Precise Vertical Reference Surface Representation and Precise Transformation of Classical Networks to ETRS89 / ITRS

General Concepts and Realisation of Databases for GIS, GNSS and Navigation Applications in and outside Europe

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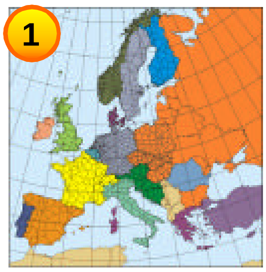
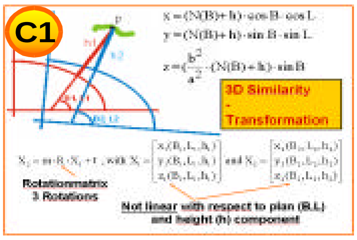
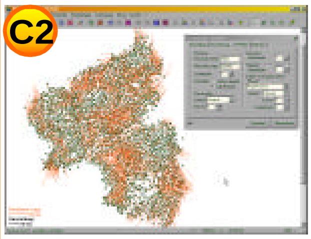


As concerns the georeferencing of position data in modern data bases, the availability of GNSS (GPS / GLONASS / GALILEO) related code- and phase-measurement DGNSS-correction data, which are provided in different ways by different GNSS positioning services (SA*POS*, ascos, SWIPOS, SWEPOS etc.) in and outside Europe leads to the replacement of the classical geodetic reference systems by GNSS-consistent ITRS-based reference systems. So the transformation of the old plan position data $(N,E)_{class}$ related to the classical reference systems to the ITRS/ETRS89 datum $(N,E)_{ITRS}$ becomes urgently necessary all over Europe (1) and the world respectively. A sophisticated and general solution of this transformation problem has to include a respective data base concept for the provision of the corresponding transformation parameters for GIS, GNSS and Navigation purposes. This is provided by the CoPaG-Concept. Further the capacity of a one-cm-positioning by GNSS services, such as e.g. SA*POS*® and ascos® in Germany, is also appropriate for a GNSS related heighting. The GNSS-based determination of sea-level (orthometric, normal) heights H requires however the transformation of the ellipsoidal GNSS heights h_{ITRS} to the respective physically defined height reference surface (HRS). A general concept for the evaluation of height reference surfaces (HRS)on the national and also on European level (E_HRS) is provided by DFHRS. Both the DFHRS and the CoPaG/DFLBF database standard are broadly accepted by theGNSS indurstry (5).

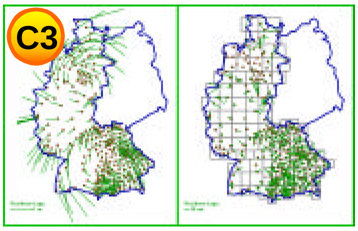
CoPaG

The CoPaG concept is dealing with the precise and continuous transformation of plan positions $(N,E)_{class}$ to the ITRS/ETRS89 datum $(N,E)_{ITRS}$. From the theoretical point of view a respective transformation can not renounce completely on height information (C1). The so-called COPAG (COntinuously PAtched Geoferencing)





concept however, has the advantage that the point height information is needed only on a poor accuracy level in the target system. If preciseheightinformation is available in both systems, it can be introduced as third observation equation in system C4. Further basic considerations and a respective problemsolution for the plandatum transition are due to the occurrence and the mathematical treatment of so-called 'weak-forms'(C2, C3 left). These are long-waved deflections of the network shape of the classical networks, reaching a range of several meters in the nation-widescale,e.g.forthe sizeof Germany (C3, left side). This requires the partition of the total network area into a set of different "patches" (C3, right). The introduction of continuity conditions along the patch borders analogue totheDFHRS (D1) implies restrictions between the transformation parameters d of neighbouring patches (C3, right side). Because of its mathematical strictness and general validity the COPAG concept has a broad and far-reaching application profile in the context with the big amount of similar datum transition problems occurring world-wide intheupcomingGNSS-age. C3 right shows the patch-layout for the computation of the <_5cm_CoPaG_DB Germany. For the different countries more precise CoPaG_DBs are also available. The inverse problem of transformation of GNSS positions $(B,L,h)_{ITRS}$ to national reference systems and grids $(N,E)_{class}$ is solved by DFLBF_DB.



C4

Functional-Model for the Computation of CoPaG-Databases

B₂ ? v ? B₁ ? ?B₁(d; ?a, ?f | B₁, L₁, h₁) ? B₁ ? ?B₁(u,v,w, ?ₓ, ?ᵧ, ?_z, ?m; ?a, ?f | B₁, L₁, h₁)

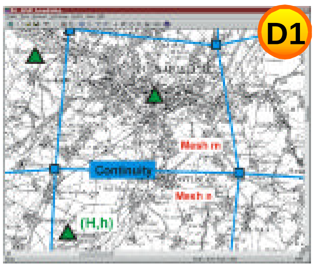
? B₁ ? [? cos L ?sin(B) / (M ? h)]₁ ?u ? [? sin L ?sin(B) / (M ? h)]₁ ?v ? [?cos(B) / (M ? h)]₁ ?w ?
[sin L ? (h ? N ?W²) / (M ? h)]₁ ??ₓ ? [? cos L ? (h ? N ?W²) / (M ? h)]₁ ??ᵧ ? 0 ??_z ?
[? e² ?N ?cos B ?sin B / (M ? h)]₁ ??m ? [N ?e² ?cos B ?sin B / (a ?(M ? h))]₁ ??a ? [M ?sin(B) ?cos(B) ?(W² ? 1) / ((M ? h)?(1 ? f))]₁ ??f

L₂ ? v ? L₁ ? ?L₁(d; ?a, ?f | B₁, L₁, h₁) ? L₁ ? ?L₁(u,v,w, ?ₓ, ?ᵧ, ?_z, ?m; ?a, ?f | B₁, L₁, h₁)

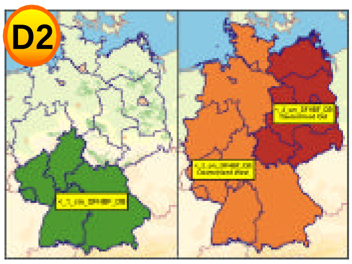
? L₁ ? [? sin L / ((N ? h) ?cos B)]₁ ?u ? [cos L / ((N ? h) ?cos B)]₁ ?v ? 0 ??w ?
[? (h ? (1 ? e²) ?N) / ((N ? h) ?cos B) ?cos L ?sin B]₁ ??ₓ ? [? (h ? (1 ? e²) ?N) / ((N ? h) ?cos B) ?sin L ?sin B]₁ ??ᵧ ? 1 ??_z ?
0 ??m ? 0 ??a ? 0 ??f

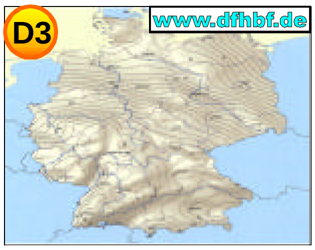
DB-Content: - Mesh Topologie
- Mesh Parameters d ? (u, v, w, ?ₓ, ?ᵧ, ?_z, ?m)ⁱ

DFHRS



The DFHRS (Digital-Finite-Element-Height-Refe-ence-Surface) concept allows a GNSS heightpositioning(GPS/GLONASS/GALILEO etc.) by a direct online conversion of ellipsoidal heights h into standard heights H referring to the height reference surface (HRS).TheDFHRSiscomputedandmodelled as a continuous HRS with parameters p in arbitrary largeareasby bivariate polynomials over grid of Finite Element meshes (FEM) (D1). Geoidheights,vertical deflections, gravity anomalies and identical points are tobeusedasobservations in a least squares computation to derive the DFHRS-parameters (D4).Any number of geoid models may be introduced simultaneously and geoid models may be parted into different "patches" with individual datum-parameters in order to reduce the effect of existing medium- and long-waved systematic errors. So the resulting DFHRS parameters p, set up as a DRHRS database, provide a three-dimensional correction DFHRS(p|B,L,h) to transform by H=h-DFHRS(p|B,L,h) ellipsoidal GNSS heights h into standard heights H (D4, top). The DFHRS-correction consists of the FEM surface of the HRS ("geoid-part") as function of (B,L) and an additional "scale part"asfunctionofh.Thepresent"high-end" of a HRS representation and the DFHRS-correction DFHRS(p,m|B,L,h) respectively is the level of less than 1 cm, provided by so-called "<1_cm_DFHRS_DB". These "<1_cm _DFHRS_DB" (D2, left side) are characterized by a mean reproduction quality of less than 1 cm (D2, left). D3 and D2, right show the <3cm DFHRS_DB of Germany available in NN and NormalHeights.





D4

DFHRS-Correction:

H ? h - NFEM(p | B, L) - h ? ? m
? h ? DFHBF(p, ?m | B, L, h)

Functional-Model for the Computation or DFRHS-Databases

h ? v ? H ? h ? ?m ? NFEM(**p** | B, L)
N_G(B, L)ʲ ? v ? NFEM(**p** | B, L) ? ?N_G(**d**ʲ)
? ? v ? ? **f**_B / M(B) ?**p** ? ?B(**d**_{?,?})
? ? v ? ? **f**_L / (N(B) ?cos(B)) ?**p** ? ?L(**d**_{?,?})
H ? v ? H
C ? v ? C(**p**)

DB-Content: - Mesh Topologie
- Mesh Parameters
p ? [(a₀₀, a₁₀, a₀₁, a₁₁, ...)ⁱ, ?m]

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Company	Logo	Software	CoPaG DFLBF	DFHRS
ALLSAT www.allsat.de	ALLSAT	GART2000	-	☑
GeoNav www.geonav.de	GEONAV	DCTOOLS	☑	☑
IBS www.ib-seiler.de		OLGA_PRO, USEDIM	☑	☑
LEICA Geosystems www.leica-geosystems.com	Leica	SKI-PRO SR530 Controller Software	☑	☑
THALES www.thales-navigation.com	THALES	GART2000 OLGA_PRO	☑	☑
TRIMBLE (in prep.) www.trimble.com	Trimble	Trimble Office 5700 Controller Software	☑	☑