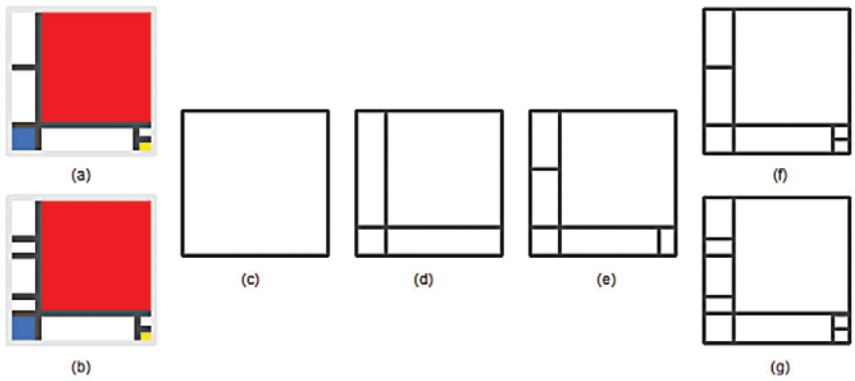

Figure 5: (Color online) Living and less-living structures and their differentiation processes. (Note: The two paintings – *Composition* (a) by the Dutch painter Piet Mondrian (1872–1944) and *Configuration* (b) modified from *Composition* by the author of this paper – meet the minimum condition of being a living structure. Both paintings can be viewed to be differentiated like cell division from the empty square (c), so they are featured by the recurring notion of far more newborn (newly generated) substructures than old ones. More specifically, there are far more newborns than old one from (c) to (d), and again from (d) to (e), except from (e) to (f) in which there is a violation of far more newborns than old ones. However, there is again far more newborns than old one from (e) to (g). On the other hand, in each iteration there are far more small substructures than large ones. Thus, the painting *Configuration* is more living or more beautiful – structurally – than the painting *Composition*. If the reader prefers *Composition* over *Configuration*, do not be panic and your preference is likely to be dominated by nonstructural factors such as cultures, faiths, and ethnicities. However, the kind of beauty determined by the underlying living structure accounts for the feelings shared by most people or peoples.)

distilled by Alexander (2002–2005) from traditional buildings, cities and artifacts. The 15 structural properties can be used to transform a space or structure into living or more living structure. Interested readers should refer to Alexander (2002–2005), specifically Volumes 2 and 3, for numerous examples. In this section, we use two working examples – two paintings and two city plans – to clarify these two design principles.

The two paintings shown in Figure 5 are not very living, as they meet only the minimum condition of being a living structure with three or four inherent hierarchical levels. Painting (a) by Dutch painter Piet Mondrian (1872–1944) is entitled *Composition II*, with the three colors of red, yellow, and blue, whereas painting (b) is modified slightly from painting (a) by the author (Jiang and Huang 2021). Figure 5 demonstrates that how these two paintings are evolved – in a step-by-step fashion – from an empty square. Structurally speaking, painting (b) is more living than painting (a). It can equally be said that structure (g) is more living than structure (f), which is more living than (e), which is more living than structure (d), which is more living than structure (c). Thus, among all these structures or substructures, the empty square is the deadest, while structure (g) is the most living. On the one hand, there is the recurring notion of far more newborn substructures than old ones; on the other hand, within each iteration there are far more small substructures than large ones. Seen from the comparison, it is not hard to understand that one structure is – objectively – more living than another.

The goodness or livingness of a space – or a city in particular – is a matter of fact rather than an opinion or personal preference, based on the underlying living structure. More specifically, the goodness of a space depends on substructures within the space, as we have already seen in the above discussion. The goodness also depends on larger space that contains the particular space. This way of judging goodness or order of things is universal across all cultures, faiths, and ethnicities,

The goodness or livingness of a space – or a city in particular – is a matter of fact rather than an opinion or personal preference, based on the underlying living structure. More specifically, the goodness of a space depends on substructures within the space: the more substructures the more beautiful, and the higher hierarchy of the substructures the more beautiful.

not only for natural things, but also for what we make or build. This is probably the single most important message in the masterful work *The Nature of Order* (Alexander 2002–2005, 2003). This is a radical departure from the current view of space in terms of its goodness, judged by various technical parameters such as density, accessibility, and greenness. The living structure constitutes the foundation of the new kind of city science this paper seeks to advocate and promote.

The living structure perspective implies that a geographic space is in a constant evolution from less living to living or more living. Importantly, a geographic space or its design and planning process is an embryo-like evolution rather than LEGO-like assembly of prefabricated elements (Alexander 2002–2005, Jiang and Huang 2021). Note that the evolution view differs fundamentally from the assembly view, with the former being organic or natural, while the latter being mechanical or less natural. The living structure perspective implies also that a structure or substructures must be seen recursively. For example, conventionally painting (a) is seen as composed of 7 pieces, but it is more correct to say it consists of 18 (1 + 4 + 6 + 7) recursively defined structures or substructures (Figure 5). Instead of being 9 pieces for painting (b), it is more correct to say that it consists of 20 (1 + 4 + 6 + 9) recursively defined structures.

Figure 6: (Color online) Why the city of London plan is more living than the Manhattan one (Note: The city of London plan (the left) is obviously a living structure, for it meets scaling law, or the recurring notion of far more small substructures than large ones across the 6 hierarchical levels, shown in colors in those reduced panels to the left (Jiang and Huang 2021). The part of Manhattan plan (the right) is less living, with only 3 inherent hierarchical levels to the right. Additionally, the number of substructures for the city of London is almost twice that of Manhattan, which is another reason why the left plan is more living than the right one.)

Table 2: Comparison between the new science of cities (Batty 2013) and the new kind of city science

New science of cities	New kind of city science
Mechanistic world view of Descartes	Organismic world view of Whitehead
First and second views of space of Newton and Leibniz	Third view of space of Alexander
Understanding geographic forms and processes	Understanding + making living structures
Tobler's law dominated	Scaling law dominated
A minor science or application of other major sciences	A major science or a science of living structure

Using the recursive perspective, it is not hard to understand why traditional city plans are usually more living than modernist counterparts. For example, with the city of London plan, the notion of far more small substructures than large ones recurs five times, so there are 6 hierarchical levels, whereas for the Manhattan one, the notion of far more small substructures than large ones recurs twice, so there are only 3 hierarchical levels (Figure 6). Thus, the city of London city plan is more living – structurally or objectively – than the Manhattan one. There have been many human perception tests supporting the conclusion that traditional city plans are more living than modernist counterparts (e.g., Alexander 2002–2005, Wu 2015), indicating over 75% agreement between the human perception and the reasoning based on the two laws. There may be some people (fewer than 25%) who prefer modernist buildings because they look new and luminous or for whatever personal reasons. A recent biometric investigation (Salingaros and Sussman 2020) has provided further neuroscientific evidence that traditional façades are more "engaging" with people than contemporary façades.

Space has a healing effect, and this insight into space has been well established in the literature (e.g., Ulrich 1984). Human beings have an innate nature of loving lifelike things and processes such as forests and weathering. This affinity to nature is termed by the eminent biologist

Geographic information gathered through geographic information technologies has provided rich data sources for studying living structures on the Earth's surface from the perspectives of space, time, and human activities. This is particularly true for big data emerging from social media or the Internet.

E. O. Wilson (1984) as biophilia. The biophilia effect has been used to help create living environments by integrating lifelike things such as light, water, and trees (Kellert et al. 2008). It should be noted that a true biophilia goes beyond the simple integration of natural things, but to create things that look like nature structurally (Salingaros 2015). Jackson Pollock (1912–1956) once said that he was not interested in mimicking nature, yet his poured paintings capture the order of nature. In this connection, living structure or the recurring notion of far more smalls than larges, as Alexander (2002–2005) has argued, appears to be the order that exists not only in nature, but also in what we make or build. The order – or living structure – constitutes the core or foundation of the new city science.

5. The new kind of city science, its implications, and future works

The new kind of city science or new city science laid down in the paper is established on the third view of space or on the solid foundation of living structure. The new city science is inclusive of a wide range of conventional disciplines, including for example architecture, urban design and planning, geography, and regional science, all to do with how to transform our cities and communities to be more livable, more living or more beautiful. Thus, the new city science is a science of living structure, not only for understanding geographic forms and processes, but also – more importantly – for making and remaking geographic space to be living or more living (i.e., sustainable spatial planning or design).

Table 2 lists the differences between the new science of cities (Batty 2013) and the new kind of city science. The new city science goes beyond the two cultures under which science is separated from art (Snow 1959), towards the third culture (Brockman 1995) under which science and art is one. In the rest of this section, we further discuss on implications of the new City Science and future works to be done.

It is important to note that the concept of living structure is part of physics, part of mathematics, and part of psychology. As a physical phenomenon, living structure pervasively exists in physical space or in any part of space or matter, and the physical phenomenon constitutes part of physics, or part of quantum physics to be more precise rather than that of classic physics. In this connection, living structure has another name called wholeness that is essentially the same as implicate order (Bohm 1980). Living structure can be defined mathematically, but the mathematics is a nonlinear mathematics rather than a linear mathematics. The physical or mathematical structure can be psychologically or cognitively reflected in the human mind and heart, triggering a sense of livingness or beauty. Living structure is to livingness or beauty what temperature is to warmness. Given this, human related research such as spatial cognition, mental map, human way-finding, and even perception of beauty must consider the underlying living structure.

The new city science has huge implications on design and art, because goodness of art or design is no longer considered to be an arbitrary opinion or personal preference, but a matter of fact. It is essentially the underlying living structure that evokes a sense of goodness or beauty in the human mind and heart. Thus, there is a shared notion of quality or goodness of art among people or different peoples regardless of our culture, gender, and races. Goodness can be measured and quantified mathematically, and the outcome has over 70% agreement with people perception (e.g., Wu 2015, Salingaros and Sussman 2020). In this regard, the mirror-of-the-self experiment (Alexander 2002–2005) provides an effective measure for testing people on their judgement on goodness of things. In this experiment, two things or pictures (for example, those pairs in Figures 1 and 6) are put side by side and human subjects are asked to provide their personal judgment to which one they have a higher degree of belonging or wholeness. The experiment is not kind of psychological or cognitive tests that seek inter-subjective agreement, but rather on degree of livingness, something objective or structural. This kind of experiment, as well as eye-tracking and other biometrics data (Sussman and Hollander 2015), will provide neuroscientific evidence for living structure, thus being an important future work in the new city science.

The new city science is a science of living structure, substantially based on living structure that resembles yet exceeds fractal geometry (Mandelbrot 1982). Like the new science of cities, fractal geometry belongs to the camp of mechanistic thought. For example, the commonly used box-counting method for calculating fractal dimension is too mechanical, as the boxes defined at different levels of scale are not the right things (or the right perspective) for seeing living structure (cf., Section 3). As we have illustrated in Figures 1 and 2, we adopt an organismic rather than mechanistic way of seeing living structures. Fractals emerge from an iterative process, but the iterative process is often too strict or too exact. The real world is indeed evolved iteratively, but it is not as simple as fractals, neither classic fractals nor statistical fractals. Nature – naturally occurring things – has its own geometry, which is neither Euclidean nor

fractal, but a living geometry that *"follows the rules, constraints, and contingent conditions that are inevitably encountered in the real world"* (Alexander 2002–2005). The major difference between fractal and living geometries lies probably on the two different world views. More importantly, goodness of a shape is not what fractal geometry concerned about, but it is the primary issue of living geometry.

Geographic information gathered through geographic information technologies has provided rich data sources for studying living structures on the Earth's surface from the perspectives of space, time, and human activities. This is particularly true for big data emerging from social media or the Internet. The big data are better than government owned or defined data for revealing the underlying living structure for two main reasons. First, big data have high resolution (like GPS locations of a couple of meters), and finer time scales (down to minutes and seconds for social media location data). Thus, they are better than government data for seeing living structure at different levels of scale. Second, government-defined spatial units, such as census tracts, are too rough or too arbitrary for seeing living structure. Instead, we should use naturally defined spatial units such as natural cities and auto-generated substructures (Jiang 2018, Jiang and Huang 2021), which are all defined from the bottom up, rather than imposed from the top down, thus making it easy to see living structures. While working with big data, we should try to avoid using grid-like approaches such as the digital elevation model. Although the digital elevation model has far more low elevations than high ones, the grid approach is not the right perspective for seeing living structures. Instead, we should use watersheds or water streams which are naturally or structurally defined. All these topics will be studied in the future for the new city science.

6. Conclusion

This paper is intended to help set city science on the firm foundation of living structure, based on the belief that how to make and remake livable spaces – or living structures in general – should remain at the core of city science. Considering a room, for example, we should first diagnose whether it is a living structure. If not, try to make it a living structure; if it is already, try to make it more living. This pursuit of living or more living structure extends from our rooms, gardens, buildings to streets, cities, and even the entire Earth's surface. City science should not just be a minor science – as currently conceived under the Cartesian mechanistic world view – that seeks to apply other major sciences or technology for understanding geographic forms and processes (or city structure and dynamics in particular). This is because these major sciences have not yet solved the problem of how to do an effective making or creation. Instead, the problem of making or creating is commonly left to art, design, or engineering, where there is a lack of criteria for judging the quality or goodness of the created things. In this paper, city science is built on the criteria of living structure, not only for understanding geographic forms and processes, but also for transforming geographic space to be living or more living.

The new city science is founded on the third or organismic view of space, under which space is conceived as neither lifeless nor neutral, but a living structure capable of being more living or less living. The third view of space reveals that the nature of geographic space is a living structure or coherent whole, and its livingness or the degree of coherence can be quantified by the inherent hierarchy or the recurring notion of far more smalls than larges. Throughout this paper, we have attempted to argue that the scaling law should play a dominant role for it is universal, global, and across scales, whereas Tobler's law is available on each of these scales. These two laws are the two fundamental laws of living structure. To make a space living or more living, we must follow the two design principles or, more specifically, a series of biophilia design principles or the 15 structural properties. There are three fundamental issues about a geographic space (or a city in particular): (1) how it looks, (2) how it works, and (3) what it ought to be. The short response to these three issues is that a geographic space should look and work like a living structure and ought to become living or more living. Facing various challenges of our cities and environments, the new City Science provides new concepts, questions, and solutions to tackle problems and to make and remake cities and communities to be more livable and more beautiful towards a sustainable society. It is time to transform the new science of cities into the new kind of city science, a science of living structure for the Earth's surface.

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China's Space Program: A 2021 Perspective

The State Council Information Office of the People's Republic of China published a white paper titled "China's Space Program: A 2021 Perspective" . Here are some excerpts

In the next five years, China will integrate space science, technology and applications while pursuing the new development philosophy, building a new development model and meeting the requirements for high-quality development.

I. A New Journey Towards a Strong Space Presence

1. Mission

The mission of China's space program is: to explore outer space to expand humanity's understanding of the earth and the cosmos; to facilitate global consensus on our shared responsibility in utilizing outer space for peaceful purposes and safeguarding its security for the benefit of all humanity; to meet the demands of economic, scientific and technological development, national security and social progress; and to raise the scientific and cultural levels of the Chinese people, protect China's national rights and interests, and build up its overall strength.

2. Vision

China aims to strengthen its space presence in an all-round manner: to enhance its capacity to better understand, freely access, efficiently use, and effectively manage space; to defend national security, lead self-reliance and self-improvement efforts in science and technology, and promote high-quality economic and social development; to advocate sound and efficient governance of outer space, and pioneer human progress; and to make a positive contribution to China's socialist modernization and to peace and progress for all humanity.

3. Principles

China's space industry is subject to and serves the overall national strategy. China adheres to the principles of innovation-driven, coordinated, efficient, and peaceful progress based on cooperation and sharing to ensure a high-quality space industry.

- Innovation-driven development

China puts innovation at the core of its space industry.

- Coordination and efficiency

China adopts a holistic approach in building its space industry. It mobilizes and guides different sectors to take part in and contribute to this key industry, and coordinates all relevant activities under an overall plan.

- For peaceful purposes

China has always advocated the use of outer space for peaceful purposes, and opposes any attempt to turn outer space into a weapon or battlefield or launch an arms race in outer space.

- Cooperation and sharing

China always combines independence and self-reliance with opening to the outside world. It actively engages in high-level international exchanges and cooperation, and expands global public services for space technology and products.

II. Development of Space Technology and Systems

China's space industry serves its major strategic needs, and targets cutting-edge technology that leads the world.

1. Space Transport System

From 2016 to December 2021, 207 launch missions were completed, including 183 by the Long March carrier rocket series. The total launch attempts exceeded 400.

China now provides a variety of launch vehicle services. The Long March-11 carrier rocket has achieved commercial launch from the sea; the Smart Dragon-1, Kuaizhou-1A, Hyperbola-1, CERES-1 and other commercial vehicles have been successfully launched; successful demonstration flight tests on reusable launch vehicles have been carried out.

In the next five years, China will continue to improve the capacity and performance of its space transport system, and move faster to upgrade launch vehicles.

2. Space Infrastructure

(1) Satellite remote-sensing system

China now provides improved land observation services, having launched the Ziyuan-3 03 earth resources satellite, the Huanjing Jianzai-2A/2B satellites for environmental disaster management, a high-resolution multi-mode imaging satellite, a hyper-spectral observation satellite, and a number of commercial remote-sensing satellites.

In ocean observation, China is now able to view multiple indexes of contiguous waters around the globe on all scales, with high-resolution images from the Haiyang-1C/1D satellites and the Haiyang-2B/2C/2D satellites.

China's ability to observe the global atmosphere has achieved a significant increase. Its new-generation Fengyun-4A/4B meteorological satellites in the geostationary orbit are able to perform all-weather, precise and uninterrupted atmospheric monitoring and disaster monitoring to boost response capability. The successful launches of Fengyun-3D/3E satellites enable coordinated morning, afternoon and twilight monitoring, and the Fengyun-2H satellite provides monitoring services for countries and regions participating in the Belt and Road Initiative.

(2) Satellite communications and broadcasting system

China has made steady progress in developing fixed communications and broadcasting satellite network, which now covers more areas with greater capacity. The Zhongxing-6C and Zhongxing-9B satellites ensure the uninterrupted, stable operation of broadcasting and television services. The Zhongxing-16 and APSTAR-6D satellites, each with a 50Gbps capacity, signify that satellite communications in China have reached the stage of high-capacity service.

The mobile communications and broadcasting satellite network has expanded with the launch of the Tiantong-1 02/03 satellites, operating in tandem with the Tiantong-1 01 satellite, to provide voice, short message and data services for hand-held terminal users in China, its neighboring areas, and certain parts of the Asia-Pacific.

The relay satellite system is being upgraded with the launch of the Tianlian-1 05 and Tianlian-2 01 satellites, giving a powerful boost to capacity.

(3) Satellite navigation system

The completion and operation of the 30-satellite BeiDou Navigation Satellite System (BDS-3) represents the successful conclusion of the system's three-step strategy and its capacity to serve the world. BeiDou's world-leading services include positioning, navigation, timing, regional and global short-message communication, global search and rescue, ground-based and satellite-based augmentation, and precise point positioning.

In the next five years, China will continue to improve its space infrastructure, and integrate remote-sensing, communications, navigation, and positioning satellite technologies. It will:

- Upgrade its spatial information services featuring extensive connection, precise timing and positioning, and all dimension sensoring;
- Develop satellites for geostationary microwave monitoring, new-type ocean color observation, carbon monitoring of the territorial ecosystem, and atmospheric environmental monitoring;
- Develop dual-antenna X-band interferometric synthetic aperture radar (InSAR), land water resources and other satellite technology, for efficient, comprehensive earth observation and data acquisition across the globe;
- Build a satellite communications network with high and low orbit coordination, test new communications satellites for commercial application, and build a second-generation data relay satellite system;
- Study and research navigation-communications integration, low-orbit augmentation and other key technologies for the next-generation BeiDou Navigation Satellite System, and develop a more extensive, more integrated and smarter national positioning, navigation and timing (PNT) system;
- Continue to improve the ground systems for remote-sensing, communications and navigation satellites.

3. Manned Spaceflight

The Tianzhou-1 cargo spacecraft has docked with the earth-orbiting Tiangong-2 space laboratory. With breakthroughs in key technologies for cargo transport and in-orbit propellant replenishment, China has successfully completed the second phase of its manned spaceflight project.

The launch of the Tianhe core module marks a solid step in building China's space station. The Tianzhou-2 and Tianzhou-3 cargo spacecraft and the Shenzhou-12 and Shenzhou-13 manned spacecraft, together with the Tianhe core module to which they have docked, form an assembly in steady operation. Six astronauts have worked in China's space station, performing extravehicular activities, in-orbit maintenance, and scientific experiments.

In the next five years, China will continue to implement its manned spaceflight project. It plans to:

- Launch the Wentian and Mengtian experimental modules, the Xuntian space telescope, the Shenzhou manned spacecraft, and the Tianzhou cargo spacecraft;
- Complete China's space station and continue operations, build a space laboratory on board, and have astronauts on long-term assignments performing large-scale scientific experiments and maintenance;
- Continue studies and research on the plan for a human lunar landing, develop new-generation manned spacecraft, and research key technologies to lay a foundation for exploring and developing cislunar space.

4. Deep Space Exploration

(1) Lunar exploration

Achieving relay communications through the Queqiao satellite, the Chang'e-4 lunar probe performed humanity's first soft landing on the far side of the moon, and conducted roving exploration. The Chang'e-5 lunar probe brought back 1,731 g of samples from the moon, marking China's first successful extraterrestrial sampling and return, and the completion of its three-step lunar exploration program of orbiting, landing and return.

(2) Planetary exploration

The Tianwen-1 Mars probe orbited and landed on Mars; the Zhurong Mars rover explored the planet and left China's first mark there. China has achieved a leap from cislunar to interplanetary exploration.

In the next five years, China will continue with lunar and planetary exploration.

5. Space Launch Sites and Telemetry, Tracking and Command (TT&C)

(1) Space launch sites

Adaptive improvements have been completed at the Jiuquan, Taiyuan and Xichang launch sites, with new launch pads installed at Jiuquan for the commercial launch of liquid fuel rockets, and the Wenchang Launch Site entering service. China has formed a launch site network covering both coastal and inland areas, high and low altitudes, and various trajectories to satisfy the launch needs of manned spaceships, space station modules, deep space probes and all kinds of satellites. In addition, its first sea launch site has begun operation.

(2) Space TT&C

In the next five years, China will strengthen unified technical standard-setting for its space products, and on this basis will:

- Further adapt the existing launch site system to better serve most launch missions, and make launch sites smarter, more reliable and more cost-effective to support high-intensity and diversified launch missions;
- Build commercial launch pads and launch sites to meet different commercial launch needs;
- Improve the space TT&C network in terms of organization, technology and methodology, grow the capacity to utilize and integrate space- and ground-based TT&C resources, and build a space TT&C network providing ubiquitous coverage and connections;
- Coordinate the operation and management of the national space system for greater efficiency;
- Strengthen the deep-space TT&C communications network to support missions probing the moon and Mars.

6. Experiments on New Technologies

In the next five years, China will focus on new technology engineering and application, conduct in-orbit tests of new space materials, devices and techniques, and test new technologies in these areas:

- Smart self-management of spacecraft;
- Space mission extension vehicle;
- Innovative space propulsion;
- In-orbit service and maintenance of spacecraft;
- Space debris cleaning.

7. Space Environment Governance

With a growing database, China's space debris monitoring system is becoming more capable of collision warning and space event perception and response, effectively ensuring the safety of in-orbit spacecraft.

In compliance with the Space Debris Mitigation Guidelines and the Guidelines for the Long-term Sustainability of Outer Space Activities, China has applied upper stage passivation to all its carrier rockets, and completed end of life active deorbit of the Tiangong-2 and other spacecraft, making a positive contribution to mitigating space debris.

Progress has been made in the search and tracking of near-earth objects and in data analysis. A basic space climate service system is now in place, capable of providing services in space climate monitoring, early warning, and forecasting, and is providing broader applications.

III. Developing and Expanding Space Application Industry

To serve the economy and society, China has promoted public and commercial application of its satellites and space technology, growing the industry towards greater efficiency.

1. Boosting Public Services with Satellites

The satellite remote-sensing system has been used by almost all departments at national and provincial levels to conduct emergency monitoring of over 100 major and catastrophic natural disasters around the country. It provides services to tens of thousands of domestic users and over 100 countries, having distributed over 100 million scenes of data.

The communications and broadcasting satellite network has made direct services available to over 140 million households in China's rural and remote areas, provided returned data for over 500 mobile phone base stations, and ensured efficient emergency communications during the responses to the forest fire in Liangshan, Sichuan province, to the heavy rainstorm in Zhengzhou, Henan province and to other major disaster relief work.

The BeiDou Navigation Satellite System has guaranteed the safety of over seven million operating vehicles, provided positioning and short message communication services to over 40,000 seagoing fishing vessels, and offered precise positioning services for the freighting of supplies and tracking of individual movement for Covid-19 control, and for hospital construction.

In the next five years, under the overarching goal of building a safe, healthy, beautiful and digital China, we will intensify the integration of satellite application with the development of industries and regions, and space information with new-generation information technology such as big data and Internet of Things. We will also extend the integrated application of remote-sensing satellite data on land, ocean and meteorology, advance the construction of infrastructure for integrated application of the BeiDou Navigation Satellite System, satellite communications, and the ground communications network, and improve our capacity to tailor and refine professional services.

2. Space Application Industry

A group of competitive commercial space enterprises are emerging and realizing industrialized large-scale operation. A variety of products and services such as high-accuracy maps using remote-sensing data, full dimensional images, data processing, and application software are improving the service to users in transport, e-commerce, trading of agricultural products, assessment of disaster losses and insurance claims, and the registration of real estate.

The ability to commercialize satellite communications and broadcasting services has further improved.

The satellite navigation industry has witnessed rapid growth as evidenced by sales of over 100 million chips compatible with the BeiDou system. Its industrial applications have been widely introduced into mass consumption, the sharing economy, and daily life. Achievements in space technology have helped traditional industries transform and upgrade, supported emerging industries such as new energy, new materials and environmental protection, enabled new business models such as smart cities, smart agriculture and unmanned driving to grow, making a great contribution to building China's strengths in science and technology, manufacturing, cyberspace and transport.

In the next five years, China's space industry will seize the opportunities presented by the expanding digital industry and the digital transformation of traditional industries, to promote the application and transfer of space technology. Through innovative business models and the deep integration of space application with digital economy, more efforts will be made to expand and extend the scope for applying satellite remote-sensing and satellite communications technologies, and realizing the industrialized operation of the BeiDou Navigation Satellite System.

IV. Research on Space Science

China's research on space science focuses on scientific questions such as the origin and evolution of the universe, and the relationship between the solar system and humanity. It has launched programs to explore space and conduct experiments, advanced research on basic theories, and incubated major research findings.

1. Research on Space Science

(1) Space astronomy

(2) Lunar and planetary science

(3) Space earth sciences

(4) Space physics

In the next five years, China will continue with the research and development of programs such as the satellite for space gravitational wave detection, the Einstein Probe, the advanced space-based solar observatory, the panoramic imaging satellite for solar wind and magnetosphere interaction, and the high precision magnetic field measurement satellite, focusing on the subjects of the extreme universe, ripples in time and space, the panoramic view of the sun and the earth, and the search for habitable planets.

2. Science Experiments in Space

With the help of the Shenzhou spacecraft series, the Tiangong-2 space laboratory, and the Shijian-10 satellite, China has achieved mammalian embryonic development in space and in-orbit verification of the world's first space cold atom clock, expanded the understanding of the mechanisms behind particle segregation in microgravity, pulverized coal combustion, and material preparation, and achieved research findings in space science of international standing.

In the coming five years, China will make use of space experiment platforms such as the Tiangong space station, the Chang'e lunar probe series, and the Tianwen-1 Mars probe to conduct experiments and research on biology, life, medicine, and materials, to expand humanity's understanding of basic science.

V. Modernizing Space Governance

The Chinese government has been proactive in developing the space industry, through policy measures and well-thought-out plans for space activities.

1. Enhancing Innovation

2. Strengthening Basic Industrial Capabilities

3. Expanding Application

4. Encouraging Commercialization

5. Promoting Law-Based Governance

6. Strengthening Team-Building

7. Promoting Space Education and Culture

VI. International Cooperation

Peaceful exploration, development and utilization of outer space are rights equally enjoyed by all countries. China calls on all countries to work together to build a global community of shared future and carry out in-depth exchanges and cooperation in outer space on the basis of equality, mutual benefit, peaceful utilization, and inclusive development.

1. Basic Policies

China's basic policies on international exchanges and cooperation are as follows:

- Safeguarding the central role of the United Nations in managing outer space affairs; abiding by the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies; upholding the guiding role of relevant UN principles, declarations and resolutions; actively participating in the formulation of international rules regarding outer space; and promoting greater sustainability of space activities;
- Strengthening international exchanges

and cooperation on space science, technology and application; working together with the international community to provide public products and services; and contributing to global efforts to address common challenges;
- Strengthening international space cooperation that is based on common goals and serves the Belt and Road Initiative, and ensuring that the space industry benefits the Initiative's participating countries, especially developing countries;
- Supporting the Asia-Pacific Space Cooperation Organization (APSCO) to play an important role, and giving weight to cooperation under the BRICS and Group 20 mechanisms and within the framework of the Shanghai Cooperation Organization;
- Encouraging and endorsing the efforts of domestic research institutes, enterprises, institutions of higher learning, and social organizations to engage in international space exchanges and cooperation in diverse forms and at various levels in accordance with relevant policies, laws and regulations.

2. Major Achievements

Since 2016, China has signed 46 space cooperation agreements or memoranda of understanding with 19 countries and regions and four international organizations. These measures have yielded fruitful results.

(1) Global governance of outer space

- China participates in consultations on issues such as the long-term sustainability of outer space activities, the development and utilization of space resources, and the prevention of arms race in outer space. Together with other parties, it has proposed discussions on space exploration and innovation, and advanced the Space2030 Agenda of the UN.
- China supports the work of the Beijing office of the United Nations Platform for Space-based Information for Disaster Management and Emergency Response, and has participated in the activities of the International Committee on Global Navigation Satellite Systems in an in-depth manner. It has joined international mechanisms such as the Space Missions Planning Advisory Group and the International Asteroid Warning Network.
- China plays its role as the host country of APSCO, and supports the organization's Development Vision 2030.
- China has strengthened international exchanges on space debris, long-term sustainability of outer space activities, and other issues through mechanisms such as the Space Debris Work Group of China-Russia Space Cooperation Sub-committee and the Sino-US Expert Workshop on Space Debris and Space Flight Safety.
- China supports the activities of international organizations such as the International Telecommunication Union, Group on Earth Observations, Inter-Agency Space Debris Coordination Committee, Consultative Committee for Space Data Systems, International Space Exploration Coordination Group, and the Interagency Operations Advisory Group.

(2) Manned spaceflight

- China has carried out gamma-ray burst polarization monitoring research with the European Space Agency on the Tiangong-2 space laboratory, conducted human body medical research in a micro-gravitational environment with France during the Shenzhou-11 manned spaceflight mission, carried out joint CAVES training and maritime rescue drills with the European Astronaut Centre.
- China has completed the selection of the first batch of international space science experiments to be conducted on the Chinese space station, and conducted technological cooperation and exchanges with Germany, Italy and Russia on space science experiments and the development of space station sections.

(3) BeiDou Navigation Satellite System

- China has coordinated the development of China's BeiDou Navigation Satellite System and the United States' Global Positioning System, Russia's GLONASS system, and Europe's Galileo system. It has carried out in-depth cooperation with them in the fields of compatibility, interoperability, monitoring and assessment, and joint application.
- China has pressed ahead with international standardization of the BeiDou system, which has been included in the standard systems of the International Electrotechnical Commission and many other international organizations in fields such as civil aviation, maritime affairs, international search and rescue, and mobile communications.
- China has increased the BeiDou system's global service capacity by establishing BeiDou cooperation forum mechanisms with the League of Arab States and the African Union, completing the first overseas BeiDou center in Tunisia, and conducting satellite navigation cooperation with countries such as Pakistan, Saudi Arabia, Argentina, South Africa, Algeria, and Thailand.

(4) Deep-space exploration

- China launched the international lunar research station project together with Russia, and initiated the Sino-Russian Joint Data Center for Lunar and Deep-space Exploration. It is working with Russia to coordinate Chang'e-7's lunar polar exploration mission with Russia's LUNA-Resource-1 orbiter mission.
- In the Chang'e-4 lunar exploration mission China cooperated with Russia and the European Space Agency on engineering technology, and with Sweden, Germany, the Netherlands and Saudi Arabia on payloads. It has launched international onboard payload cooperation in the Chang'e-6 lunar exploration mission.

- In the Tianwen-1 mission, China's first Mars exploration project, China cooperated with the European Space Agency on engineering technology, and with Austria and France on payloads. It has established a Mars probe orbit data exchange mechanism with the United States, and launched international onboard payload cooperation in its asteroid exploration mission.
- In the fields of lunar and deep-space exploration, China cooperated on TT&C with the European Space Agency, Argentina, Namibia, and Pakistan.

(5) Space technology

- Together with relevant partners China has developed and successfully launched the China-France Oceanography Satellite, China-Brazil Earth Resources Satellite 04A, and the Ethiopian Remote-Sensing Satellite. It has launched the Student Small Satellites (SSS) for APSCO. It is jointly developing the MisrSat-2 remote-sensing satellite.
- China completed the in-orbit delivery of the Pakistan Remote-Sensing Satellite (PRSS-1), Venezuelan Remote-Sensing Satellite (VRSS-2), Sudan Remote-Sensing Satellite (SRSS-1), and the Algerian Communications Satellite (Alcomsat-1).
- China has provided satellite carrying or launching services for countries including Saudi Arabia, Pakistan, Argentina, Brazil, Canada, and Luxembourg.
- China has conducted space product and technology cooperation with countries including Russia, Ukraine, Belarus, Argentina, Pakistan, and Nigeria.
- China has helped developing countries boost their space science and research. It has built satellite research and development infrastructure with countries including Egypt, Pakistan and Nigeria. It has pressed ahead with the construction of the Belt and Road Initiative Space Information Corridor, and opened China's space facilities to developing countries.

(6) Space applications

- China has established an emergency support mechanism for disaster prevention and mitigation for international users of the Fengyun meteorological satellites, and data from China's meteorological satellites have been widely used in 121 countries and regions.
- China has signed cooperation agreements for the BRICS Remote-Sensing Satellite Constellation, cooperated with the European Space Agency on earth observation satellite data exchange, and built the China-ASEAN Satellite Information Offshore Service Platform and the Remote-Sensing Satellite Data-Sharing Service Platform. It has worked with Laos, Thailand, Cambodia, and Myanmar to build the Lancang-Mekong Space Information Exchange Center.
- China has built satellite data receiving stations with countries including Bolivia, Indonesia, Namibia, Thailand and South Africa.
- China actively participates in the mechanism of the International Charter on Space and Major Disasters, providing satellite remote-sensing data totaling 800 scenes and adding eight new on-duty satellites (constellations) to the satellite system, thereby improving the international community's capacity for disaster prevention and mitigation.
- China actively provides satellite emergency monitoring services. It has initiated emergency monitoring in response to 17 major disasters in 15 countries. For instance, in response to the severe drought in Afghanistan and the dam collapse in Laos in 2018, and to the cyclone that struck Mozambique in 2019, it provided monitoring services for the authorities of affected countries.
- China released its GEO Strategic Plan 2016-2025: Implementing GEOSS. It served as the rotating chair of the Group on Earth Observations in 2020 and promoted the construction of a global earth observation system.

(7) Space science

- Using science satellites including Wukong, Mozi, Shijian-10, and Insight, China has conducted joint scientific research and experiments with countries including Switzerland, Italy, Austria, the United Kingdom, and Japan.
- China co-developed and successfully launched the China-Italy Electromagnetic Monitoring Experiment Satellite. It has continued the joint development of the Sino-European Panoramic Imaging Satellite for Solar Wind and Magnetosphere Interaction, Sino-French Astronomic Satellite, and China-Italy Electromagnetic Monitoring Experiment Satellite 02. It has joined countries including Italy and Germany in developing and calibrating the payloads of satellites such as the advanced space-based solar observatory, Einstein Probe, and enhanced X-ray timing and polarimetry observatory.
- Using the China-Brazil Joint Laboratory for Space Weather, it co-built the space environment monitoring and research platform for South America.

(8) Personnel and academic exchanges

- China has taken part in the activities organized by the International Astronautical Federation, International Committee on Space Research, International Academy of Astronautics, and International Institute of Space Law. It has hosted the 2017 Global Space Exploration Conference, the 13th Meeting of the International Committee on Global Navigation Satellite Systems, the United Nations/China Forum on Space Solutions: Realizing the Sustainable Development Goals, the Wenchang International Aviation and Aerospace Forum, the Zhuhai Forum, the International Summit on BDS Applications, and the Fengyun Satellite User Conference.
- China has helped developing countries train professionals. Through the Regional Centre for Space Science and

Technology Education in Asia and the Pacific (China) (Affiliated to the United Nations), it has trained almost 1,000 space-industry professionals for more than 60 countries, and established the "Belt and Road" Aerospace Innovation Alliance and the Association of Sino-Russian Technical Universities. It has also promoted personnel exchanges in remote-sensing and navigation technology through the International Training Program and other channels.

- China has promoted scientific and technological exchanges in the fields of space science, remote sensing and navigation through the China-Europe Space Science Bilateral Meeting, the China-EU-ESA Dialogue on Space Technology Cooperation, and the Dragon Programme - a joint undertaking between ESA and the Ministry of Science and Technology of China.

3. Key Areas for Future Cooperation

In the next five years China will be more open and active in broadening bilateral and multilateral cooperation mechanisms, and will engage in extensive international exchanges and cooperation in the following key areas:

(1) Global governance of outer space

(2) Manned spaceflight

(3) BeiDou Navigation Satellite System

(4) Deep-space exploration

(5) Space technology

(6) Space applications

(7) Space science

(8) Personnel and academic exchanges

The complete paper can be accessed at http://www.cnsa.gov.cn/english/n6465652/n6465653/c6813088/content.html

Entry-level hydrographic survey software

EIVA's new software variant NaviSuite Kuda Core provides advanced hydrographic survey software capabilities at an entry-level price. It is tailored to support hydrographic surveys with a single USV or small survey vessel using multi-beam echosounder (including backscatter), LiDAR and/or camera *www.eiva.com*

Collaborative project to advance Geo-data science skills

Fugro has joined the University of Houston (UH) and its four partnering universities, UH-Downtown, UH-Victoria, UH-Clear Lake and Sam Houston State University, on a collaborative project to advance Geo-data science skills in the energy sector. The project, "Data Science for the Energy Transition," is being funded through a 3-year grant with the National Science Foundation (NSF) and will offer undergraduate and master's students specialized training in statistical and machine learning techniques for subsurface Geo-data. Fugro's role as an industry partner on the project is to provide UH with real-world Geo-data and guidance on their use for hands-on training opportunities. *www.fugro.com*

Developing Australia's UTM framework

Global UTM services provider OneSky awarded a contract with Airservices Australia (Airservices) to develop a working prototype of a Flight Information Management System (FIMS) for its Uncrewed Traffic Management (UTM) network. The Airservices tender calls for providers to build out a concept for a FIMS tailored to the needs of the Australian aviation industry. While FIMS can refer to an interface between an Air Traffic Management System and UTM for the transfer of data, the goal is to collaborate with Airservices to create a platform for a wide variety of services: one that will ensure that drones operate safely within regulations and have minimum impact on other aircraft and the communities they fly over, and ensure "efficient, fair, and competitive access to airspace.

Supporting rural broadband mapping across the Canada

Ecopia AI has been awarded a contract by the Government of Canada to provide next-generation mapping data in support of the deployment of high-speed Internet across rural Canada.

With a large percentage of the population working from home due to the COVID-19 pandemic, the critical need for high-speed Internet connectivity across the country has been highlighted – and a deep digital divide has been revealed.

Ecopia will leverage its AI-based mapping systems to mine a variety of geospatial datasets and identify broadband serviceable locations across rural Canada – including many locations in remote and indigenous communities. This data will be used to identify connectivity gaps and accelerate the deployment of broadband infrastructure across the country.

Use of quantum computing in strategic industries

A consortium comprised of seven companies (Amatech, BBVA, DAS Photonics, GMV, Multiverse computing, Qilimanjaro Quantum Tech and Repsol), supported by five research centers (BSC, CSIC, DIPC, ICFO and Tecnalia), and one public university (UPV) has launched the CUCO project for research into quantum computing applied to strategic industries in the Spanish economy: energy, finance, space, defense, and logistics.

The CUCO project, subsidized by the CDTI and supported by the Spanish Ministry of Science and Innovation as part of the Recovery, Transformation and Resilience Plan, is the first major quantum computing project at the national and business level with the objective of progressing in the scientific

and technological knowledge of quantum computing algorithms by means of public-private collaboration between companies, research centers and universities, making it possible to accelerate the implementation of these technologies for their use in the medium term. In addition to identifying a series of relevant usage cases in the Spanish economy in which to conduct proofs of concept to study whether quantum computing could improve the performance of classic computing in responding to business needs and proposing the corresponding metrics. In this context, usage cases will be researched in Earth observation, the fight against climate change and the environment, traceability of information throughout the supply chain, optimization and simulation of complex financial calculations, signals intelligence, etc.

Quantum technologies, and specifically quantum computing, are destined to play a disruptive role due to the impact they will have in many areas, given the massive calculation capacity, which could mark the beginning of a new era in technology. Spain cannot afford to be left behind, and it has the capability to lead in this new race.

Through its research into quantum computing, the CUCO project will also have an impact on improving environmental sustainability, as quantum computing promotes more energy-efficient algorithms. *www.gmv.com*

Solar mapping coverage of over 107 million US buildings

Palmetto have announced that its Mapdwell division has mapped the solar potential and energy load profiles of over 107 million rooftops — approximately 75% of all US buildings equating to 81% of the U.S. population — using its proprietary technology. Acquired by Palmetto in April 2021, Mapdwell also licenses this data via application programming interfaces (APIs) to leading utility companies, such as ConEd, Pepco, BGE and others, to further renewable energy initiatives across the country.

Arianespace to launch 8 new Galileo satellites

The European Union Agency for the Space Programme (EUSPA) has chosen Arianespace to launch four new Galileo satellites. With this order, EUSPA takes over the role of placing launch services contracts for Galileo from ESA, which acted so far in the name and on behalf of the European Commission and will continue to be the technical authority for these launches. This order follows European Space Agency's (ESA) order for the launch of four satellites in October 2021, and will complete the deployment of first-generation Galileo satellites. *www.arianespace.com*

Arianespace Soyuz rocket launches two Galileo satellites

Arianespace successfully launched another two satellites for Europe's Galileo satellite navigation system. The FOC-M9 (23-24) and SAT 27-28 payloads lifted off on a Soyuz rocket from French Guiana. This was the 11th launch for the constellation by Arianespace, which has now orbited 28 satellites, including 4 IOV, for Galileo.

Info Note on the Galileo Open Service Navigation Message Authentication available

The European Union Agency for the Space Programme has published a 41-page Info Note on the Galileo Open Service Navigation Message Authentication (OSNMA).

Following publication of the Info Note, an OSNMA Public Observation Test Phase now gets underway. The Test Phase will allow any interested users to access the OSNMA Signal In Space (SIS) and related products for testing purposes.

Target users for OSNMA are receiver manufacturers, application developers, members of research institutions, or similar. EUSPA and the European Commission will consider users' feedback for future OSNMA service phases.

The OSNMA service is an authentication mechanism that allows Open Service users to verify the authenticity of GNSS information, making sure that the data they receive is indeed from Galileo and has not been modified in any way. It is an open-access and free-of-charge service, based on the provision of cryptographic data by the Galileo E1 signal (E1-B, data component) from a subset of the Galileo satellites, enabling receivers to authenticate the Open Service navigation messages.

OSNMA is authenticating data for geolocation information from the Open Service through the Navigation Message (I/NAV) broadcast on the E1-B signal component. This is realised by transmitting authentication-specific data in previously reserved fields of the E1 I/NAV message. By using these previously reserved fields, OSNMA does not introduce any overlay to the system, thus the OS navigation performance remains untouched. *www.gsc-europa.eu*

Last Glonass-M satellite to be ready for launch in March 2022

The last Glonass-M navigation satellite will be ready for a launch in March 2022, according to a source in Russia's space industry. The first navigation satellite of the new generation Glonass-K may be launched in the middle of the second quarter of 2022. *https://tass.com*

Euroconsult releases "Government Space Programs" report for 2021

Space consulting and market intelligence firm Euroconsult has released its "Government Space Programs" report for 2021. The highlight of this year's findings is a continued, even accelerated, volume of governmental investment in the space sector, driven by two major drivers: ambitious space exploration programmes by leading space countries, and rivalries driving the militarization of space.

Despite a year of uncertainty, the space sector has received record government investment totaling over $92 Billion, an

8% increase compared to 2020. Civilian space budgets, totaling $53 billion in 2021, continue to receive more funding than defense space programs, at 58% of total spending, though the share going to defense, $39 billion in 2021, is increasing. Geopolitical tensions, increasing rivalry between leading space powers, and the value of space as the ultimate high ground drive the militarization of space trend, with leaders increasing their investments in defense space assets and technologies.

This year's edition of the report takes a close look at the surge of public funding intended to shore up the space industry against the economic repercussions of the COVID-19 pandemic. Government Space Programs 2021 provides details on national space programmes' spending priorities as well as two potential 10 year forecast scenarios, digested into negative and optimistic models.

Sequans introduces low-power GNSS positioning capability

Sequans Communications S.A has announced the availability of low-power GNSS positioning capability on its Monarch 2 LTE-M/NB-IoT platform. The integrated GNSS solution offers Sequans' IoT customers accurate positioning with lower power consumption, removing the need of an external positioning chipset for an overall higher performing, lower cost tracking solution. *www.sequans.com*

Affordable high precision GNSS module

Quectel Wireless Solutions and Point One Navigation recently announced the LG69T-AM, the latest addition to the LG69T GNSS Module Series. Point One's positioning engine powers the LG69T-AM and enables cm-level global accuracy by integrating augmented GNSS in an affordable module with open-source API. The LG69T-AM GNSS module features STMicroelectronics› TeseoV positioning receiver platform with 80 tracking and 4 fast acquisition channels compatible with GPS, GLONASS, Galileo, BeiDou, QZSS and NAVIC. *quectel.com*

Planet launches 44 SuperDove satellites

Planet Labs PBC has announced the successful launch of its 4x Flock, consisting of 44 SuperDove satellites, into orbit on a SpaceX Falcon 9 rocket. These 44 satellites will join Planet's existing fleet of roughly 200 satellites in orbit. It has now launched 127 satellites across eight launches with SpaceX, and over 500 satellites total since the company's founding 10 years ago. With the latest addition of 44 SuperDove satellites, the company's PlanetScope product will continue to offer customers satellite data captured from the latest and strongest technology. *www.planet.com*

Data from newly-launched Chinese RS satellite

China's remote-sensing ground stations received the first 159 gigabytes of data from the newly-launched remote-sensing satellite Ziyuan I-06. The satellite was launched recently from the Taiyuan Satellite Launch Center in Shanxi Province, which is part of the country's plan to develop its national civil space infrastructure. *www.ecns.cn*

LEO satellite broadband service in India

OneWeb, the low Earth orbit satellite communications company, and Hughes Network Systems LLC ("Hughes"), have announced a strategic six-year Distribution Partner agreement to provide low Earth orbit (LEO) connectivity services across India. The arrangement between OneWeb and Hughes Communications India Private Ltd. (HCIPL), a joint venture between Hughes and Bharti Airtel Limited ("Airtel"), follows the Memorandum of Understanding signed by the companies in September 2021.

HCIPL will deliver services to enterprise and government with OneWeb capacity, especially in areas outside the reach of fiber connectivity. OneWeb will connect towns, villages, and local and regional municipalities in those hardest-to-reach areas, playing a critical role in bridging the digital divide. *https://oneweb.net*

S. Somanath is the new Chairman of Indian Space Research Organisation

Mr. S. Somanath assumed the charge of Secretary, Department of Space and Chairman, Space Commission on 14 January 2022. In his previous assignment he was Director, Vikram Sarabhai Space Centre (VSSC), the lead Centre responsible for Launch vehicle technology development. Prior to that he has been the Director of Liquid Propulsion Systems Centre (LPSC) at Valiamala, Thiruvananathapuram till December 2017. He was the Associate Director (Projects) of Vikram Sarabhai Space Centre and also the Project Director of GSLV Mk-III Launch vehicle. Under his leadership as the Project Director, the first Experimental flight of LVM3-X/CARE mission was successfully accomplished on 18th December 2014.

Mr. Somanath is an expert in the area of system engineering of launch vehicles. His contributions in PSLV and GSLV Mk-III were in their overall architecture, propulsion stages design, structural and structural dynamics designs, separation systems, vehicle integration and integration procedures development. He has been the Deputy Director of the 'Structural Engineering' Entity in VSSC and also the Deputy Director of 'Propulsion and Space Ordnance Entity' in VSSC till November, 2014.

Enhancing location accuracy experience for smartphone users in

HERE Technologies has announced that Transsion has selected HERE Network Positioning to improve its location accuracy capabilities in emerging markets such as Kenya, Nigeria, Ghana, Bangladesh, India, Pakistan, Indonesia and Thailand.

By deploying HERE Network Positioning, Transsion will be able to identify accurate positioning of its devices both indoors and outdoors. This works especially when satellite signals of GPS are not available, such as when the device is located indoor or the GPS signals are blocked by objects. As a result, Transsion will enable its smartphone users to locate devices, people, and objects faster, with higher precision and confidence. *www.here.com*

Agtonomy raises additional $5

Agtonomy, a hybrid autonomy and tele-assist service platform, has announced that it has raised an additional $5 million in Seed II funding from strategic and venture investors Toyota Ventures, Flybridge, Hampton VC, E²JDJ and Momenta, for a total of $9 million in seed funding to date. This latest round will be used to accelerate development and trials of the Agtonomy platform to address the growing labor and sustainability challenges facing local agriculture. *http://agtonomy.com*

NAVYA and VALEO partnership

NAVYA, and VALEO are extending their collaboration and are combining their know-how as part of the French government's 4th Investment Program for the Future to develop and design the future "Autonomous Vehicle Failsafe System" (AVFS).

The technological building blocks that compose the AVFS (Autonomous Vehicle Failsafe System) connect to the NavyaDrive®. VALEO will supply its latest generation of sensors aligned with automotive standards. Combined with the autonomous driving system embedded containing all the ISO-standard algorithms, they will provide the expected safety redundancy and ensure a second control chain. *https://navya.tech*

Aidrivers, Ashok Leyland to develop clean, greener autonomous vehicles

Aidrivers and Ashok Leyland have joined hands for the development of AI-enabled autonomous vehicles to meet the needs for a sustainable future. The two companies have signed a MoU for a long-term collaboration which will combine their specialist knowledge and experience to push forward together in this rapidly advancing field.

Aidrivers provides autonomous mobility solutions for industrial mobility automation, which optimise clients' business operations and enable the delivery of efficiency and quality services. Ashok Leyland manufactures commercial vehicles, chassis, industrial engines, marine engines and engines for gensets.

Nokia selected by GO Malta

Nokia has been selected by GO Malta (GO) as its sole strategic partner for a nationwide 5G RAN rollout in a seven-year deal. The deal will see the introduction of scalable, ultra-reliable, high-speed, and low latency mobile connectivity to GO's consumer and enterprise customers. The move will also support GO's ambitions to drive new business opportunities via 5G networks by introducing innovative new use cases such as digital automation, Internet of Things (IoT), remote monitoring, and 'immersive' technologies such as virtual reality. Nokia is the incumbent vendor in this expansion deal.

Precise location solution with low-power Wi-Fi chipset

Infineon Technologies AG and Deeyook have announced their collaboration on location solutions. The location-as-a-service (LaaS) company has invented and patented an award-winning tracking solution to determine indoor and outdoor locations of items, assets, and employees. Both companies fuse Deeyook's ultra-precise, innovative algorithms into Infineon's best-in-class, low power AIROC™ Wi-Fi portfolio to enable an accurate, passive, ubiquitous, and efficient location solution. *www.infineon.com*

Brand Capital International invests in what3words' India expansion

what3words has announced that it has received a $10 million USD investment from Brand Capital International to support its expansion across India. Brand Capital International will also be providing strategic guidance, marketing support, and assistance with developing partnerships to help drive what3words' growth in India.

what3words has built the simplest way to talk about location by enabling people around the world to identify and share any precise location using just three words. It has divided the globe into a grid of 3 metre squares and given each square a unique identifier of three words: a what3words address. *https://what3words.com*

Expanding LoRaWAn coverage through IoT to satellite connectivity

Semtech Corporation has announced a joint initiative with Lacuna Space to further increase coverage and resilience of LoRaWAN® connectivity.

In areas of the world without cellular or Wi-Fi signals, satellites fill connectivity gaps – especially in hard-to-reach areas. LoRaWAN is the unique standard that is capable of bridging terrestrial networks with worldwide satellite connectivity in order to offer low power ubiquitous connectivity and fills this gap.

The collaboration is built on Long Range Frequency Hopping Spread Spectrum (LR-FHSS), the latest addition to the LoRaWAN standard. LR-FHSS is unique because it takes up less room on the network, which future-proofs capacity while maintaining low power consumption capabilities – which, in turn, enables affordable and simple satellite IoT platforms. *http://semtech.com*

Financial support by govt. of India to promote drones in agriculture

In a major boost to promote precision farming in India, the Union Ministry of Agriculture and Farmers Welfare has issued guidelines to make drone technology affordable to the stakeholders of this sector. The guidelines of "Sub-Mission on Agricultural Mechanization" (SMAM) have been amended which envisages granting up to 100% of the cost of agriculture drone or INR10 lakhs, whichever is less, as grant for purchase of drones by the Farm Machinery Training & Testing Institutes, ICAR institutes, Krishi Vigyan Kendras and State Agriculture Universities for taking up large scale demonstrations of this technology on the farmers' fields.

The Farmers Producers Organizations (FPOs) would be eligible to receive grant up to 75% of the cost of agriculture drone for its demonstrations on the farmers' fields.

A contingency expenditure of Rs.6000 per hectare would be provided to implementing agencies that do not want to purchase drones but will hire drones for demonstrations from Custom Hiring Centres, Hi-tech Hubs, Drone Manufacturers and Start-Ups. The contingent expenditure to implementing agencies that purchase drones for drone demonstrations would be limited to Rs.3000 per hectare. The financial assistance and grants would be available until March 31, 2023.

In order to provide agricultural services through drone application, 40% of the basic cost of drone and its attachments or Rs.4 lakhs, whichever less would be available as financial assistance for drone purchase by existing Custom Hiring Centers which are set up by Cooperative Society of Farmers, FPOs and Rural entrepreneurs. The new CHCs or the Hi-tech Hubs that will be established by the Cooperative Societies of Farmers, FPOs and Rural entrepreneurs with financial assistance from SMAM, RKVY or any other Schemes can also include Drone as one of the machines along with other agricultural machines in the projects of CHCs/Hi-tech Hubs.

Agriculture graduates establishing Custom Hiring Centers would be eligible to receive 50% of the basic cost of drone and its attachments or up to Rs.5 lakhs in grant support for drone purchases. Rural entrepreneurs should have passed class tenth examination or its equivalent from a recognized Board; and should have remote pilot license from Institute specified by the Director General of Civil Aviation(DGCA) or from any authorized remote pilot training organization.

The subsidized purchase of agriculture drones for CHCs/Hi-tech Hubs will make the technology affordable, resulting in their widespread adoption. This would make drones more accessible to the common man in India and will also significantly encourage domestic drone production.

The drone operations are being permitted by Ministry of Civil Aviation (MoCA) and Director General of Civil Aviation (DGCA) through the conditional exemption route. MoCA has published 'Drone Rules 2021' vide GSR No. 589(E) dated 25th August 2021 to regulate the use and operation of Drones in India. The Department of Agriculture & Farmers Welfare has also brought out Standard Operating Procedures (SOPs) for use of Drone application with pesticides for crop protection in agricultural, forestry, non-cropped areas, etc. and for Drone Application in Spraying for Soil and Crop Nutrients. *https://static.pib.gov.in*

Drone swarm control solution shines in DARPA field exercise

Raytheon Intelligence & Space recently supported the fifth OFFensive Swarm-Enabled Tactics, or OFFSET, DARPA program field exercise. Using integrated swarm technology developed by a Raytheon BBN-led team, a single operator successfully controlled a swarm—composed of 130 physical drone platforms and 30 simulated drone platforms—both indoors and outdoors in an urban setting. During the exercise, the team used a combination of commercial off-the-shelf and custom-built hardware and software to deliver swarm autonomy. This enabled a single or small group of operators to direct and manage the activities of a large swarm of autonomous air and ground vehicles with minimal training. *www.raytheonintelligenceandspace.com*

AUS bags Survey of India contract to map Haryana, India

AUS (Aarav Unmanned Systems wins a Large-Scale Mapping Project from the Survey of India (SoI). The company has bagged the $2 million mandate to deploy nearly 44 drones to map the entire state of Haryana covering roughly 32000 sq km. Under this project, AUS will deploy its proprietary survey grade drones to ensure accurate data capturing which will further be processed by the survey of India to update the revenue maps and GIS database by digitizing the land records. *https://aus.co.in*

Department 13 drone technology

Department 13 has commenced work with another national critical infrastructure organization in Australia, to enable the safe and controlled use of autonomous drone capabilities at multiple sites and drive new and innovative business outcomes from capabilities and intelligence delivered by the drones and its operating system. Integrating Department 13's specialized drone technology into the site's current operations is elevating safety and security postures and enabling a range of autonomous duties to be conducted by the new drone fleet. The capabilities of the system that will further extend into, support, and innovate a range of areas in the organization like never before.

Supporting the organization through the entire technology integration, Department 13 will help plan and manage all mandatory compliance work required by the Civil Aviation Safety Authority (CASA) for Beyond Visual Line of Sight (BVLOS) operations at the site. *https://department13.com*

MC-X Platform and MC-Max machine control solution by Topcon

Topcon Positioning Group has announced its MC-Max machine control solution. Based on its MC-X machine control platform, and backed by Sitelink3D — the company's real-time, cloud-based data management ecosystem — it is a scalable solution for mixed-fleet heavy equipment environments. It is designed to adapt to owners' machine control and data integration needs as their fleets and workflows expand. *www.topconpositioning.com*

Bringing high accuracy GNSS corrections to the China market

Hexagon's Autonomy & Positioning division has announced its partnership with Chinese positioning company Dayou. This collaboration will bring TerraStar X technology to the Chinese market, providing fast precise point positioning (PPP) corrections for autonomous vehicles and mass-market use such as smartphones. The partnership enables Hexagon and Dayou to provide consistent positioning solutions globally, including North America, Europe and China, so OEMs can deploy the same design worldwide. The GNSS corrections generated from TerraStar X technology enable lane-level accuracy with convergence in under a minute for consumer and automotive-grade GNSS receivers, supporting ADAS, autonomous applications, safety-critical applications, mobile phone applications and more. *HexagonPositioning.com*

SBG Systems drives GNSS+inertial in Paris

Autonomous vehicles require lane-level accuracy at all times and in all conditions. However, under many conditions, such as in urban canyons and tunnels, they may lose line-of-sight to enough GNSS satellites to achieve accurate and robust positioning or may have no signal at all. In these situations, they need data from other sensors, including an odometer and an inertial measurement unit (IMU). Creating reliable and safe autonomous navigation requires fusing GNSS and inertial technology in a multi-layered system. SBG Systems and its partners LeoDrive.ai and Intempora, have been doing this to develop solutions for autonomous vehicles. SBG's technology enables multi-sensor integration while addressing such autonomous navigation challenges as time synchronization, integrity, precise positioning and high-definition mapping. *www.sbg-systems.com*

Development of GNSS module by Alps Alpine and Furuno

Alps Alpine and Furuno Electric Co., Ltd. have jointly developed the UMSZ6 Series GNSS Module realizing high-accuracy positioning to within 50 cms without correction data for automotive applications. The GNSS Module uses a multi-frequency GNSS receiver chip based on Furuno's Extended Carrier Aiding3 technology: the eRideOPUS 9 (model ePV9000B) and algorithm. Running costs associated with RTK4 base stations, correction data receiving, and correction data use are no longer needed, maximizing cost performance, while reliable vehicle positioning down to the lane level is possible even on general roads. *www.alpsalpine.com*

Test sequence fulfilling requirements of E112 emergency caller location

All smartphones sold in the European Union have to be compliant as of March 17, 2022, with the Delegated Regulation (EU) 2019/320. A supplement to the Radio Equipment Directive (RED) 2014/53/EU, it defines that 112 emergency calls provide caller location information to emergency services in a fast and accurate way, to make sure first responders can arrive at the site of an accident quickly. Compliance with Galileo, Advanced Mobile Location (AML) and Wi-Fi positioning will be mandatory.

Rohde & Schwarz has developed a software based extension to its well-established R&S TS-LBS location based services test system, making it a tailored solution in line with the European Commission's guideline document and the upcoming ETSI standard TS 103 825 for AML protocol testing. *www.rohde-schwarz.com*

Testing the world's first fully autonomous ship navigation systems

The Nippon Foundation, Mitsubishi Shipbuilding Co., Ltd., a part of Mitsubishi Heavy Industries Group, and Shin Nihonkai Ferry Co., Ltd., have successfully completed a demonstration test of the world's first fully autonomous ship navigation systems on a large car ferry, conducted on the Iyonada Sea from Shinmoji, Kitakyushuu City, on January 17.

This demonstration was part of MEGURI 2040, a project promoting the development of fully autonomous vessels supported by The Nippon Foundation. This test demonstrated the world's first fully autonomous navigation system, on a 222-meter ferry, with autonomous port berthing and unberthing using turning and reversing movements and high-speed navigation of up to 26 knots. Other new technologies included in the advanced fully autonomous operation system include sensors to detect other ships using infrared cameras, a remote engine monitoring system, and a sophisticated cyber security system. *www.mhi.com*

New Vega 60™ Heading and Positioning OEM Board by Hemisphere GNSS

Hemisphere GNSS has announced another Vega™ heading and positioning OEM board using the Lyra II™ and Aquila™ chipsets. The board fits industry-standard 46 by 71mm form factors with a 60-pin connector. Vega 60 can be used to replace more expensive and lesser-abled 60-pin boards with either single or dual antenna capabilities. It also offers similar or lower power consumption than pin-compatible competitors. Hemisphere's Lyra II™ and Aquila™ ASIC (application-specific integrated circuit) designs provide the ability to simultaneously track and process over 1100 channels from all GNSS constellations and signals including GPS, GLONASS, Galileo, BeiDou, QZSS, NavIC, SBAS, and L-Band. *www.hgnss.com*

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mdGroup acquires GeoCu

mdGroup has bought aerial Lidar mapping technology provider GeoCue Group for an undisclosed sum from its founders. The company already owns Microdrones, a Germany-based business that supplies aerial data to make digital twins of industrial sites. *www.group-md.com*

New contract by Intermap with a leading European airline

Intermap Technologies has announced a new contract with a leading European airline to provide elevation data as a service for route planning operations through an online data subscription service. The European airline has subscribed to Intermap's web services to access high-resolution NEXTMap® elevation datasets. This subscription enables the airline to access terrain data on-demand to visualize terrain and perform line-of-sight analyses to model safer and more efficient routes in parallel with other operations and engineering software tools.

EarthCam 4D by EarthCam

EarthCam has introduced EarthCam 4D, empowering virtual design and construction (VDC) teams to overlay and synch live imagery with their digital twins. An intuitive time-line allows users to scroll backward and forward in time to view live imagery in relation to their 4D models. *https://earthcam.net*

SAR Data for Geohazard Mitigation Projects in Philippines

AMH Philippines, Inc. and Synspective have signed a MoU to use SAR technology as part of an integrated and comprehensive approach to mitigate geohazards for infrastructure in the Philippines. The partnership includes the Land Displacement Monitoring (LDM) service, fully developed and automated by Synspective, and is empowered with AMH's years of local experience in various projects in transportation infrastructure, energy, property, and mining sectors. Both parties will attempt to mutually leverage the strengths in their respective fields and deliver comprehensive end-to-end geohazard consultation to support local communities that are prone to frequent natural disasters.

New survey capabilities in 1Edit

1Spatial have extended the capability of their survey application, 1Edit, with increased support for photos and 2.5D data. It allows users to attach feature photos, including automated geotagging. The latest version now includes new validation functions and improved handling for Heights (2.5D data), typically useful for detailed asset and land management surveys.

MARK YOUR CALENDAR

March 2022

Geolgnite Winter Geo 2022 (Online)
1-2 March
https://wintergeo.com

Munich Satellite Navigation Summit 2022
7-9 March
Munich, Germany
munich-satellite-navigation-summit.org

IGRSM 2022
8-9 March
Virtual Conference
Kuala Lumpur Malaysia
www.igrsm.org

The 10th Land Administration Domain Model Workshop
31 March - 2 April 2022
Dubrovnik, Croatia
http://isoladm.org/LADM2022Workshop

July 2022

IGARSS 2022 (hybrid form)
17-22 July 2022
Kuala Lumpur, Malaysia
https://igarss2022.org

September 2022

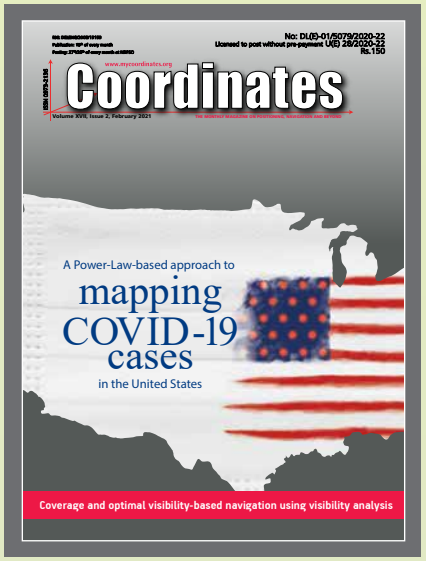
Commercial UAV Expo Americas
6-8 September 2022
Las Vegas, USA
www.expouav.com

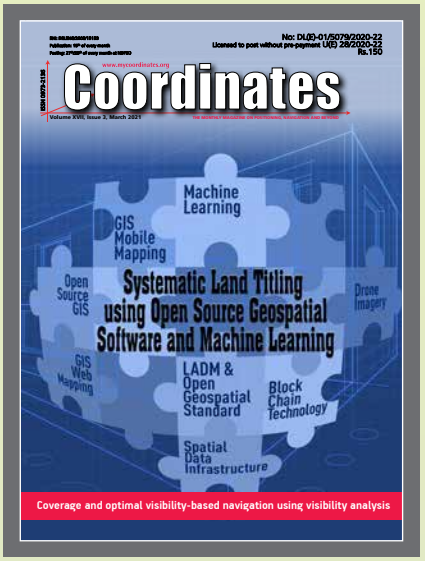
October 2022

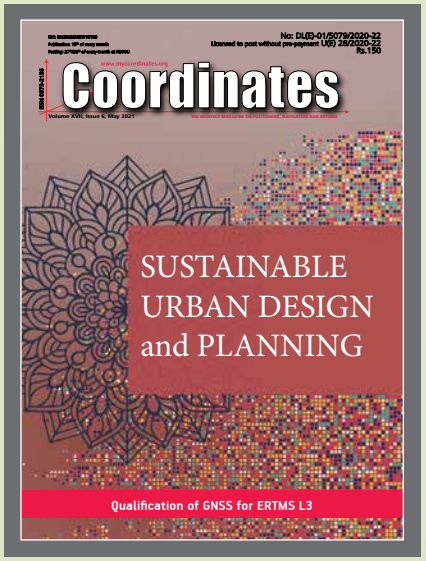
Intergeo Hybrid
18-20 October 2022
Essen, Germany
www.intergeo.de

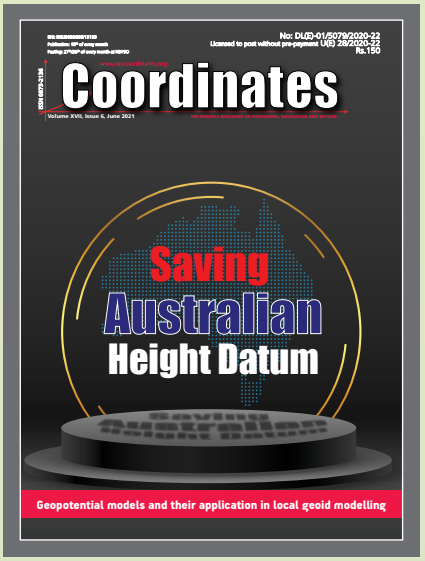
November 2022

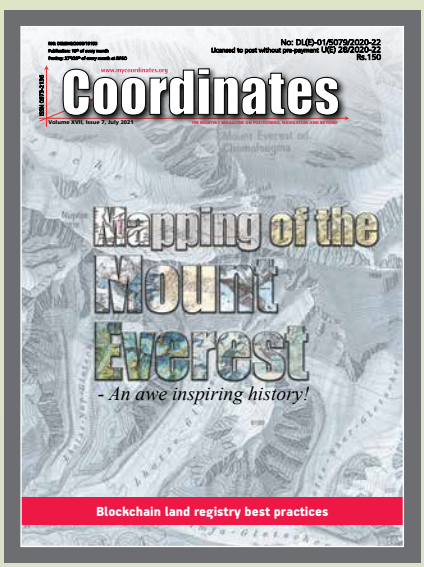
Trimble Dimensions+
7-9 November 2022
Las Vegas, USA
https://dimensions.trimble.com

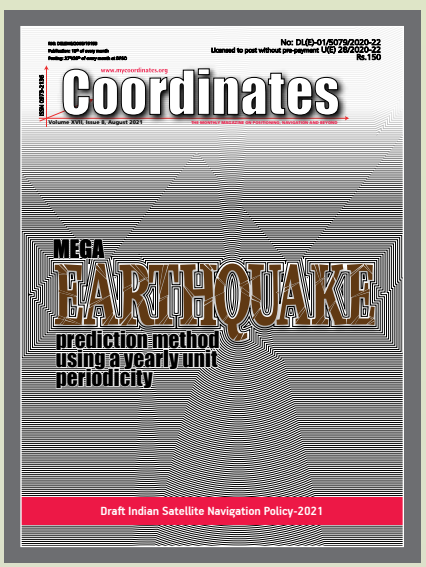


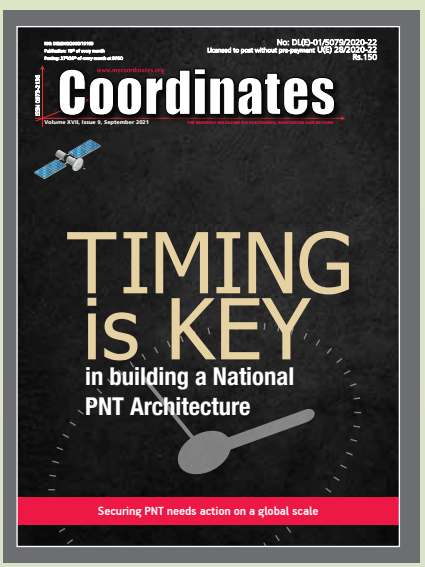












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